ATPL

Mass
&
Balance

CHAPTER 1

Introduction 1-1
CAP 696 - JAR FCL Examinations Loading Manual 1-1
Section 1 - General Notes (Pages 1 to 4) 1-2
Definitions 1-2
Conversions (Page 4) 1-3

CHAPTER 2

Mass and Balance Theory

Centre of Gravity (CG) 2-1
Effect of Mass (Weight) 2-2
Balance Arm (BA) 2-2
Datum or Reference Datum 2-2
Aeroplane Datum 2-2
SEP 1 2-2
MEP 1 2-3
MRJT 1 2-3
Moment 2-3
Loading Index (LI) 2-5
Centre of Gravity (CG) 2-6
Relocation of Weight 2-9
Adding Mass 2-10
Volumetric Measure 2-11
Questions For Chapter 2 2-14

CHAPTER 3

Mass Limitations

Finding the Basic Mass and Centre of Gravity of an Aircraft 3-1
Operating Mass (OM) 3-4
Zero Fuel Mass (ZFM) 3-4
Maximum Zero Fuel Mass (MZFM) 3-5
Structural Limitations 3-5
Maximum Structural Take-Off Mass 3-5
Maximum Structural Taxi Mass 3-5
Maximum Structural Landing Mass 3-6
Performance Limited Take-Off Mass (PLTOM) 3-7
Performance Limited Landing Mass (PLLM) 3-7
Regulated Take-Off Mass (RTOM) 3-7
Regulated Landing Mass (RLM) 3-7
Take-Off Mass (TOM) 3-7
Landing Mass (LM) 3-8
Fuel Terminology 3-8
Basic Aerodynamic Principles 3-13
Centre of Gravity and Stability 3-18
Centre of Gravity Envelope 3-20
Plotting on a CG envelope 3-20
Questions for Chapter 3 3-24

CHAPTER 4

Requirements of JAR - OPS

Weighing of Aircraft – JAR OPS 1 4-1
Fleet Mass and CG Position 4-1
Tare Mass 4-2
Loading of Aircraft 4-3
Floor Loading 4-4
Security of a Load 4-4
Mass and Balance Document 4-5
Last Minute Changes 4-5
Responsibilities 4-6
Mean Aerodynamic Chord (MAC) 4-6
Standard Crew and Passenger Masses from JAR – OPS 1 Subpart J 4-10
Infants and Children 4-11
Adults 4-11
Passenger Baggage Values 4-12
Load Shifting Formula 4-13
Useful Load and Laden 4-14
S.I Units (Systeme International) 4-14
Questions for Chapter 4 4-16

CHAPTER 5

Load shifting, Load addition and Load subtraction

Load Shifting 5-1
Load Addition 5-1
Load Subtraction 5-2

CHAPTER 6

Questionnaire for Data Sheet SEP 1

CHAPTER 7

Questionnaire for Data Sheet MEP 1

CHAPTER 8

Medium Range Jet Transport – MRJT 1

Introduction 8-1
Contents 8-1
Aircraft Description 8-1
Locations Diagram 8-1
Table to Convert Body Stations to Balance Arm 8-2
Landing Gear Retraction 8-2
Effect of Flap Retraction 8-2
Take-Off Horizontal Stabiliser Trim Setting 8-3
Obtaining Trim Units 8-3
Conversion of BA to or from % MAC 8-4
Mass and Balance Limitations 8-5
Centre of Gravity Limits 8-5
Fuel 8-5
Passengers (PAX) and Personnel 8-6

Passenger Mass 8-6
Passenger Baggage 8-6
Personnel..8-6
Cargo 8-7
Loading Manifest 8-9
The Load and Trim Sheet 8-14
Fuel Index Correction..8-15
The Load Sheet 8-17
Solving a Scale Space Problem..8-28
Other Methods of Deriving the CG's Location..8-29
Practice Questions Based on the MRJT 1 Data Sheet 8-30

Intentionally Left Blank

Chapter 1

Introduction to Mass and Balance

Introduction

The subject of mass and balance for the JAR exams deals with the loading of aircraft. This is to ensure that they are not:

- Overloaded
  or
- Incorrectly loaded

In the JAR syllabus and examinations the subject of Mass and Balance is an integral part of Aircraft Flight Performance and Planning. The subject encompasses elements of Principles of Flight, Performance and Flight Planning as well as the main subject of Mass and Balance.

Note: While the term weight denotes a mass that is being acted on by the earth's gravitational force, the JAR-FCL examinations will make use of either the term mass or weight to describe a weight condition.

These notes are designed to teach you:

- The basic fundamentals of mass and balance
- The current definitions applicable to the course, and of course
- Prepare you for the examination.

These notes are written in the assumption that you have a copy of CAP 696 - JAR FCL Examinations Loading Manual and will direct and guide you through this manual, so that you are familiar with its layout and content. The intention is to ensure that during the examination:

- You are able to find the relevant data
- You calculate your answers quickly and accurately

CAP 696 - JAR FCL Examinations Loading Manual

This manual is spilt into 4 sections:

Section 1	General Notes	
Section 2	Data for single engine piston/propeller aeroplane	(SEP 1)
Section 3	Data for light twin engine piston/propeller aeroplane	(MEP 1)
Section 4	Data for medium range twin jet	(MRJT 1)

Please note that the data given in the aircraft data sheets are for examination purposes only, they are not to be used for any flight planning that involves a real aeroplane of the types shown.

Section 1 - General Notes (Pages 1 to 4)

Aircraft Description

The aircraft descriptions are for generic types related to the classes of aircraft used in the JAR examinations. The data for each aircraft is given on different coloured paper; this colour coding is used in the sister publications for the Performance and Flight Planning examinations.

Green Paper   Single Engine Piston

This is based on the Beech Bonanza, a single, piston engined aircraft that was manufactured prior to the implementation of JARs and therefore is not certified under JAR 23 (Light Aeroplanes). As this aircraft's MTOM is less than 5700 kg and is piston powered it is grouped as JAR performance class B aircraft and for the performance group of exams [mass and balance, flight planning and performance] - this is referred to as SEP 1

Blue Paper   Multi Engine Piston

This is based on the Piper Seneca, a multi, piston engine aircraft that was manufactured prior to the implementation of JARs and therefore is not certified under JAR 23 (Light Aeroplanes). Again due to the MTOM being less than 5700 kg and the aircraft is classed as performance 'B' and is referred to as MEP 1

White Paper   Medium Range Jet Transport

A medium range twin turbine engined aircraft certified under JAR 25 performance class A – this is referred to as MRJT 1

Definitions

The main definitions are given on pages 2, 3 and 4. You must be conversant with them during the early part of the course; this will assist in speeding up answering the questions. Note that definitions in CAP 696 are given in two formats:

- If the definition is in normal text then it can be found in either ICAO or JAA documentation
- If the definition is in italics then it is not an ICAO or JAA definition but is one that is in common use

Throughout the text reference will be made as to which page of the CAP 696 and under what heading the item is found

Conversions (Page 4)

The conversion factors are given to the 8th decimal place. This is due to the fact that they have been taken from the ICAO manual, for any calculation where a conversion is required use only four decimal places.

For the JAA exams all calculations should be possible using the CRP 5, however it is highly recommended that in mass and balance a calculator is used. The answers will indicate the level of accuracy required be it a whole number or too two places decimal, in any calculation work to 3 decimal places then round up or down.

The following conversion factors are taken from the ICAO Annexes.

Conversions		
Mass Conversions	**ICAO Conversion Factor**	**Use the following conversion**
Pounds (LB) to Kilograms (KG)	LB x 0.45359237KG	LB x 0.4536 KG
Kilograms to Pounds	KG x 2.20462262LB	KG x 2.2046 lb
Volumes (Liquids)		
Imperial Gallons to Litres (L)	Imp Gal x 4.546092	Imp Gal x 4.5461
US Gallons to Litres	US Gal x 3.785412	US Gal x 3.7854
Lengths		
Feet (ft) to Metres (m)	ft x 0.3048	ft x 0.3048
Distances		
Nautical Mile (NM) to metres (m)	NM x 1852.0	NM x 1852.0

Note: The last two conversions will have to be used as listed in the CAP

Intentionally Left Blank

Chapter 2

Mass and Balance Theory

Centre of Gravity (CG)

The definition of CG can be found on page 3 under "OTHER DEFINITIONS".

"Is that point through which the force of gravity is said to act on a mass"

Note: The definition is given in italics and is therefore a common use definition.

In aircraft, it is vitally important to find the CG as it is the point where the combined weights of both the aircraft and its load are said to act. This is not necessarily located at the centre point of the aircraft. As the aircraft burns fuel, the resultant change in weight can cause the aircraft's centre of gravity to move. Finding the location of, and predicting the movement of, the centre of gravity becomes important for the captain of an aircraft

There is normally a forward and aft limit to the CG. The following lists some of the effects of having the CG outside the normal limits:

CG outside the forward limit	CG outside the aft limit
Large elevator deflection is needed to produce the balancing download required. Increased drag will result from the control surface deflection; this is termed 'Trim drag'. Induced drag is increased because of the wing lift required to balance the tailplane download. All the above will of course reduce performance	Large elevator deflection is needed to produce up-wards lift from the tailplane to 'lift' the tail of the aircraft. Increased drag will result from the control surface deflection; this is termed 'Trim drag'.
Stalling speed will increase because of the increase in the wing lift required	Spin recovery becomes difficult because the possibility of flat spins developing.
Longitudinal stability is increased. This will lead to higher stick forces in pitch.	Longitudinal stability is reduced. The further the CG is aft the less stable the aircraft. Stick forces become "light" which leads to the possibility of overstress.
Both range and endurance will be decreased. The increased trim drag causes this as the elevators are used to trim the aircraft.	Both range and endurance decrease because of the extra trim drag.
Because the elevators are used to trim the aircraft they have less range in upwards. Nose up pitch is reduced as a consequence	Any glide angle is difficult to maintain because of the aircraft's tendency to pitch up.

Effect of Mass (Weight)

Due to the gravitational pull on a body, the weight always acts towards the centre of the earth. When holding an item at arms length it will "feel heavier" than if it is held close to the body. The weight is trying to pull the arms down. This is the turning moment and is created by:

Mass X The arm.

The arm is referred to as a Balance Arm and can also be called a lever arm or moment arm.

Balance Arm (BA)

Found on page 3 under OTHER DEFINITIONS.

Balance Arm (BA)	*Is the distance from the Datum to the Centre of gravity of a mass"*

Normal convention is to make:

- All arms behind the datum positive
- All arms forward of the datum negative

Datum or Reference Datum

Found on page 3 under OTHER DEFINITIONS

Datum or Reference Datum	*(Relative to an aeroplane) is that plane from which the centres of gravity of all masses are referenced*

As with all measurements we need a fixed point as a starting point this is referred to as a datum. As this is the starting point for measuring the balance arms the datum is always labelled 0 or 0.0. The CG datum can also be specified as a percentage of the Mean Aerodynamic Chord (MAC).

Aeroplane Datum

The datum in aircraft is considered to be a vertical or perpendicular line or plane. The location of an aircraft's datum is decided by the manufacturer and can be anywhere within the fuselage, in front of it, or behind it. Wherever the manufacturer decides to locate the datum for the aircraft it is the point from which all balance arms are measured.

Each component that is used to make up an aeroplane or item that is loaded into the aeroplane has its own mass and centre of gravity through which its mass is said to act. All these separate masses have balance arms; their distance from the datum.

SEP 1 (Page 5)

In the diagram of the light single engined aircraft to locate the Datum the Firewall is first located:

Reference Datum	39.00 inches forward of the firewall

As the location of the datum for this aeroplane is not a physical item but an arbitrary position decided by the manufacturer the firewall is used as a reference point from which to take a measurement to locate the datum. All balance arm measurements are made from the reference datum.

MEP 1 (Page 12)

In the light twin engine aircraft the reference datum is found 78.4 inches forward of the reference point. This is the leading edge of the wing inboard of the inboard edge of the inboard fuel tank.

MRJT 1 (Page 20)

In this diagram the datum is located in the nose section of the aircraft, 540 inches forward of the front spar (FS). The Front Spar being the reference point.

Moment

Found under OTHER DEFINITIONS.

Moment *Is the product of the mass and the balance arm*
= Mass X Arm

The moment, or to be completely correct the "turning moment" is the product of multiplying the mass by the arm. Because the arm can be positive or negative the moment will also be positive or negative.

While this is simply a basic multiplication task you must be aware that the arm's length and the mass can be given in imperial or metric units of measurement as shown below:

Mass (weight)		**Arm**	**Moment**	**Mass (weight)**		**Arm**	**Moment**
10 kg	X	10 cm	100 kgcm	10 kg	X	10 ins	100 kgins
10 lb	X	10 cm	100 lbcm	10 lb	X	10 ins	100 lbins
10 kg	X	10 feet	100 kgfeet	10 kg	X	10 m	100 kgm
10 lb	X	10 feet	100 lbfeet	10 lb	X	10 m	100 lbm

However, care must be taken in labelling the moment units. As can be seen from the table above, although the weights and arms are the same in every case and the resulting moment number is the same, the label denotes the size of the effect.

Example A kilo is equal to 2.205 lb and a foot is equal to 12 inches etc

For mathematical calculations moments of the same label must be added together. If there is a variation in the units of weight or arm then conversion into a single unit must be done first.

Example 1 In the example below the weight needs to be converted

Mass (weight)		Arm	Moment
10 kg	X	10 cm	100 kgcm
10 lb	X	10 cm	100 lbcm

STEP 1 Convert 10 lb into kg

Using the conversion table Chapter 1, Page 3

LB X 0.454 = 10 X 0.454 = 4.54 kg

STEP 2 Now recalculate the arm using the new figure calculated in STEP 1

	10 kg X 10 cm	**=**	**100 kgcm**
	<u>4.54 kg X 10 cm</u>	**=**	**<u>45.54 kgcm</u>**
Total	**14.54 kg**		**145.54 kgcm**

Example 2 In the following example both mass and length need to be converted into common factors

Mass (weight)		Arm	Moment
10 kg	X	10 ft	100 kgft
10 lb	X	10 cm	100 lbcm

STEP 1 Convert 10 lb into kilograms

LB ÷ 2.205 kg = 10 ÷ 2.205 = 4.535 kg

STEP 2 Convert 10 cm into m

cm ÷ 100 = 10 ÷ 100 = 0.1 m

STEP 3 Convert 10 ft into m

ft X 0.3048 = 10 X 0.3048 = 3.048 m

STEP 4 Now recalculate the arm using the new figures calculated in STEPS 1 to 3

	10 kg X 3.048 m	**=**	**30.48 kgm**
	<u>4.535 kg X 0.1 m</u>	**=**	**<u>0.4535 kgm</u>**
Total	**14.54 kg**		**30.9335 kgm**

STEP 5 Round the answer down to two decimal places

14.54 kg **30.93 kgm**

Loading Index (LI)

Found on page 4 under OTHER DEFINITIONS.

Loading Index *Is a non-dimensional figure that is a scaled down value of a moment. It is used to simplify mass and balance calculations*

Example 3 A moment of 12 300 000 kgm is quite an unwieldy number to carry around calculations. By using an LI then a smaller more manageable number can be carried forward. The following calculation assumes an LI of 100 000 kgm.

STEP 1 Divide the moment by a constant of 100,000 kgm

12,300,000 kgm ÷ 100,000 kgm = 123 kgm

STEP 2 123 kgm is carried forward in the calculation until the final answer is required

STEP 3 Multiply the final answer by the LI (100,000 kgm) to give the required answer

A series of more manageable numbers can be used and be re-converted if required.

Example 4 Find the sum of 0.6 kgm, 12 kgm and 0.01 kgm with an LI of 1,000,000 kgm.

STEP 1 Calculate the sum

0.6 kgm
12 kgm
0.01 kgm
total = 12.61 kgm

STEP 2 Using the LI calculate the final answer

12.61 kgm X 1,000,000 kgm = 12,610,000 kgm

Loading indices can be used for all types of aircraft, and are used in each of the aircraft types in CAP 696.

The following examples are very basic and laid out in a very formalised way. The intention is to get you to lay out your work in a logical progression so it can be checked and any errors corrected easily.

This might appear to be time consuming. However, with practice you will speed up and be able to omit stages. Simple errors made by skipping several stages can remain undetected or are noticed at the end of a series of calculations. Tracking down and reworking Mass and Balance questions is time consuming. We would suggest that the time to correct will be more than the time and effort to set out your work logically.

Centre of Gravity (CG)

To find the centre of gravity the formula below can be used:

Total Moment ÷ Total Mass = Centre of Gravity

The moment is the product of multiplying a mass by an arm, when it is divided by a mass the answer will be given in the units of the arm.

These units are always measured from the datum's location.

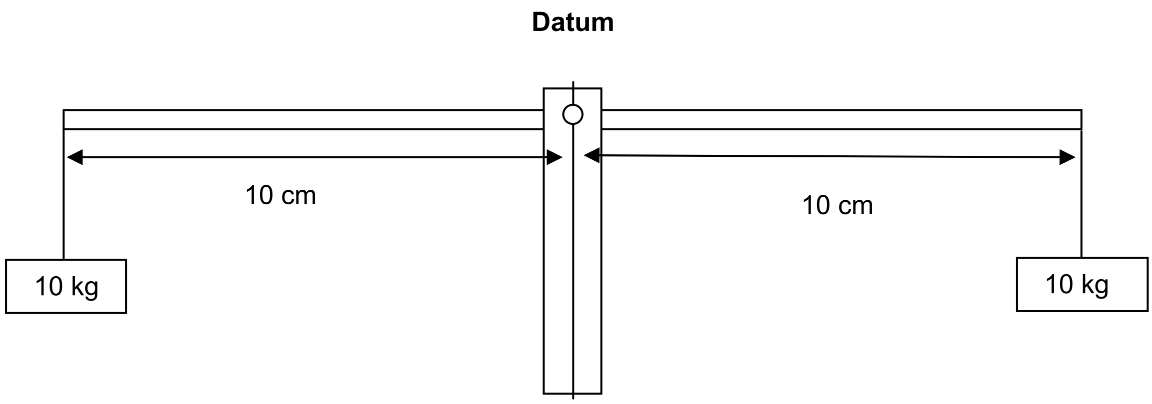


Fig 1.0

Using an old fashioned balance scale as shown above in Fig 1.0, the bar is supported by a central pivot point (the CG of the bar) forming two arms of equal length. We can refer to an arbitrary line drawn through the pivot point as the datum.

If items of equal mass (weight) are suspended from the beam at equal distances from the pivot point (datum) then the beam will remain in balance. This is due to the turning moments cancelling each other out see Fig 1.1

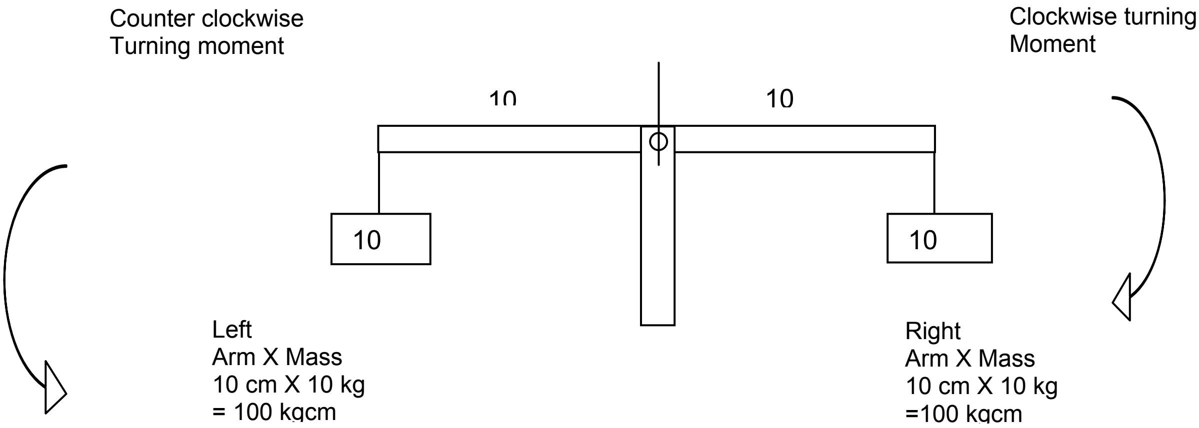


Fig 1.1

As the left arm moment cancels the right arm moment it is convention to label the left arm minus and the right arm plus:

	Mass		Arm	- Moment	+ Moment
Left arm	10 kg	X	- 10 cm	- 100 kgcm	
Right arm	10 kg	X	+ 10 cm		+ 100 kgcm
Totals	20 kg			- 100 kgcm	+ 100 kgcm
Total Mass	20 kg		**Total Moment**	0.0 kgcm	

The Centre of Gravity is found by dividing the Total Moment by the Total Mass

Total Moment ÷ Total Mass

0 ÷ 20 = 0 cm

The datum is always labelled 0, so the CG is located on the datum.

The formula can also be expressed as:

Total moment ÷ Total mass = CG

or

Total moment ÷ Total weight = CG

If the same balance scale is used, but the location of the datum is moved the centre of gravity is calculated by using the Tm ÷ Tw formula.

See fig 1.2

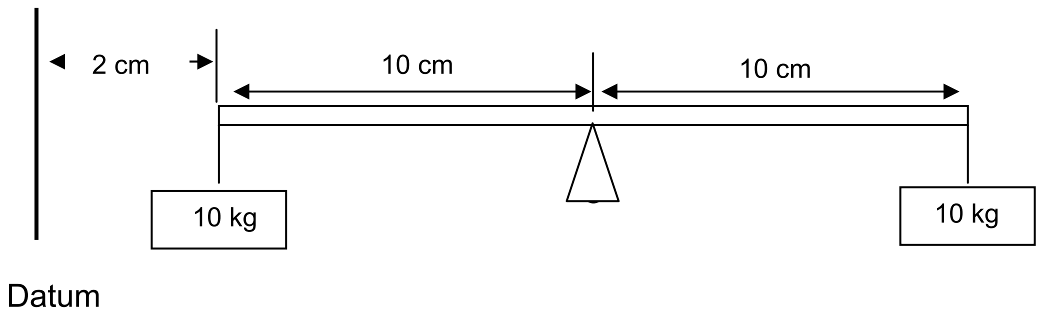


Fig 1.2

If the datum is located 2 cm in front of the left hand arm our calculation will alter. The CG will stay at the same point in this case 12 cm to the right of the datum.

	Mass		Arm	- Moment	+ Moments
	10 kg	X	+2 cm		+ 20 kgcm
	10 kg	X	+22 cm		+ 220 kgcm
Totals	20 kg		**Total Moment**		+ 240 kgcm

Centre of Gravity = Tm ÷ Tw

CG = + 240 kgcm ÷ 20 kg

CG = + 12 cm

The centre of gravity is located 12 cm to the right of the datum

If the weights are changed then the balance point, the CG, would alter.

Example The left balance arm has a weight of 8.5 kilos 10 cm from the datum. The right arm has a weight of 7.75 kilos 10 cm from the datum. the datum is located on the pivot point. Where is the CG located:

STEP 1 Draw a simple not to scale line diagram, see Fig 1.3 below.

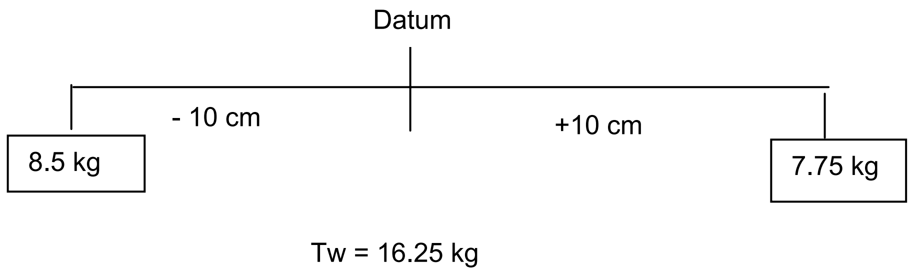


Fig 1.3

STEP 2 Tabulate the data

Item	Mass		Arm	- Moment	+ Moments
left arm	8.5 kg	X	- 10 cm	- 85 kgcm	
right arm	7.75 kg	X	+ 10 cm		+ 77.5 kgcm
Totals	16.25 kg			- 85 kgcm	+ 77.5 kgcm
			Total Moment	- 7.5 kgcm	
Tmass	16.25 kg				

STEP 3 Calculate the CG position

CG = Tm ÷ Tw

CG = -7.5 kgcm ÷ 16.25 kg

CG = - 0.461 cm = - 0.46 cm

CG is located 0.46 cm to the left of the datum

The next consideration is the effect of, relocating, removing or adding weight to the arms

Relocation of Weight

Using the example above:

- The current location of the CG is –0.46 cm
- The current mass is16.25 kg and
- The Total moment is –7.5 kgcm.

If a 1.3 kg mass is moved from the left arm to the right arm it will have two effects as shown in Fig 1.4.

- The positive effect of removing a mass from the negative arm
- The positive effect of adding the same mass onto the positive arm

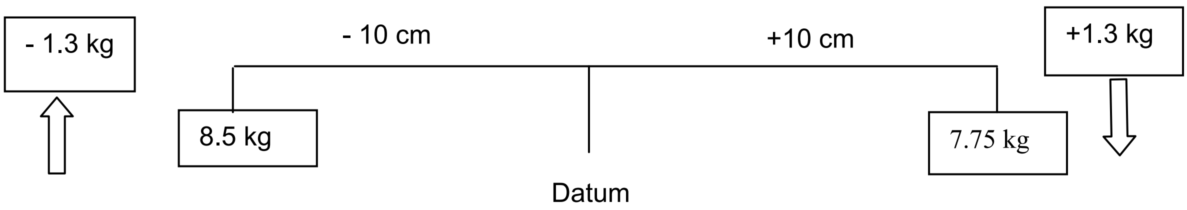


Fig 1.4

Item	Mass kg		Arm cm	- Moment kgcm	+ Moments kgcm
Total mass	16.25	X	- 0.46	- 7.5	
left arm	- 1.3	X	- 10		+ 13
right arm	+1.3	X	+ 10		+ 13
Totals	16.25 kg			- 7.5	+ 26
			Total Moment	+18.5 kgcm	

CG = +18.5 kgcm ÷ 16.25 kg

CG = + 1.138

= + 1.14 cm

The CG is now located 1.14 cm to the right of the datum

The distance of the CG from the datum represents the balance arm for all the masses of the scale, the total mass remained constant but the total moment changed as the weight was relocated.

If the relocation was to be from the positive arm to the negative arm then the effect would be to:

- Reduce the positive moment
- Increase the negative moment

Adding Mass

If weight is added to the basic scale, then there are two different effects:

- The overall mass will increase,
- If the extra mass is added unevenly, to one arm only, then the moment of that arm will increase, changing the total moment.
- The CG will move.

Example Using the example from Fig 1.3, if 1.7 kg is added to the left arm then:

Item	Mass kg		Arm cm	- Moment kgcm	+ Moments kgcm
Total mass	16.25	X	+ 1.138		+ 18.5
left arm	+ 1.7	X	- 10	- 17	
Totals	17.95 kg			- 17	+ 18.5
			Total Moment	+1.5 kgcm	

CG = +1.5 kgcm ÷ 17.95 kg

CG = + 0.0835654 cm

= + 0.08 cm

The CG is located 0.08 cm to the right of the datum

When removing weight then the reverse effects must be considered.

- The overall mass will reduce
- If the extra mass is removed unevenly, from one arm only, then the moment of that arm will decrease.
- The CG will again move.

Example Using the same example Fig 1.3 but removing the 1.7 kg from the right arm:

Item	Mass kg		Arm cm	- Moment kgcm	+ Moments kgcm
Total mass	16.25	X	+ 1.138		+ 18.5
right arm	- 1.7	X	+ 10	- 17	
Totals	14.55 kg			- 17	+ 18.5
			Total Moment	+1.5 kgcm	

CG = +1.5 kgcm ÷ 14.55 kg

CG = + 0.1030927 cm

= + 0.10 cm

The CG is located 0.1 cm to the right of the datum

Volumetric Measure

Found on page 4 under conversions. There are three volumetric measures of liquids used:

- The Imperial gallon
- The USA gallon, and

- The litre

A supplementary conversion that can be required in addition to those on Page 4 is that from imperial gallons to US gallons.

The imperial gallon is larger than the US gallon; there are 1.2 US gallons to one Imperial gallon. To convert from Imperial Gallons to US Gallons multiply by 1.2, to convert from US Gallons to Imperial Gallons divide by 1.2. Imperial gallons can be referred to as gallons (UK).

Another conversion is that from liquid volume into mass, the calculation is made using the fluids Specific Gravity or SG. Based on the assumption that 1 Imperial Gallon of water has a mass of 10 pounds the SG is given a value of 1, therefore SG has a constant of 10.

Example A gallon (UK) of fluid with an SG 0.72 has a mass of 7.2 pounds. As the US gallon is only 0.8333 of an Imperial gallon, the fastest way to find its mass is to divide the mass of an equivalent UK gallon by 1.2

Example 1 US gal of fuel at SG 0.72

7.2 lb ÷ 1.2 = 6 lb

1US gallon at SG 0.72 has a mass of 6 pounds

A litre of water has a mass of 1 kilogram, so the Specific Gravity of 1 is used. This means that a litre of fuel at SG 0.72 has a mass of 0.72 kg.

During powered flight fuel will be consumed, the rate of this consumption will depend on a combination of factors such as aircraft mass, power setting, flight level and meteorological conditions.

- In light aircraft the fuel consumption is often quoted in volume/time eg US gallons per hour.
- In larger aircraft the fuel consumption is normally quoted in mass/time eg kg per hour.

SEP 1 For SEP 1 on page 6 Fig 2.3 a usable fuel table is shown by dividing any of the weights by the volume (gallons). Each gallon weighs 6 lb. From this we can deduce that these are US gallons and the fuel Aviation Gasoline (AVGAS) has specific gravity of 0.72. (See above)

MEP 1 For MEP 1 page13 under Standard Allowances the fuel's relative density is given as a mass of 6 lb per gallon. As this a piston engine the fuel is AVGAS at SG 0.72 and the volume is the US gallon.

MRJT 1 For MRJT 1 page 22 the table given as Fig 4.5 shows the volume as US gallons but the mass as kilograms, a mixture of USA and metric measures.

The mass in kg per US gallon is found by dividing the mass by the volume.

Example Using the first line of the table where the volume is given as 1499 US gallons and the mass as 4542 kg. The numbers in the MRJT 1 data sheet have already been rounded into whole numbers. Work to the third decimal place, this will give accurate data

4542 kg ÷ 1499 US gallons = 3.030kg

1 US gallon = 3.030 kg which is 6.680 lb.

Convert the mass and volume into an imperial measure by multiplying by 1.2

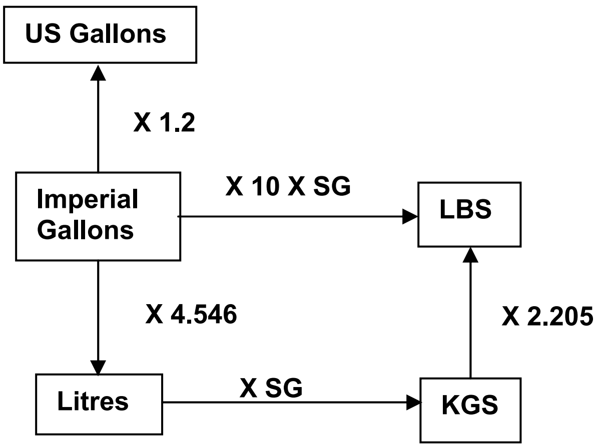
6.680 lb X 1.2 = 8.02 lb per imperial gallon.

This can now be expressed as a Specific Gravity of 0.8, which also translates into 0.8 kg per litre, as a US gallon = 3.785412 litres

3.785412 litres X SG 0.8 = 3.0283296 kg which given to two places decimal = 3.03 kg and the original mass per gallon of 3.03 also given to two places decimal would be 3.03 kg.

By combining the information of basic Centre of Gravity effects on a CG of changing a mass fluid density and volume can be found. Calculations can be made of the effect on a CG due to consumption of fuel from a tank.

The following guide is a quick method for converting volume to mass:



Having completed this first part of the course answer the questions in practice 1 before continuing.

Questions For Chapter 2

Question 1. Find the point of balance of a beam that is 12ft long and has a mass of 30 kg placed at 1ft from the left end and a mass of 51 kg placed at 5 ft from the right end.

a. 1.22 ft to the right of the beam's centre.

b. 1.22 ft to the left of the beam's centre.

c. 1.22 ft from the left end of the beam.

d. 1.22 ft from the right end of the beam.

Question 2. A balance scale with arms of 60 inches has a 16 lb mass placed on the left arm and a 13 lb weight located on the right arm. Give the location of the CG relative to a datum 3 ins to the left of the left hand end of the left arm.

a. + 60.5 ins

b. + 63.0 ins

c. + 55.95 ins

d. + 56.79 ins

Question 3. A beam balance is pivoted 1.37m from the left end, the pivot point is also the beam's CG and datum. A 55.5 lb weight is suspended from a point 1.2 m to the left of the pivot. Using a 23 lb mass, give the BA required to put the beam back in balance.

a. + 2.87

b. + 2.88

c. + 2.89

d. + 2.90

Question 4. A bar with a datum located at 90 inches from the left end has two 6kg weights located 50 inch each side of the datum and is in balance.

Further masses of 1.35 kg and 0.75 kg are added to the left and right arms respectively at the given locations.

Give the new CG.

a. -2.13 ins

b. - 2.12 ins

c. +2.13 ins

d. +2.12 ins

Question 5. What is the sum of 0.34 kgcm + 1.47 kgcm and 45.779 kgcm at a LI of 1000.

a. 47.589 kgcm
b. 47589.0 kgcm
c. 0.047589 kgcm
d. 4758.9 kgcm

Question 6. The correct definition of a BA is:

a. is the distance from the centre of gravity to a reference point.
b. is the distance from the datum to a reference point.
c. is the distance from the datum to the CG of a mass.
d. is the distance from the CG of a mass to the reference point.

Question 7. Complete the following table and give the CG.

	Weight		Arm cm	- Moment kgcm	+ Moment kgcm
	591.78 kg	X	-67		
	267 kg	X	100		
		X	50		69578.5
	37 kg	X	-98		
	32675kg	X	-15		
	1.5 kg	X	657		
Total					
			Total Moment		

CG is Tm ÷Tw =
CG =

a. –12.5
b. –12.47 cm
c. -5.8 cm
d. –5.2 cm

Question 8. Complete the following table, by converting the following masses.

	kg	lb
Line 1	71.4	
Line 2		33.97
Line 3	477.89	
Line 4		676.8
Totals		

Select the correct answers from the list below.

Line	a	b	c	d
1	15.44 lb	157.45 lb		157.44 lb
2	15.42 kg		15.42 kg	
3	1053.77 lb		1053.57 lb	1053.75 lb
4		307.27 kg		
totals	872 kg	1922.96 lb	871.72 kg	1921.96 lb

Question 9. Convert 3000 imperial gallons into litres

a. 13638.28 lts
b. 13638.26 lts
c. 13638.3 lts
d. 13638.2 lts

Question 10. Give the CG of an aircraft where the total mass is 50 000 kg and the total moment is 175.96 kg ins indexed at 1000.

a. + 35.192 ins
b. 35.192 ins
c. + 3.5192 ins
d. 3.5192 ins

Question 11. Given that the mass of an aircraft is 3560 lb and the CG is located at -576.3 cm, what is the moment for the aircraft indexed to 1000 and corrected to two places decimal.

a. -2051628.0 lb cm
b. –20.52 lbcm
c. –2051.62 lbcm
d. –2051.63 lbcm

Question 12. Given that the CG is located at 47.77 ins aft of the datum and that the total moment of the aircraft is 357 469.99 kg ins. What is the correct weight of the aircraft?

a. 7483.15 kg
b. 7483.2 kg
c. 7483.14 kg
d. 7483 kg

Question 13. Convert 20 000 US gallons of fuel with a SG of 0.87 into litres and pounds.

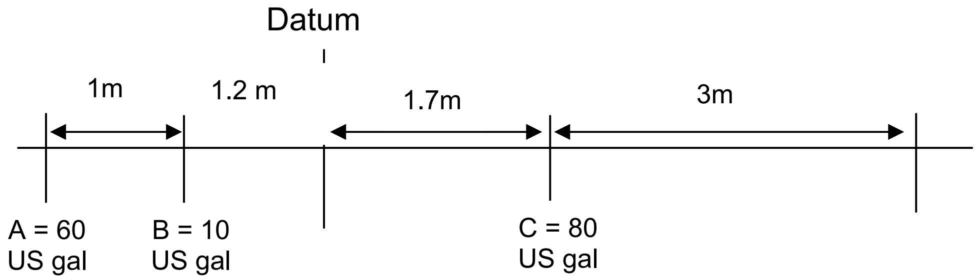
	Litres	Pounds
a.	75708.24	174000
b.	90921.84	174000
c.	90921.84	145000
d.	75708.24	145000

Question 14. Convert 15 000 litres of fuel at SG 0.76 into US gallons and give the weight of the fuel in pounds.

	US gallons	Pounds
a.	3962.59	25132.44
b.	3299.54	25096.34
c.	3299.54	25096.35
d.	3962.58	25080

Question 15 From the following diagram determine the current centre of gravity and then calculate the centre of gravity position 3.5 hours later if fuel is consumed at a rate of 70 lb per hour. Usage is 1.5 hours from tank A, 1 hour from tank C and .5 hour from tanks B and D.

The fuel has a SG of 0.76



D = 12
US gal

Original CG		New CG
a.	- 0.30	- 0.39
b.	+0.30	-0.39
c.	- 0.30	+0.39
d.	+0.30	+0.39

Answers to Chapter 2 Questions

Question 1

Answer B

Any point can be used as the datum as it has not been specified but the answer will be the same.

Using the centre of the beam will give

a – arm of 5ft X 30 kg = -150 kgft and

a + arm of 1 ft X 51 kg = +51 kgft.

Giving a total moment of –99kgft ,
the CG is equal to –99 kgft ÷ 81 kg = -1.222ft.

Question 2

Answer D

Datum 3 ins to the left of balance scale, so

16 lb X +3ins = +48 lbins

13 lb X +123 ins = +1599 lbins.

Tm +1599+48 = +1647 lbins.

Tmass 16 + 13 = 29 lb. CG is +1647÷ 29 = + 56.79 ins.

Question 3

Answer D

Datum pivot point, 55.5 lb at – arm 1.2m gives

A moment of -66.6lbm to balance the beam a +66.6lbm moment is required as the mass 23 lb has been given

Divide +66.6lbm by 23lb to find the BA.

+66.6 ÷ 23lb = 2.895m = 2.90.

Question 4

Answer A

Add the additional mass to the existing masses first.

Also remember that the arms are taken from the datum.

left arm – 50ins X 7.35 kg = - 367.5 kgins

right arm +50ins X 6.75 kg = +337.5 kgins

Totals 14.1 kg -30 kgins

Question 5

Answer B — Add 0.34 + 1.47 + 45.779 kgcm together and multiply by 1000
= 47589 X 1000 = 47589.0 kgcm

Question 6

Answer C — Page3 of CAP 696 under other definitions.

Question 7

Answer B — –12.47 cm

Question 8

Answer D

	kg	lb
Line 1	71.4	*157.44*
Line 2	*15.42*	33.97
Line 3	477.89	*1053.75*
Line 4	*307.27*	676.8
Totals	871.98	*1921.96*

Question 9

Answer A — Using the conversion factors given on page 4 ot the CAP696
multiply 3000 by 4.546092 = 13638.276.
= 13638.28 L

Question 10

Answer C — Multiply 175.96 by 1000 to give Tmoment then divide it by 50000 to give CG location.
175.96 X 1000 = 175960 kgins ÷ 50000 = 3.5192 ins.
CG is located at + 3.5192 ins

Question 11

Answer D — Multiply 3560 lb by –576.3 cm = -2051628 lbcm,
divide –2051628 by 1000 = -2051.628 lbcm
= -2051.63 lbcm

Question 12

Answer A

Divide 357469.99 kgins by 47.77 ins = 7483.1482 kg
= 7483.15 kg

Question 13

Answer D

A two part answer question, firstly convert the US gallons into Litres using the conversion factors on page 4 of CAP 696

20,000 X 3.785412 = 75708.24 L.

To convert the volume into mass given SG.87

1 Imp gall = 8.7 lb

Divide 8.7 by 1.2 to convert it into mass for US gallon = 7.25.

Multiply 20,000 by 7.25 = 145,000.

Question 14

Answer A

Always work the shortest route to the answers, firstly convert the 15,000 L into US gallons using the conversion factors in the CAP 696.

15,000 litres ÷ 3.7854 = 3962.59 US gallons

15,000 litres X SG.76 = 11400 kg

multiply 1140 kg by 2.2046 = 25132.44 lb

Question 15

Answer D

A compound question, firstly convert the fuel volumes into masses and calculate the original CG.

1 Imp gal SG.76 = 7.6 lb, divide this by 1.2 to convert it into mass for US gallon

7.6 ÷ 1.2 = 6lb

Tank	**Volume**		**Mass**		**Arm**	**Moment**
A	60	X 6 =	360 lb	X	-2.2	- 792
B	10	X 6 =	60 lb	X	-1.2	- 72
C	80	X 6 =	480 lb	X	+1.7	+ 816
D	12	X 6 =	72 lb	X	+4.7	+ 338.4
Total mass			972 lb	**Tmoment**		290.4 lbm

Original CG is 290.4 lbm ÷ 972 lb = +0.2987m

Work out the weight of fuel used and subtract it from the start fuel to find the weight of fuel remaining, then recalculate the CG.

Tank	**Time hr**	**%**	**Consumed**

	70 lb	**lb**
A	1.5 X 70 =	- 105
B	0.5 X 70 =	- 35
C	1.0 X 70 =	- 70
D	0.5 X 70 =	- 35

Tank	**Fuel**					
	Orn	**Used**	**Left**		**Arm m**	**Moment lbm**
A	360	- 105	= 225	X	- 2.2	- 561
B	60	- 35	= 25	X	- 1.2	-30
C	480	- 70	= 410	X	+ 1.7	+ 697
D	72	- 35	= 37	X	+4.7	+ 173.9
New Total mass			727	**New Tm**		+ 279.9

CG equals +279.9 lbm ÷ 727 lb = + 0.385 m

= +0.39 m

Atlantic Flight Training Ltd

Chapter 3

Mass Limitations

Before starting this chapter read the definitions listed on Pages 2 to 4 of CAP 697

Finding the Basic Mass and Centre of Gravity of an Aircraft

All aircraft have to be weighed at set intervals throughout their operational life. The operator must establish the mass and CG of any aircraft in accordance to JAR-OPS, Subpart J, 1.605. At present an aircraft must be weighed and the CG calculated:

Prior to entering service, and

- Every 4 years if individual aeroplane masses are used, or
- Every 9 years if fleet masses are used
- Or when the effect of any modification / repair cannot be properly documented
- On entry in a JAA certified operator's service if bought from a non-JAA operator

There are three basic methods of weighing aircraft:

Electronic Strain Gauges	The strain gauges vary their resistance with the load of the aircraft.
Hydrostatic Weighing	The hydrostatic units use the principle that the pressure is proportional to the load applied.
Weigh-Bridge	Each undercarriage leg is placed on a separate weighing platform.

Whichever method is used, at each point of contact only part of the total mass is felt. This part mass is termed a reaction mass; the total mass is the sum of all the reaction masses. As each reaction point will be a set distance from the datum, the reaction moment for each point can be calculated individually, added together and divided by the total mass to find the aircraft's centre of gravity.

The manufacturer first weighs the aircraft after completion of manufacture. This is when the aircraft has its basic equipment installed. The aircraft weight in this condition is referred to as its **B**asic **E**mpty **M**ass (**BEM**) or **B**asic **M**ass (**BM**) and its centre of gravity in this condition is referred to as the BEM CG. This is the starting point for all other mass and balance calculations.

Basic Empty Mass (Basic Mass)

Found on page 2 under DEFINITIONS.

Basic Empty Mass (Basic Mass) Is the mass of an aeroplane plus standard items such as:

- Unusable fuel and other unusable fluids
- Lubricating oil in the engine and auxiliary units

- Fire extinguishers
- Pyrotechnics
- Emergency oxygen equipment, and
- Supplementary electronic equipment.

The term unusable in the case of fuel and oil means the fuel that cannot be drawn from the tanks to operate the engine, and the oil that cannot be drawn from the sump to lubricate the engine. Other unusable fluid covers; hydraulic fluid and cooling fluid etc. This does not include the potable water (drinking water) or the lavatory pre-charge.

All items of equipment that have to be in the aircraft when it is weighed are placed in their designated locations. This ensures that the mass and arm of all removable equipment fitted to the aircraft can be calculated. This is determined by the manufacturer who produces a list of **basic equipment** as part of the weight and centre of gravity schedule for the aircraft. From this the operator is able to adjust the mass and balance documentation for any equipment that is removed for a particular flight.

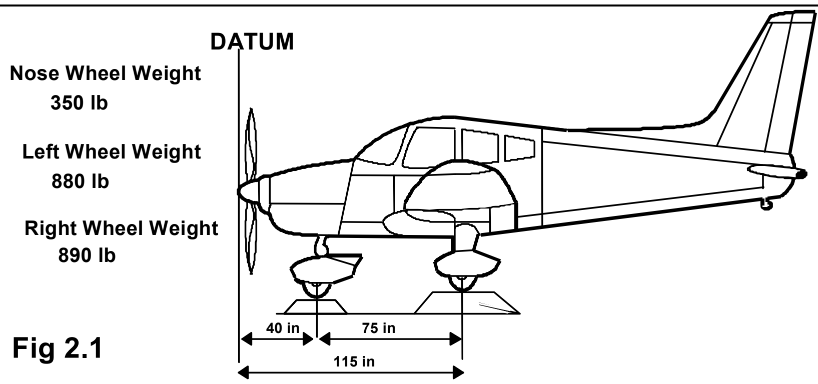


Fig 2.1

In the Fig 2.1 above, a light aircraft is being weighed, the reaction weights and arms are given, using the method previously shown. The centre of gravity can be located as follows.

Item	Mass	Arm	+ Moment	- Moment
Nose wheel	350 lb	+ 40 ins	14000 lbins	
Left main wheel	880 lb	+ 115 ins	101200 lbins	
Right main wheel	890 lb	+ 115 ins	102350 lbins	
Totals	2120 lb		217550 lbins	
		Total Moment	+ 217550 lbins	

C of G = TM ÷ Tm

C of G = + 217550 lbins ÷ 2120 lb

C of G = + 102.617 ins

C of G = + 102.62 ins

To operate an aircraft certain extras are added:

- Crew
- Personal baggage
- Catering and removable passenger service equipment.
- Potable water and lavatory chemicals.
- Food and beverages

All the above are counted as Variable Load (VL). Remember that the last three items are for commercial operations.

When an aircraft has been loaded to the above condition it is at the Dry Operating Mass (DOM).

Basic Empty Mass	Variable Load
Dry Operating Mass	

Dry Operating Mass (DOM)

Found on page 2 under DEFINITIONS.

Dry Operating Mass (DOM) Is the total mass of the aeroplane ready for a specific type of operation excluding all usable fuel and traffic load. The mass includes items such as:

- Crew and crew baggage
- Catering and removable passenger service equipment
- Potable water and lavatory chemicals
- Food and beverages

Traffic Load

Found on page 2 under DEFINITIONS.

Traffic Load The total mass of passengers, baggage and cargo, including any “non-revenue” load

The non-revenue load is those items that the aircraft carries that:

- Are not used in flight, or

- Are part of the aircraft's role equipment and no financial charge is made

This does not include usable fuel or oil.

At this point an aircraft at DOM could be loaded in one of two ways:

- All of the fuel but none of the passengers, baggage and cargo
- All of the passengers, baggage and cargo, but no fuel.

Both conditions have their own definitions.

Operating Mass (OM)

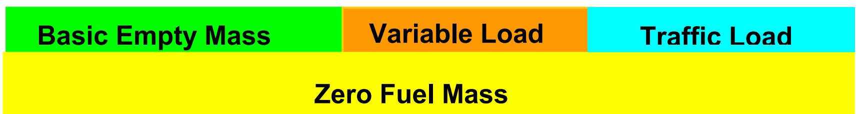
Found on page 2 under DEFINITIONS.

Operating Mass (OM) Is the DOM plus fuel but without traffic load

Zero Fuel Mass (ZFM)

Found on page 3 under DEFINITIONS

Zero Fuel Mass (ZFM) Is DOM plus traffic load but excluding fuel



For the majority of aircraft the fuel is stored in fuel tanks located in the wings outboard of the main wheels, while the traffic load is located in the fuselage. For larger aircraft the mass of the fuel is used to balance the combined masses within the fuselage, as represented in Fig 2.2 below.

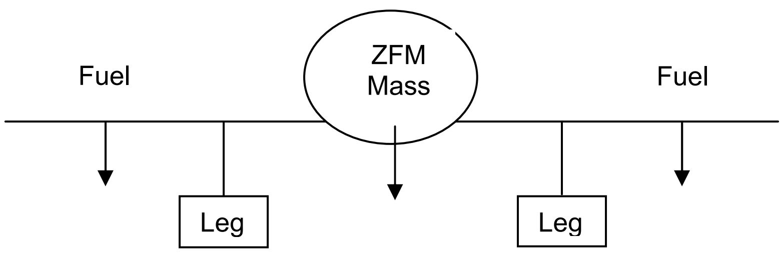


Fig 2.2

Where fuel tanks are located within the fuselage, the mass of the fuel acts with the traffic load. So a limit is placed on how much fuel may be put into the centre tank until the wing tanks are filled.

Example CAP 696, MRJT 1, page 22

Fuel tank location diagram and the caution between Figs 4.5 and 4.6

If centre tank contains more than 450 kg the wing tanks must be full

As the mass of the fuel is used to balance the internal load, a limit is placed on how much weight may be put into the aircraft before fuel has to be added into the wing tanks. Without this limit called **M**aximum **Z**ero **F**uel **M**ass **(MZFM)** the aircraft can suffer structural damage.

Maximum Zero Fuel Mass (MZFM)

Found on page 3 under DEFINITIONS

Maximum Zero Fuel Mass (MZFM) The maximum permissible mass of an aeroplane with no usable fuel

Comparing CAP 696, page 5, SEP 1 with page 12, MEP 1. The lighter single engined aircraft has no MZFM limit whereas the heavier light twin has a MZFM of 4470 LB.

Structural Limitations

There are further weight limitations to prevent structural damage and overloading. The greatest mass an aircraft can ever be is its Maximum All-Up Weight (MAUW), if this is exceeded then structural damage can occur.

These are:

Maximum Structural Take-Off Mass

Found on page 3 under DEFINITIONS

Maximum Structural Take-Off Mass The maximum permissible total aeroplane mass at the start of the take-off run

Maximum Structural Taxi Mass

Found on page 3 under DEFINITIONS

Maximum Structural Taxi Mass Is the structural limitation on the mass of the aeroplane at the commencement of taxi

This allows for the fuel that the aircraft will consume during start, run-up and taxi. This is also referred to as Maximum Ramp Mass.

Basic Empty Mass	Variable Load	Traffic Load	Fuel	S/T
Ramp Mass				

S/T Start and Taxi Fuel

Maximum Structural Landing Mass

Found on page 3 under DEFINITIONS

Maximum Structural Landing Mass The maximum permissible total aeroplane mass on landing under normal circumstances

Depending on the size, mass and design of the aircraft these can be set at the same or different masses

Comparing CAP 696, page 5 **SEP 1** and page 12 **MEP 1** with page 21 **MRJT 1** mass and balance limitations:

- The lighter aeroplanes (SEP 1 and MEP 1) have the single limit of Maximum Structural Take-Off Mass whereas the MRJT 1 has both taxi and take-off structural limitations.

Maximum Structural Taxi Mass	63 060 KG
Maximum Structural Take-Off Mass	62 800 KG

- For the light single engined aircraft page 5 **SEP 1** the Maximum Structural Take-Off Mass and Maximum Structural Landing Mass are the same.
- For the light twin engined aircraft

Maximum Structural Landing Mass	4513 LB
Maximum Structural Take-Off Mass	4750 LB

The limitations above define the maximum masses for given conditions. The other factors that must be taken into account are performance related:

- The altitude of the airfield)
- The air temperature) Density
- The length of the runway
- The topography of the area

This is not the complete list. You must be aware that to meet the performance requirements an aircraft's mass can be limited. These limits have to be taken into account not only for the take-off, but also for the landing. In some cases the conditions en route may also become limiting factors.

Performance Limited Take-Off Mass (PLTOM)

Found on page 3 under DEFINITIONS

> **Performance Limited Take-Off Mass (PLTOM)** Is the take-off mass subject to departure airfield limitations. It must never exceed the maximum structural limit.

Performance Limited Landing Mass (PLLM)

Found on page 3 under DEFINITIONS

> **Performance Limited Landing Mass (PLLM)** Is the mass subject to the destination airfields limitation. It must never exceed the structural limit.

Other definitions limiting the aircraft's take-off and landing masses are

Regulated Take-Off Mass (RTOM)

Found on page 3 under DEFINITIONS

> **Regulated Take-Off Mass (RTOM)** Is the lowest of "Performance Limited" and "Structural Limited" Take-off Mass.

Regulated Landing Mass (RLM)

Found on page 3 under DEFINITIONS

> **Regulated Landing Mass (RLM)** Is the lowest of "Performance Limited" and "Structural Limited" landing mass.

The RTOM is also referred to as Maximum Allowable Take-Off Mass (MATOM) and the RLM as Maximum Allowable Landing Mass (MALM).

Even when taking off from an airport with the most favourable conditions in the world the maximum take-off mass cannot be exceeded. The aircraft's actual take-off mass might have to be reduced because of regulation and performance limitations in force at the destination airport.

The actual mass of the aeroplane at take-off is called the Take-Off Mass (TOM) and the actual mass at landing is called the Landing Mass (LM).

Take-Off Mass (TOM)

Found on page 3 under DEFINITIONS

> **Take-Off Mass (TOM)** Is the mass of the aeroplane including everything and everyone contained within it at start of the take-off run.

Basic Empty Mass	Variable Load	Traffic Load	Fuel
Take-off Mass			

Landing Mass (LM)

Not given in CAP 696.

Landing Mass (LM) Is the mass of the aeroplane including everything and everyone contained within it at start of the landing run.

Fuel Terminology

Aircraft carry more fuel than that required to fly from A to B. Below is a list of terms and definitions that cover different aspects of the fuel-load.

The fuel that is used in flight is called trip fuel **(TF)**. Other fuel is added to cover:

- Start, run-up and taxi
- Diversions
- Extra or reserve
- Contingencies

The total put into an aircraft before start is called the **fuel load** or **block fuel**.

The take-off fuel **(TOF)** - is the fuel load in the aircraft at the start of the take-off run.

The aircraft's Ramp Mass **(RM)** includes the given allowance of fuel for the aircraft to:

- Start
- Run up, and
- Taxi to the runway.

This extra fuel must have been consumed by the start of the take-off run so the aircraft is at the correct take-off mass, during the flight the **Trip Fuel (TF)** is being consumed at a given rate. The landing mass should be equal to the **TOM** less the **(TF)**.

During flight the current mass referred to as Gross Mass (GM) and centre of gravity can be calculated by working out:

- The time X rate of consumption per hour and
- The consumed mass X fuel tank arms.

This will give the current gross mass or all up mass.

Example An aircraft that has a TOM of 21,759 kgs and CG of +176 ins is on a 5 hour flight with an average fuel consumption of 180 kgs per hour from a fuel arm of + 169 ins

STEP 1 Calculate the LM and CG plus the midpoint Gross Mass and CG

Condition	**Mass kgs**	**Arm**	**+ Moment**	**- Moment**
TOM	21,759	+176	3,829,584	
Fuel Used	-900	+169		152,100
LM	20,859		+3,677,484	

LM CG = +3, 677,484 ÷ 20,859 = +176.3ins

For the GM @ mid point divide the fuel used and its moment effect by 2 and recalculate with these figures.

Condition	**Mass kgs**	**Arm**	**+ Moment**	**- Moment**
TOM	21,759	+176	3,829,584	
Fuel used	-450	+169		76,050
GM	21309		+3,753,534	

GM CG = +3,753,534 ÷ 21,309 = +176.15 ins

Using Table 1 and the example below calculate the CGs required in the example below. The answer for this example is given at the end of the chapter.

Example An aircraft with a BEM of 2120 lb and BEM CG of +102.62 has a fuel tank arm of + 112 ins and is fuelled with 30 US gallons of Avgas SG.72. A pilot of 112 lb mass seated at +108.5 is to fly from A to B, with a 37 lb package in the baggage compartment located at + 123 ins. The flight is planned to take 5.5 hrs with an average fuel consumption of 3.37 gallons per hour, the fuel allowance for start, run-up and taxi is 7.3 lbs.

Calculate the mass and CG for the following:

- DOM
- OM
- ZFM
- RM
- TOM
- TOF
- LM
- GM at mid point

Table 1

Condition	**Mass lb**	**Arm ins**	**+ Moment**	**- Moment**
BEM				
VL				
DOM				
DOM CG				
DOM				
Block Fuel				
OM				
OM CG				
DOM				
Pay load				
ZFM				
ZFM CG				
OM				
Pay load				
RM				
RM CG				
RM				
Start Fuel				
TOM				
TOM CG				
Block Fuel				
Start Fuel				
TOF				
Trip Fuel				
TOM				
TF				
LM				

LM CG

mid point fuel consumption =

TOM

Fuel used

GM

GM CG at mid point

The table above shows the mass and CG for the different load conditions. In the case of the **RM** payload was added to the **OM**, it could have been determined by adding the block fuel to the **ZFM**.

At each stage of the calculation the conditions can be compared with any limiting factors as shown in the table below

Condition	Mass lb	Arm ins	+ Moment	- Moment
BEM	2120	+102.62	217554.4	
VL	112	+108.50	12152	
DOM	2232	+102.91	+229706.4	
Pay load	37	+123.00	4551	
ZFM (**MZFM 2270**)	2269	+103.24	+234257.4	
Block Fuel	180	+112.00	20160	
RM (**MAUM 3500**)	2449	+103.88	+254417.4	
Start Fuel	-7.3	+112.00		- 817.6
TOM (**MTOM 3475**)	2441.7	+103.86	+253599.8	
PLTOM **2777**				
TF	-111.21	+112.00		- 12455.52
LM (**MALM 3000**)	2330.49	+103.47	+241144.28	
PLLM **2340**				

Many light aircraft use a loading sheet or loading manifest as per the examples in CAP 696 pages 8 and 14. The BEM and the BEM CG being taken from the aircraft's weight and balance report which forms part of the technical log.

In Fig 2.1 of these notes the light aircraft depicted is shown in the conventional manner looking at it from the left wing tip, with the nose to the left. This is also seen in SEP 1 and MEP.1, however in some cases the aircraft is viewed from the opposite side so the nose is shown to the right, see Fig 2.3 below and MRJT 1 (fig 4.1). In all cases the negative arm is always towards the nose of the aircraft.

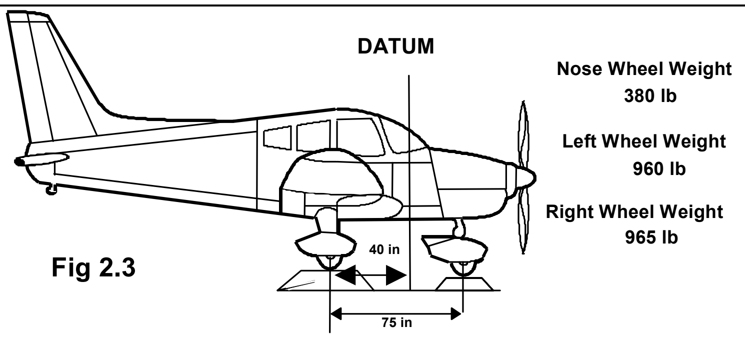


Fig 2.3

Basic Aerodynamic Principles

This section covers the basic aerodynamic principles that are required for understanding the effect the location of the CG has on the flight and stability of an aircraft and the reason for CG limits. A full explanation of aerodynamic forces is given in the Principles of Flight section, which is covered later in the course.

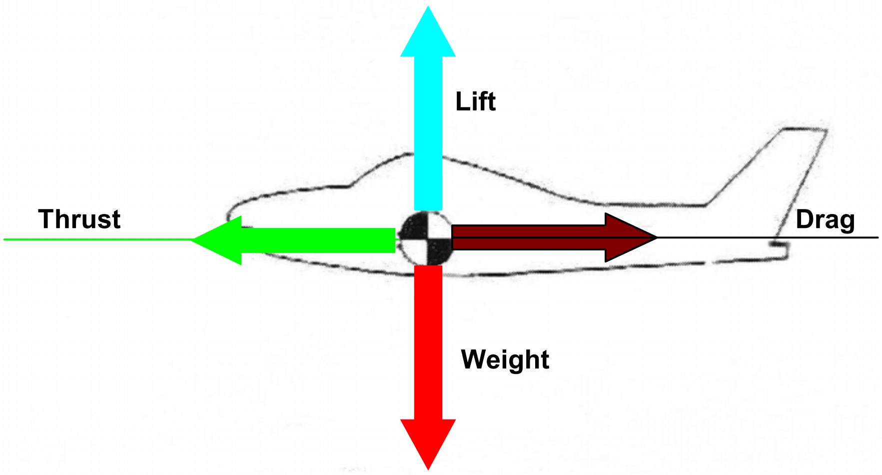


Fig 2.4

In flight there are four forces acting upon the aircraft as shown above in Fig 2.4:

- Thrust
- Drag
- Lift and
- Weight

These are said to act through the aircraft's Centre of Gravity. In straight and level and un-accelerated flight these forces are balanced.

The wings provide the lifting force. However, the lifting force is not distributed evenly across the Chord (width) of the wing as shown in the diagram Fig 2.5 below.

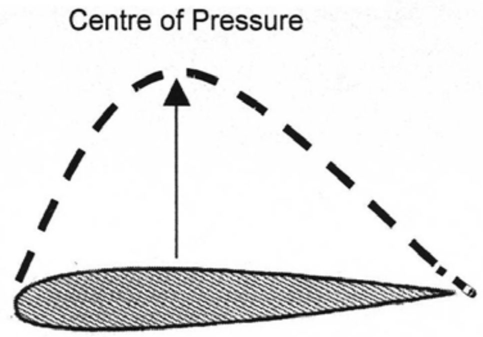


Fig 2.5

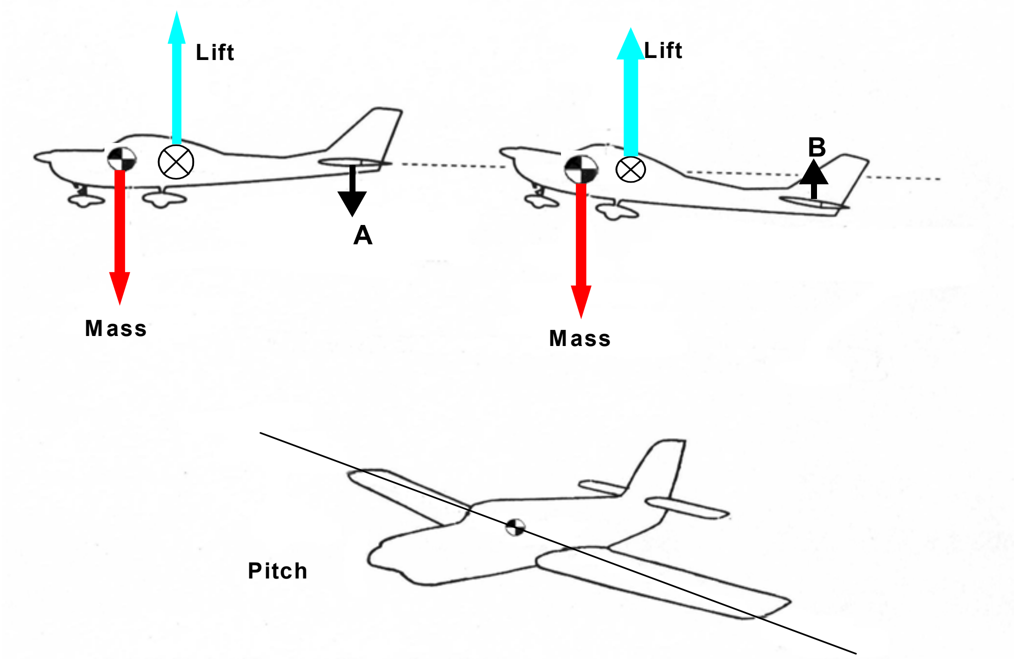
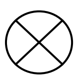


Fig 2.6 Effect of Changing Airspeed on Pitching

 Centre of Gravity

 Centre of Pressure

A The balancing aerodynamic force is produced by the tailplane and elevator

B At a slower airspeed there is an altered balancing aerodynamic force due to the Centre of Pressure moving forward

In flight the lifting force produced by the wings is balanced by the aerodynamic force generated by the tailplane, the force from the tailplane acts to stabilise the aircraft, and acts from the tailplane to the CG.

The aircraft's pitch/pitching attitude can be controlled by moving the elevator and altering the aerodynamic force generated by the tailplane. For normal flight conditions the pilot has:

- The full range of the elevator's movement for altering the aircraft's angle of climb or dive, and
- The full range of trim to balance the stick force to off load the pilot.

However other factors must be taken into account, these are:

- Movement of the CG due to fuel and oil consumption
- Movement of the CG due to extending and retracting flaps and forward and rearward moving gears
- Movement of the CP
- The effect on stability caused by the length of arm between the CG and tailplane
- Gross Mass

CG Limits Ideally the Gross Mass acting through the CG should be directly under the point of maximum lift which is the centre of pressure (CP). This ideal situation rarely occurs in flight due to:

- The CG's movement as trip fuel is consumed, and
- The CP's movement due to the change in the amount of lift generated by the wings at different speeds and angle of attack.

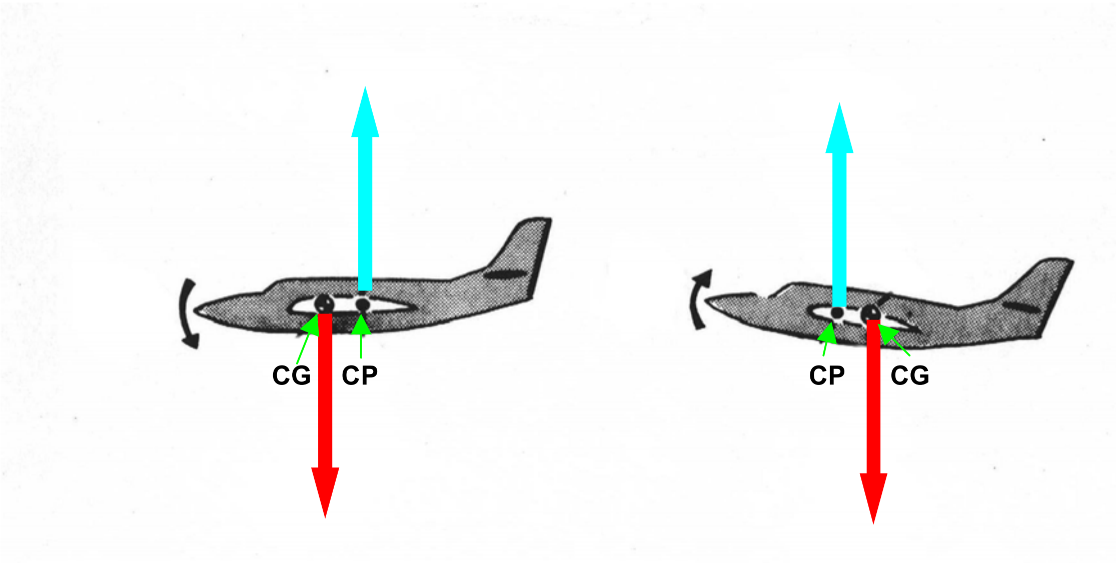
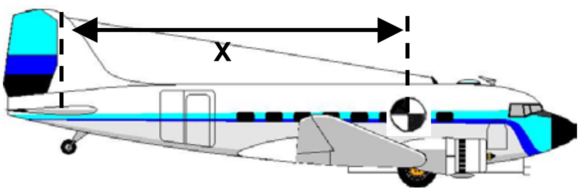


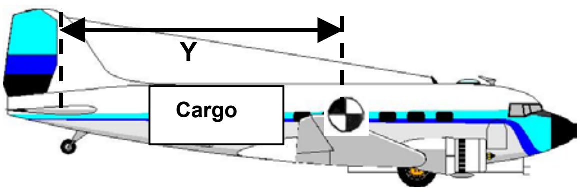
Fig 2.7 Lift and Mass Producing a Pitching Couple

When the CG is not directly beneath the CP a turning moment is generated causing the aircraft to pitch about the lateral axis which passes through the CG's location as shown above in Fig 2.7.

As the CG moves forward of the CP the aircraft becomes progressively nose heavier, increasing the nose down pitching effect conversely as the CG moves rearward behind the CP the aircraft becomes tail heavy and the nose pitches up.



The further forward the CG's location the longer the moment arm between the tailplane (the balancing aerodynamic force) and CG, this increases the stability of an aircraft. Obviously an over stable aircraft is difficult to manoeuvre.



The further aft the CG's location the shorter the arm, this decreases the stability of the aircraft. In the diagram above Y is obviously shorter than X and so with the same balancing force there must be a lower restoring moment. This means that:

- A forward CG means a more stable aircraft
- An aft CG means a less stable aircraft

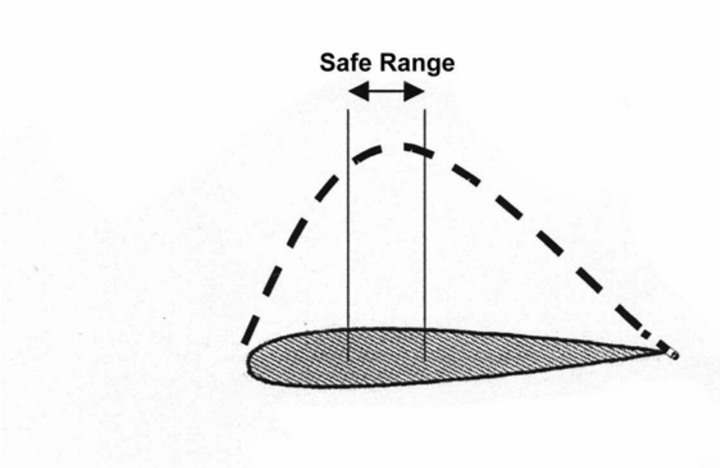


Fig 2.9

The design of the wings determines the range through which the CP moves under normal operation. When these factors are taken into account it can be seen that the location of the CG must be controlled and its movement predicted. So fore and aft CG limits are set by the designer and licensed by the controlling aviation authority, and is referred to as the aircraft's CG safe range as shown in Fig 2.9 above.

Providing the aircraft is not overloaded, the CG may fall **on** or **between** these limits. However as the CG location moves with the consumption of fuel both the TOM and LM must be compared to the limits. The ZFM should also be compared to ensure that the CG is in limits when the aircraft is on the ground and that should for some reason the entire fuel load be used or lost that the aircraft would is still flyable.

If the CG falls outside the limits corrective action must be taken. Some examination questions will require a statement as to whether the aircraft is safe for a particular condition.

For example if an aircraft's safe range is between +119" and +127":

- With a TOM CG is +125" the LM CG is +120" the aircraft is **safe for flight**.

- If an aircraft's safe range is between + 119" and +127" and its TOM CG is +125" the LM CG is + 118.9" the aircraft is **un-safe for flight** however the exact condition is that it is safe to take-off but **unsafe** to land.

Centre of Gravity and Stability

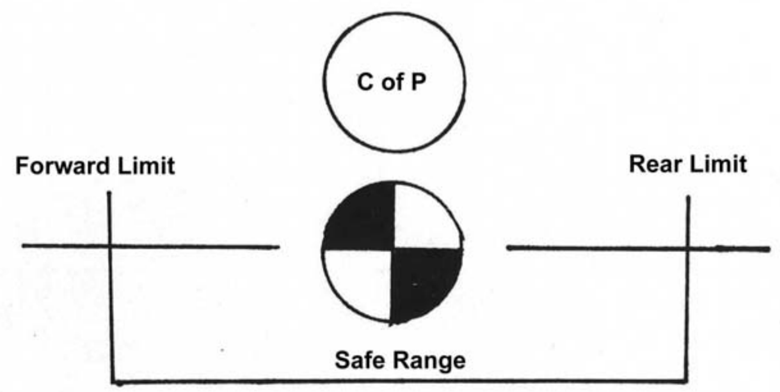


Fig 2.10 CG and Stability

From a starting position of the CG being located directly beneath the CP in the centre of the safe range:

- Movement of the CG in either direction will alter both the point through which the mass acts in relation to the lift, and the length of the arm between the CG and tailplane.
- Both of which will effect the aircraft's performance and handling due to the need to increase the amount of elevator applied to restore the couple and elevator trim to off load the stick forces.
- This reduces the amount of elevator and trim movement available for control.

A Centre of Gravity Fwd of the limit results in the aircraft:

- Being more stable.
- Less likely to stall.
- More likely to nose in on landing as difficult to round out.
- Difficult to rotate on take off, so increasing the take-off run and ground speed.
- Having increased drag due to elevator and trim deflection.
- Having to use more power for a given airspeed.
- Having greater fuel consumption, therefore a reduced range.
- Decrease in performance.

A Centre of Gravity Aft of the limit results in the aircraft:

- Being less stable.
- More likely to stall, as stalling speed increases.
- Having to land at higher speed.
- Will rotate on take-off before reaching the take-off safety speed.

- Having increased drag due to elevator and trim deflection.
- Having to use more power for a given airspeed.
- Having greater fuel consumption, therefore a reduced range.
- Decrease in performance.

The further the CG is from the safe range the more radical the effect.

If an aircraft's MTOM is exceeded, but the CG is located within the safe it will result in:

- Having a greater take-off run, because it requires a greater speed to produce the lift required.
- Reduced climb performance.
- Reduced air speed.
- Higher stalling speed.
- More likely to stall.
- Reduced climb performance.
- Reduced service ceiling.
- High power setting to maintain airspeed.
- Increased fuel consumption.
- Decreased range.
- High landing speed.
- Longer landing run.
- Heavy braking.
- Decrease in performance.

The greater the overload condition the more radical the effects become.

For light aircraft these limits can be given in one or both of two ways, numerically or graphically. The numerical limits are given in the weighing report, as per the limits in the SEP 1 and MEP 1 data sheets.

This is shown graphically as a CG envelope – as shown below in Fig 2.11 below.

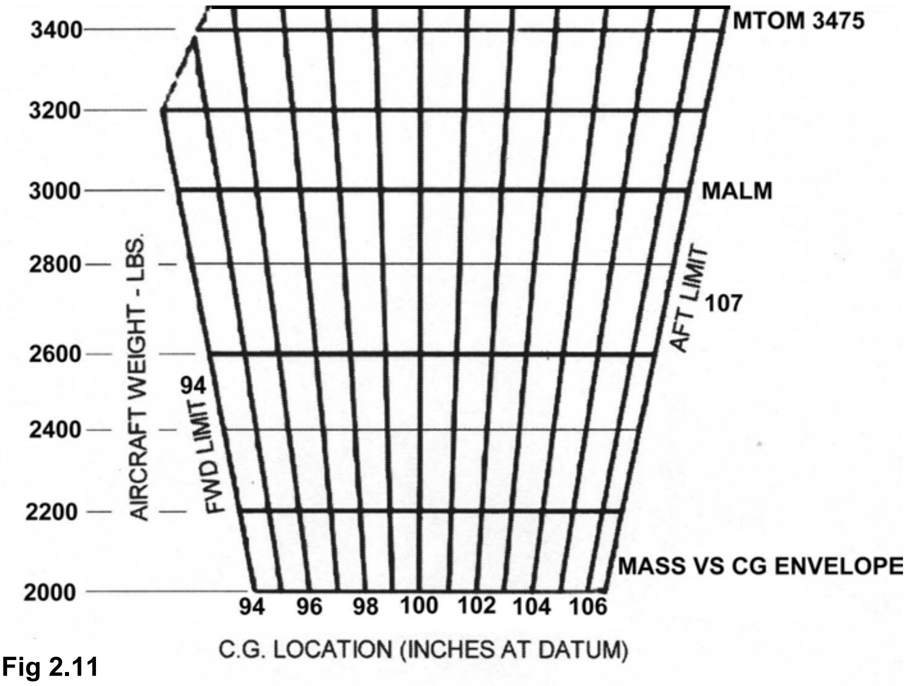


Fig 2.11

Centre of Gravity Envelope

The vertical and inclined lines of the envelope represent the front and rear CG limits, the upper horizontal line represents the maximum take-off mass.

Between the base line and the MTOM line the envelope will be marked of with further horizontal lines at set mass intervals. Dependant on the style of CG envelope the vertical lines will be marked off as either units of moment or CG linear positions.

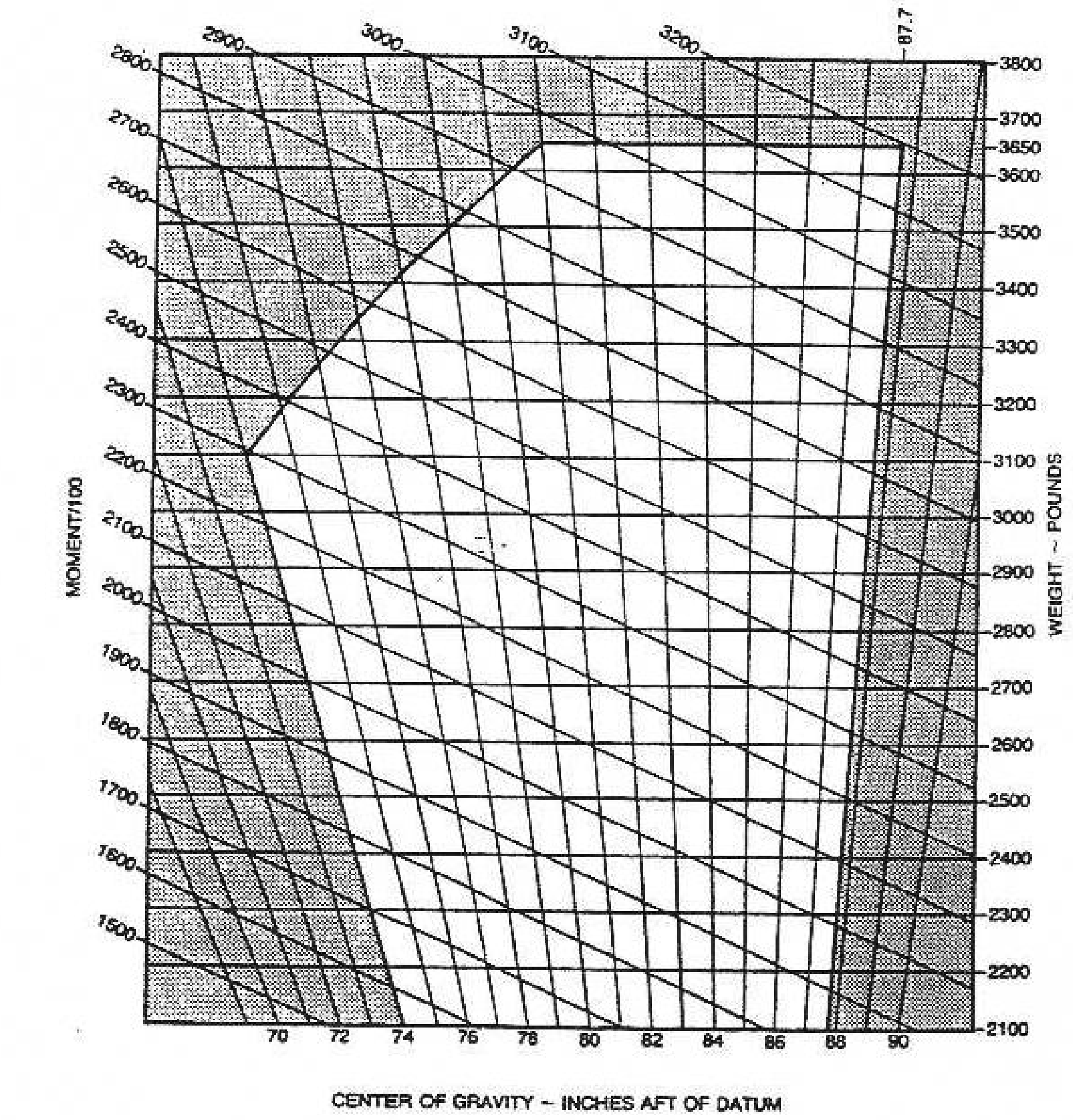
Plotting on a CG envelope

The points to plot are the TOM, LM and ZFM, a straight line drawn from the TOM to ZFM should pass through the LM plot and will show the aircraft's CG location should some reason all the fuel be consumed or lost. It will also ensure that the MZFM is not exceeded. Other points can be plotted to ensure that CG does not go out of limits as the aircraft is loaded.

In the case of the CG envelope Fig 2.5 of SEP 1:

- The horizontal lines represent mass
- The vertical lines represent CG position,
- The diagonals $^{moment}/_{100}$

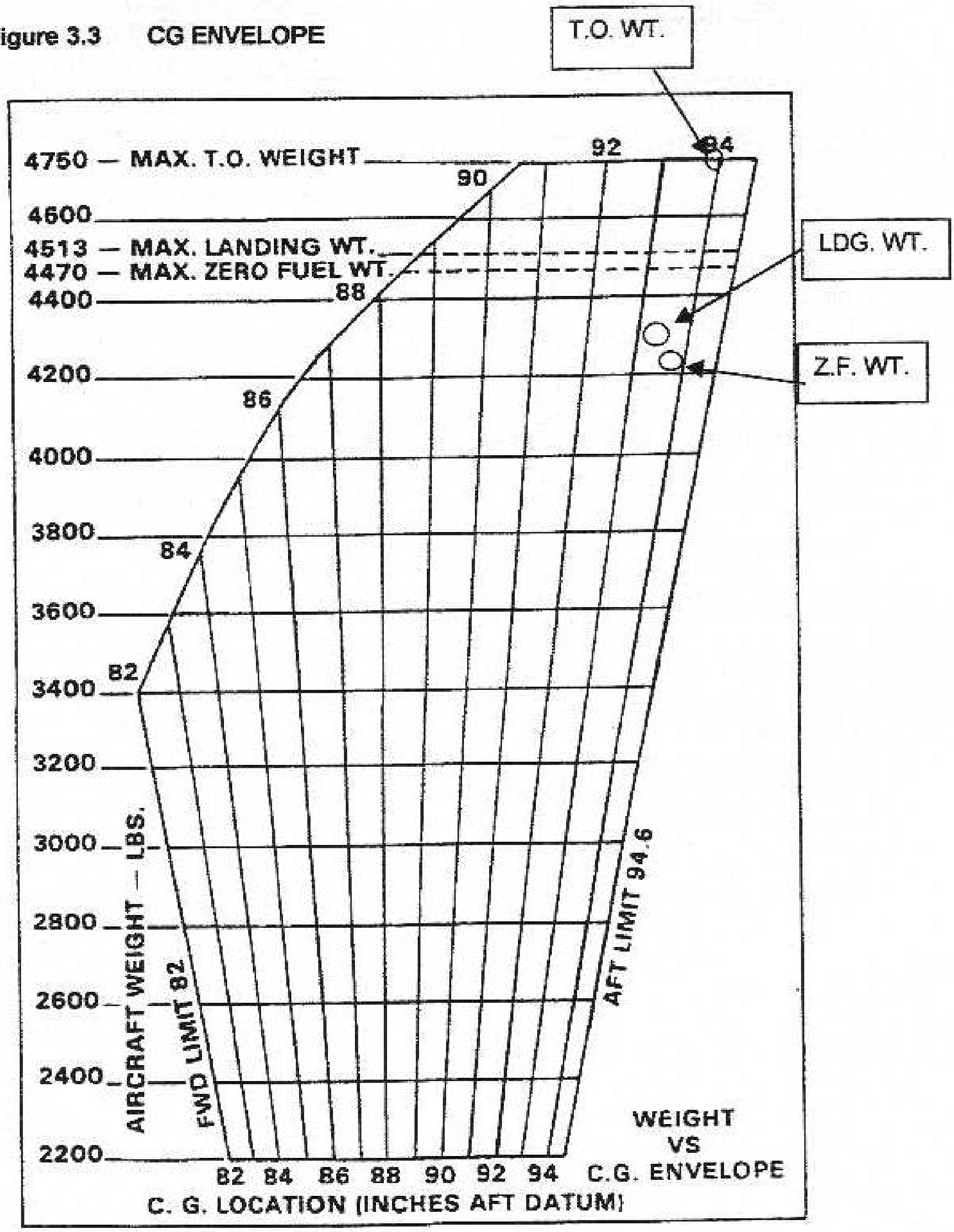
It will also be seen that the forward limit diverges from, then converges towards the rear limit as the aircraft's mass changes. This causes the vertical lines to diverge, so care must be taken when measuring the scale before plotting the points.



CAP 696, SEP 1, Fig 2.5, Page 9

For aircraft where landing and zero fuel masses are limited the envelope is marked with horizontal lines denoting these limits. This is shown in the diagram below.

Figure 3.3 CG ENVELOPE



CAP 696, MEP 1, Figure 3.3, Page 15

Though not shown in the CG envelopes of the CAP 696 some aircraft have areas marked off within the envelope which denote the aircraft's maximum utility mass and the CG limits for this type of flying.

In the Fig 2.12 below a TOM, LM and ZFM are plotted:

TOM	3250 @ +106”
LM	2600 @ +100.2”
ZFM	2300 @ +97”

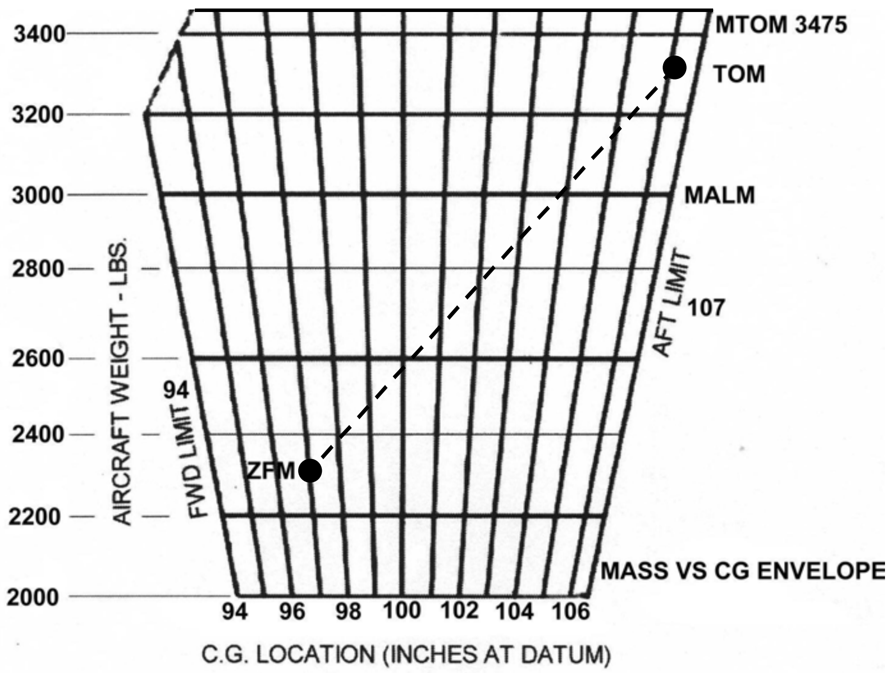


Fig 2.12

Example Given the following information for the SEP 1 calculate the:

- Ramp Mass
- Take-off Mass
- Landing Mass
- CG Position at take-off
- CG position for landing

Use Figs 2.4 and 2.5 to help your calculation.

Front Seat Occupants	320 lb
Third and fourth seat Pax	350 lb
Baggage Zone “B”	100 lb
Fuel at Start	74 US Gal
Trip Fuel	65 US Gal

Questions for Chapter 3

1. The pay load and basic mass and VL can be defined as:
   a. DOM
   b. OM
   c. MAUM
   d. ZFM

2. RLM is:
   a. always equal or greater than MLM
   b. always equal or less than MLM
   c. always equal to MLM
   d. never equal to MLM

3. MZFM is defined as
   a. the minimum permissible mass of an aeroplane with no useable fuel, but including payload
   b. the maximum permissible mass of an aeroplane with useable fuel, but no payload.
   c. the minimum permissible mass of an aeroplane with the useable fuel but no payload.
   d. the maximum permissible mass of an aeroplane without the useable fuel but including payload.

4. The unusable fuel is accounted for as part of:
   a. DOM
   b. Block fuel
   c. BM
   d. RM

5. An aircraft has a loaded mass of 4000 kg acting at an arm of +112.5 cm, he fwd limit is +114 cm. How much ballast must be added to the aft baggage hold at an arm of +190 cm to place the CG on the fwd limit ?
   a. 21.05 kg
   b. 64.42 kg
   c. 78.95 kg
   d. 90.03 kg

6. Given an aircraft with a ramp mass of 4995 kg, a VL of 108 kg, a DOM of 2478 kg and a fuel allowance of 7 kg for start run up and taxi, and 13kg of unusable fuel, TOF of 800 kg. What is the traffic load?
   a. 1602 kg
   b. 1697 kg
   c. 1710 kg
   d. 1717 kg

7. An aircraft of 66000 kg MTOM is to make a 6 hr flight to an airport where its landing mass is regulated to 47000 kg.

   The basic mass of the aircraft is 21759 kg.

   The VL component is 500kg.

   The aircraft has a MZFM of 41000 kg.

   The anticipated fuel consumption is 3500 kg per hour.

   For this flight the aircraft must land with 5000 kg as a reserve.

   An allowance of 60 kg is made for start, run up and taxi.

   Using the lowest limiting factor calculate the Payload can the aircraft carry on this flight?

   a. 13741 kg

   b. 18741 kg

   c. 19741 kg

   d. 14741 kg

8. An aircraft has been loaded as follows:

BEM	6500 kg	@ + 23”
VL	300 kg	@ - 70”
Payload	2900 kg	@ +104”
Fuel	500 kg	@ + 50”

   The CG limits are +42.5” to 45.7”. It is expected that the fuel consumption for the flight will be 300 kg. Is the aircraft:

   a. safe for flight.

   b. safe for take-off, but unsafe for landing.

   c. unsafe for take-off, but safe for landing.

   d. Unsafe for take-off or landing.

9. The reaction masses for an aircraft are:

Nose wheel	7000 kg acting at –900 ins
L main wheel	31000 kg acting at + 16 ins
R main wheel	31320 kg acting at + 16 ins

   Choose the correct CG for this aircraft:

   a. + 76.5 ins

   b. - 76.5 ins

   c. + 76.49 ins

   d. - 76.49 ins

10. A light tail wheeled aircraft with its datum located on the trailing edge of the rudder, has the following reaction masses when levelled for flight

Tail wheel	98 lb at –15”
L main wheel	1000 lb at – 96”
R main wheel	1005 lb at – 96”

Prior to a 1.5 hr flight a load sheet is prepared. Fuel load 30gallons of avgas SG 0.72 located in a tank with an arm of – 95”, a 112 lb passenger in the front right seat with an arm of – 98” and a pilot of 160 lb in the front left seat which has the same arm. The expected fuel consumption is 5 gallons per hour, the safe range is between – 93” and –78”.

Choose the correct statements from those listed below.

(i) at ZFM the CG is fwd of the ground safety limit

(ii) TOM is 2519 kg at an arm of –92.99 and is in limits

(iii) TOM is 2519 lbs at an arm of –93.01 and is out of limits

(iv) the TF is 36 lbs and has a moment of + 3420 lbins

(v) the LM is 2483 lb and has a moment of – 230875.69 lbins

(vi) the BEM CG is – 92.23”

a. i, iii, v, vi

b. i, ii, v, vi

c. iii, iv, v, vi .

d. i, ii, iii, iv

Answers to Questions for Chapter 3

Answer to Example Page 8

Condition	Mass lb	Arm ins	+ Moment	- Moment
BEM	2120	+102.62	217 554.4	
VL	112	+108.50	12 152	
DOM	**2232**	**+102.92**	**+229 706.4**	

DOM CG +229706.4 + 2232 = +102.92

DOM	2232	+102.92	229 706.4	
Block Fuel	180	+112.00	20160	
OM	**2412**	**+103.91**	**+249 866.4**	

OM CG +249866.4 + 2412 = +103.59

DOM	2232	+102.92	229706.4	
Pay load	37	+123.00	4551	
ZFM	**2269**	**+103.24**	**+234257.4**	

ZFM CG +234257.4 + 2269 = +103.24

OM	2412	+103.91	249866.4	
Pay load	37	+123.00	4551	
RM	**2449**	**+103.88**	**+254417.4**	

RM CG +254417.4 + 2449 = +103.89

RM	2449	+103.88	254417.4	
Start Fuel	-7.3	+112.00		- 817.6
TOM	**2441.7**	**+103.86**	**+253599.8**	

TOM CG +253599.8 + 2441.7 = +103.86

Block Fuel	180	+112.00	20160	
Start Fuel	-7.3	+112.00		- 817.6
TOF	**172.7**	**+112.00**	**+19342.4**	

Trip Fuel 5.5hr % 3.37gals = 18.535 gals @ 6 lb = **111.21 lb**

TOM	2441.7	+103.86	+253599.8	
TF	-111.21	+112.00		- 12455.52
LM	**2330.49**	**+103.47**	**+241144.28**	

LM CG +241139.88 + 2330.49 = +103.471

mid point fuel consumption = 111.21 lb + 2 = 55.605 lb

TOM	2441.7	+103.86	+253599.8	
Fuel used	-55.61	+112.00		- 6228.32
GM	**2386.09**	**+ 103.67**	**+ 247371.48**	

GM CG at mid point =+ 247371.48 + 2386.09 = + 103.67

Example Page 21

Start by filling in Fig 2.4

ITEM	**MASS**	**ARM (IN)**	**Moment x 100**
Basic Empty Condition	**2415**	**77.7**	1876.45
Front seat occupants	320	**79**	252.8
Third and Fourth seat pax	350	**117**	409.5
Baggage zone "A"		**108**	
Fifth and sixth seat pax		**152**	
Baggage zone "B"	100	**150**	150
Baggage zone "C"		**180**	
SUB-total = ZFM	3185		
Fuel loading	444	**75**[1]	**333**
Sub-total = Ramp Mass	3629		
Subtract fuel for start, taxi and run-up (see below)	**-13**		**-10**
Sub-total = take-off mass	3616		3011.75
Trip fuel	390	**75**[1]	**293**
Sub total = Landing mass	3226		2718

Fuel for Start, Taxi and Run-up is normally 13 lbs at an average entry of 10 in the moment x 100 column

Figures in bold are available from the CAP

Note: 1. CAP 696, Page 6

Zero Fuel Mass	3185 lb
Ramp Mass	3629 lb
Take-Off Mass	3616 lb
Landing Mass	3226 lb

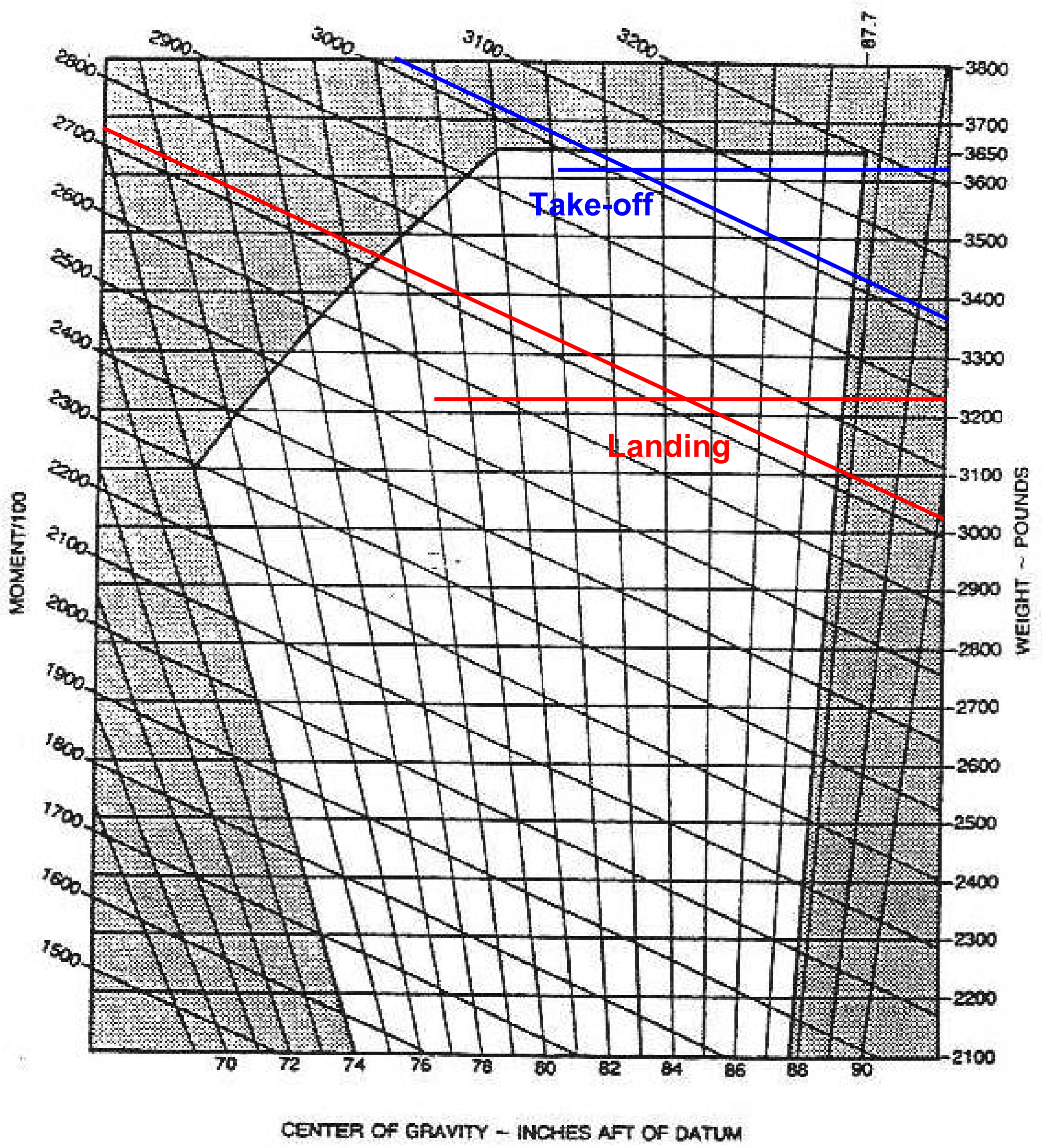
To get the CG position at Take-off use:

TOM Moment ÷ TOM Mass
301175 ÷ 3616 = 83.29 inches aft of the datum

To get the CG position at Landing use:

LM Moment ÷ LM Mass
271825 ÷ 3226 = 84.26 inches aft of the datum

The CG could also be found by plotting on Fig 2.5 the relative figures from Fig 2.4



Answers to Questions for Chapter 3

Question 1 D

Question 2 B

Question 3 D

Question 4 C

Question 5 C treat fwd limit as new datum so mass acts at -1.5 cm fwd of this datum [114 cm – 112.5 cm] the moment is –6000 cmkg [-1.5 × 4000] the baggage arm equals +76cm [190cm – 114 cm] to equal the left arm moment 6000 / 76 = 78.95 kg

Question 6 C

RM – S/t	=	TOM
4995 kg – 7 kg	=	4988kg.
TOM – DOM	=	TL + TOF
4988 kg – 2478 kg	=	2510 kg.
TL –TOF	=	TL
2510 kg – 800	=	1710 kg

Question 7 A 13741 kg lowest limiting factor is the MZFM 41000, add the DOM, then subtract the OM and the landing fuel as this will remain on board.

Question 8 A safe for flight.

Question 9 B

	7000 kg x -900 ins	=	-6300000 kgins
	31000 kg x + 19 ins	=	+ 496000 kgins
	31320 kg x + 19 ins	=	+ 501120 kgins
Total	69320 kg		-5302880 kgins

CG = -5302880 divided by 69320
CG = -76.498 ins worked to three places decimal
CG = -76.5 ins corrected to two places decimal

Answers given as one or two places decimal for exam accuracy problems must be worked to three places decimal then corrected to the accuracy required as indicated by the answer

Question 10 C

Fuel	Imp gal		SG	Mass
TOF	20	x	.72	144 lb
Trip	-5	x	.72	- 36 lb

Aircraft	Lbs		Arm	Moments
First reaction point	98	x	-15	-1470.00
Second reaction point	1000	x	-96	-96000.00
Third reaction point	1005	x	-96	-96480.00
BEM	2103		-92.23	-193950.00

Load Manifest

BEM	2103	x	**-92.23**	-193950.00
Pilot	160	x	-98.00	-15680.00
Pax	112	x	-98.00	-10976.00
ZFM	2375		**-92.89**	-220606.00
TOF	144	x	-95.00	-13680.00
TOM	2519		**-93.01**	-234286.00
TRIP	-36	x	-95.00	+ 3420.00
LM	2483		**-92.98**	-230866.00

Limits	Fwd	AFT
CG Range	-93 ins	-78 ins
BEM	In limits	In limits
ZFM	In limits	In limits
TOM	Out of Limits	In limits
LM	In limits	In limits

Chapter 4

Requirements of JAR - OPS

Chapters 1 to 3 cover the Basic Mass and Balance techniques of how to:

- Locate the CG of an aeroplane, and
- Calculate the change in CG location as fuel is consumed in flight.

Initially this chapter looks at the requirements of JAR-OPS for the following:

- Weighing of aircraft.
- Loading of aircraft.
- The legal responsibilities of the operator, the loading supervisor and Captain.

Weighing of Aircraft – JAR OPS 1

Aircraft are weighed:

- On completion of manufacture/prior to entry into service, and
- No later than every 4 years where individual masses are used, or
- Every 9 years where fleet masses are used (see fleet mass).

Aircraft must be re-weighed if the effects of modifications on the mass and CG are not known. Also where accumulated changes cause an aircraft's dry operating mass to alter by:

- ± 0.5% of its maximum landing mass
- ± 0.5% of the mean aerodynamic chord (see mean aerodynamic chord)

Fleet Mass and CG Position

Where operators have a fleet or a group of aircraft of the same type, model and configuration, an average of the fleet is calculated. This is then used on all the aircraft providing that the aircraft meet the tolerances laid down in the JAA regulations.

Where an aircraft's mass is within the above limits, but the CG is outside of the limits then:

- The dry operating fleet mass is used
- The CG position for the individual aircraft is used

Where the problem is due to an accurately accountable physical difference, such as the location of a galley, then the aircraft may remain in the fleet provided the appropriate corrections are applied to the mass and CG

Where an operator uses aircraft that do not have a mean aerodynamic chord published then:

- Individual masses are used, or
- Approval from the authorities to use a fleet mass must be obtained.

To obtain the fleet value the operator must weigh a minimum number of aircraft. To find the number of aircraft to be weighed the formula in table A below is used. As fleet numbers alter depending on the size of the operator "n" is used to represent the total number of aircraft in a fleet.

Table A

Number of aircraft in the fleet	Minimum number of aircraft to be weighed
2 or 3	n
4 to 9	n+3 ÷ 2
10 or more	n+ 51÷ 10

The maximum time interval between 2 fleet mass evaluations to maintain the fleet's mean is **48 months** and the aircraft selected should be those that have not been weighed for the longest period.

From table A:

- Where an operator has 3 aircraft in a fleet, all have to weighed at an interval of no more than 48 months
- Where an operator has 10 aircraft in a fleet only 6 are weighed every 48 months.

Weighing is carried out by an approved organisation (maintenance or manufacture) in an enclosed building. The aircraft will be checked for both its completeness and its equipment.

Tare Mass

Depending on the type of aircraft and the method of weighing, the mass of some ground equipment may be included. This has an effect on both the total mass and the total moment. This is referred to as Tare Mass. The tare mass and moment created are deducted from the total mass and moment of the aircraft to ensure that the correct mass and moment are used to calculate the BEM and CG. See fig 3.0 and the worked example.

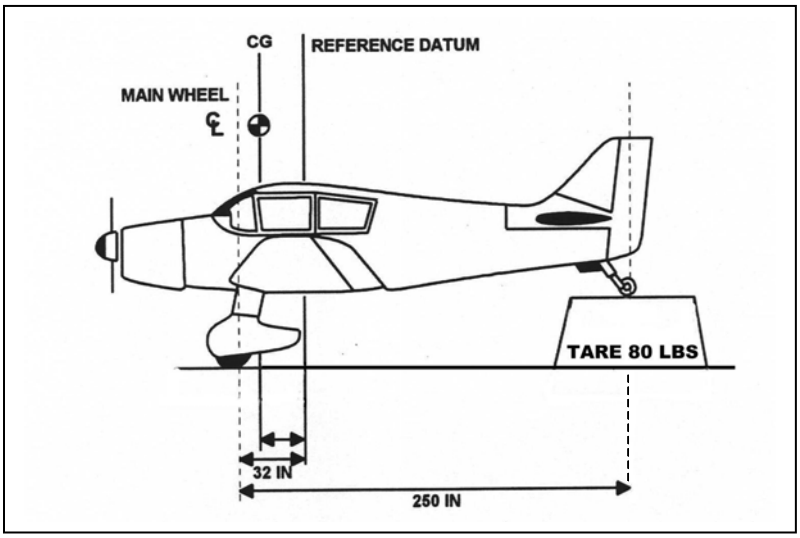


Figure 3.0

In fig 3.0 above, a tail stand is used to support the aircraft in the level position. In other cases aircraft chocks and other support equipment may be used.

Example Weighing an aircraft where a stand is included in the calculation as per Fig 3.0

Item	Mass (lbs)		Arm (ins)		Moment (lb/ins)
Left main wheel	700	X	-32	=	-22 400
Right main wheel	680	X	-32	=	-21 760
Tail wheel (total)	120	X	+250	=	+30 000
Less Tare mass	-80	X	+250	=	- 20 000
Total	1420				-34 160

-34 160 lb/ins + 1420 lbs = -24.06 inches

CG located 24.06 inches forward of the datum

Loading of Aircraft

As detailed in parts 1+ 2 the loading of an aircraft affects its handling and performance. Loading of an aircraft must be carried out under the supervision of a qualified person, who is to ensure that the aircraft is loaded in accordance with the data used for the calculations of the aircraft's mass and CG.

Taking into account:

1. Ground stability CG range of the aircraft
2. Maximum zero fuel mass of the aircraft
3. The take-off mass

4. Maximum structural taxi mass
5. Floor loading

Floor Loading

The aircraft's floor structure is kept as light as possible and the loader must take into account the limitations imposed on how much mass may be placed on it.

These are:

- Static load is the maximum mass allowed **on** a **given area** of a floor
- Running load is the **total mass** allowed **over** a length of floor.

The running load is normally greater than the static load, for example turn to page 12 of the CAP 696 MEP 1 data sheet. The bottom line shows the structural floor-loading limit as being 120 pounds over an area of a square foot, on page 13 under "configuration" each zone is given a maximum load. In zone 3 where 400 pounds can be spread across the whole zone, a package with a base area of 1 square foot and mass of 150 pounds cannot be placed directly onto the aircraft's floor. For small heavy objects where the static mass would exceed the structural limitation of a floor, load-spreading equipment allows the object's mass to be evenly distributed across a larger area.

In the data sheets for SEP 1 and MEP 1 the arms given for the baggage bays and zones are for the centre of areas; this is referred to as a "centroid". The term centroid used in the data sheet for the MRJT will be covered separately in chapter 8.

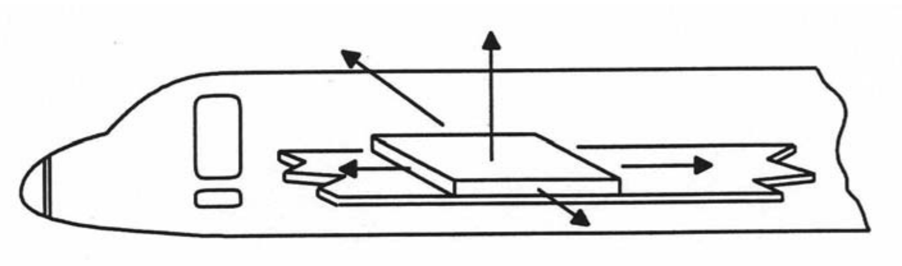


Figure 3.1

Security of a Load

Dependent on the aircraft type and the load to be carried. Large cargo aircraft use special containers or palletised cargo, passenger aircraft can load baggage into containers or stack luggage directly into the hold. Whichever method is used the loader must ensure that the load is secure and will not move during flight. Moving loads alter the CG and can cause structural damage or in the worst case control problems.

Containers, pallets, load spreaders and tie down equipment used to secure the load to the aircraft's structure have a mass. These masses have to be taken into account for the mass and balance calculations. These items are counted as “non-revenue” load and are part of the traffic load of an aircraft, they can also be referred to as Tare on some load sheets.

Mass and Balance Document

For each commercial aircraft flight a mass and balance document (load sheet) has to be prepared. This must contain the following information:

1. The aircraft type and registration
2. The flight identification number and date
3. The identity of the Commander
4. The identity of the person who prepared the document
5. The dry operating mass and the corresponding CG of the aircraft
6. The mass of fuel at take-off and the mass of trip fuel
7. The mass of consumables other than fuel
8. The components of the load including:

    Passengers
    Baggage
    Freight
    Ballast

9. The take-off mass, landing mass and zero fuel mass
10. The load distribution
11. The aircraft’s CG positions as applicable
12. The limiting CG mass and CG values

The loading supervisor signs the load sheet to confirm that the aircraft has been loaded, and the load distributed in accordance with the mass and balance documentation.

The Commander countersigns the mass and balance documentation to show that he accepts the load and its distribution.

Only with the approval of the authority can an operator reduce the amount of data from a mass and balance document

Last Minute Changes

In cases where there is a last minute change to the actual load of an aeroplane after the completion of the mass and balance document, it must be brought to the aircraft Commander’s attention and be entered on the mass and balance document. The authorities allow the operator to determine the maximum number of passengers or hold load that can be altered before a new load sheet is produced.

Mass and balance documentation can be produced by entering the load information into a computer, which then generates the load sheet. Originally, these computers were based with the dispatchers. Advances in technology have allowed them to be fitted into the aircraft, and be used as the primary source of the mass and balance documentation for dispatch. A more recent advance is the use of datalink; where the final mass and balance documentation is sent from the onboard computer to the dispatcher's computer and printer.

A copy of the final documentation as accepted by the Commander must be available on the ground. Where the document has been produced electronically and requires a signature; which would be impractical in this case a Personal Identification Number (PIN) is entered. This is used to generate a print out of the individual’s name and their professional capacity. It is considered in law to hold the same validity as the hand written signature.

Responsibilities

The aircraft operator is responsible for all the aspects of mass and balance from:

- Establishing the mass and CG of an aeroplane prior to it entering service
- Ensuring that aircraft are weighed at the correct time periods
- Determining the mass of the crew and operating equipment
- Establish the mass of traffic load
- Determine the mass of the fuel load
- Specifying the principle and methods used for loading in the Companies operations manual
- Ensuring that during any phase of operation the mass and CG of the aircraft complies with the approved flight manual and the operations manual if it is more restrictive
- Establish the mass and balance documentation for each flight specifying the load and its distribution

The person supervising the loading is responsible for:

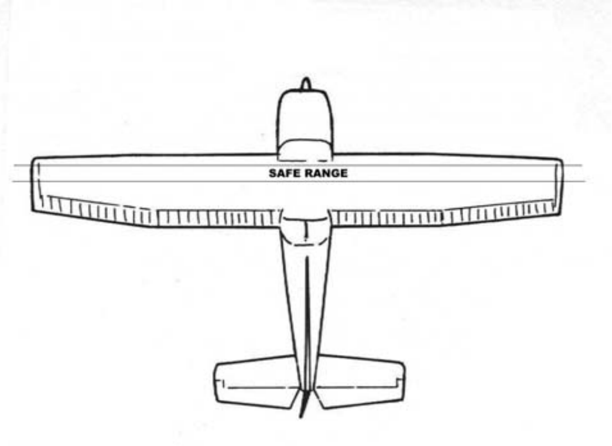
- Ensuring that the aircraft is correctly loaded

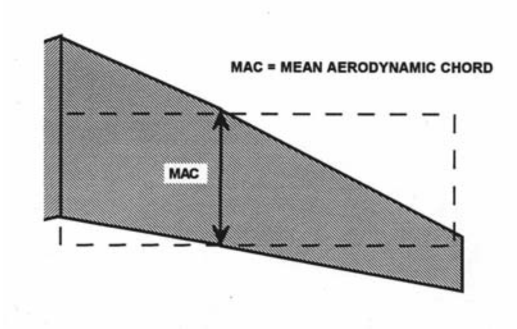
The Commander is responsible for:

- Ensuring that the aircraft’s mass and CG are in limits for the flight.

Mean Aerodynamic Chord (MAC)

As transport aircraft become larger and faster the wing planform has to change from straight wing to a swept back wing for aerodynamic reasons





(see fig 3.2 below).

Figure 3.2

As the aircraft's speed changes different parts of the wing produces the lift (this will be fully explained in Principles of Flight), however the rules about maintaining a safe range apply. To locate and quantify the CG limits of the safe range, the Mean Aerodynamic Chord (MAC), or the American term Standard Mean Chord (SMC), is used.

The MAC is the chord of the wing taken at its mid span and is the distance from the leading edge to the trailing edge (fig 3.2 above).

Throughout the entire flight envelope it is considered that the lift generated by the wing comes from the MAC, so CG limits are applied to this chord.

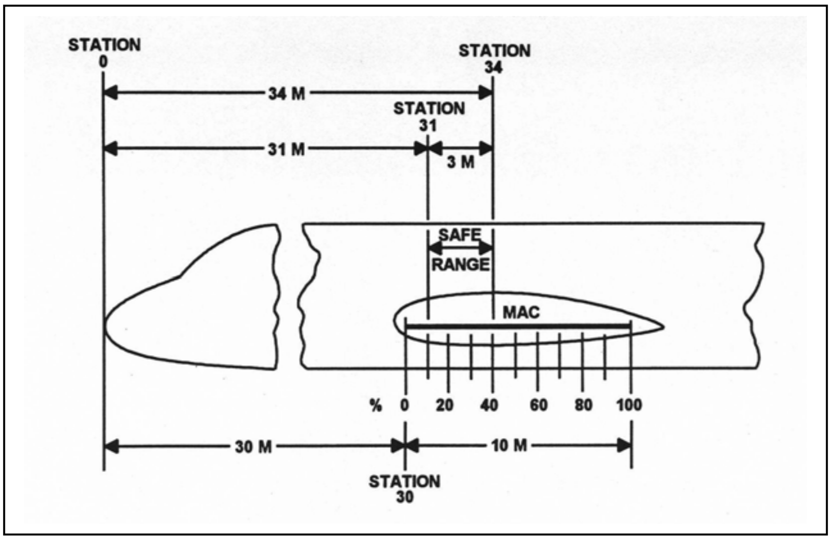


Figure 3.3

The CG limits are set behind the leading edge and in front of the trailing edge. The leading edge of the MAC is referred to as LeMAC and trailing edge as TeMAC.

Using MAC, the distance is normally converted into a percentage, so LeMAC is 0% and TeMAC 100% the location of the centre of gravity and the CG limits are then quoted as percentages of MAC.

Example

For a MAC of 7m

Fwd limit of 32.86%

Aft limit of 53.57%

CG 41.29%

These percentages have to be related to the aircraft's datum, which will be given as a linear distance from either the LeMAC or TeMAC.

To convert the % into a linear measurement:

a. Find what 1 % of MAC is, divide MAC by 100.
So 7m ÷ 100 = 0.07m, each % is equal to 0.07m

b. Multiply the % by the distance found.
32.86% MAC x 0.07 = 2.3m, the Forward limit is 2.3m aft of the Le MAC.

c. Add the measurements together 20m + 2.3m =22.3m.
The Forward limit is located 22.3m aft of the datum.

By this method the limits and CG position can be expressed as linear distances from the datum.

Where the limits and CG locations are given as linear distances from the datum (see fig 3.4) and have to be expressed as % MAC the following formula can be used:

$$\frac{A - B}{C} \times 100 = \%\ MAC$$

Where:
- A The distance from the datum to the CG.
- B The distance from the Datum to Le MAC
- C The length of MAC.

In the example in Fig 3.4 below the CG is located at 16.6% MAC

$$\frac{A - B}{C} \times 100 = \%\ MAC \qquad \frac{31.66m - 30m}{10m} \times 100 = 16.6\%\ MAC$$

In reality A-B is finding the linear distance of the CG from LeMAC.

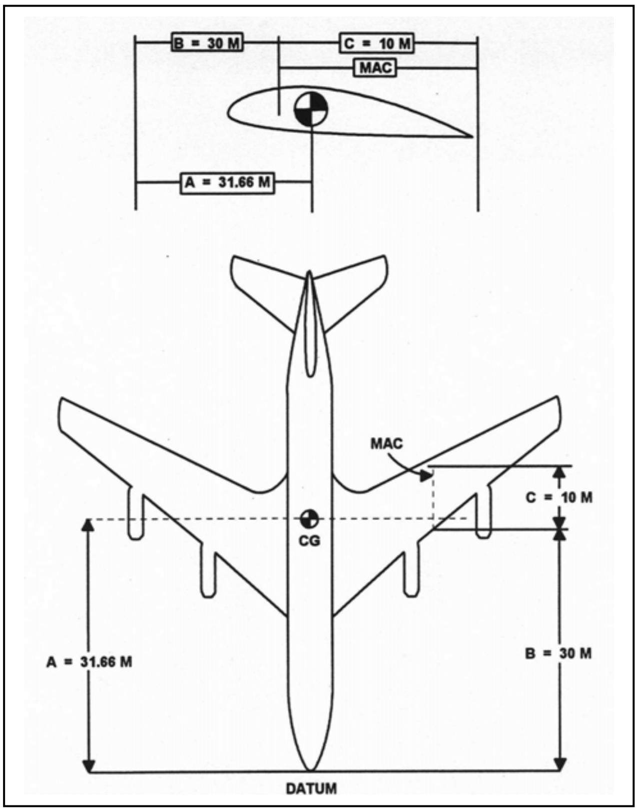


Figure 3.4

In some questions the examiner may place the Datum within the MAC this still allows the formula to be used. In this case LeMAC will be ahead of the Datum. Use the distances **without** negative or positive signs in front of them and work out as normal.

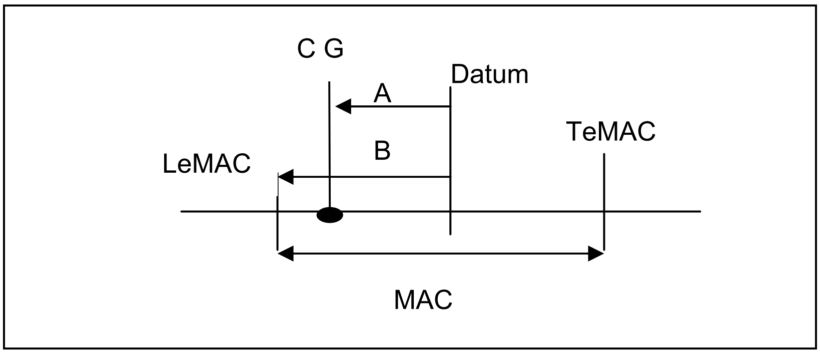


Figure 3.5

Example the — For example in fig 3.5 above if LeMAC is 2m ahead of the Datum and CG is –1.7m with MAC at 4.3m. What is the % MAC of the CG?

In this case to find the % MAC the formula would be

$$\frac{B - A}{C} \times 100 = \% \text{ MAC} \qquad \frac{2m - 1.7m}{4.3m} \times 100 = 6.98\% \text{ MAC}$$

A negative percentage means the CG is forward of LeMAC and a percentage greater than 100 means that the CG is behind the TeMAC.

Where questions give the current CG as a % MAC and then ask for a revised % MAC after some alteration to the existing load. Convert the % into a linear distance from the datum calculate the new CG location and then reconvert into a %.

In some cases such as fuel consumption, a % change can be given for a pre-determined mass of fuel in these cases the % change can be added or deducted from the original CG % MAC as required to find the new CG % MAC. This can also apply to the extending and retracting of flaps and landing gear.

Standard Crew and Passenger Masses from JAR – OPS 1 Subpart J

For light aircraft where the total mass is more limited and the safe range is smaller the pilot and passengers are normally weighed to get an accurate reading of the variable load and traffic load. For commercial operations it is not feasable to weigh each passenger, so a table of accepted weights are used. These are shown below.

The standard masses are:

- Flight crew **85 kg**, and
- Cabin crew **75 kg**

This is irrespective of gender or build, and within these masses is an allowance for the crews personal belongings etc. If a member of the crew has excessive baggage it must be accounted for separately within the DOM of the aircraft.

For the passengers' standard mass there are three groups, these are:

Infants Are defined as persons who are less than 2 years of age.

Children Defined as being persons of an age of two years and above but who are less than 12 years age.

Adults Male and Female are defined as people aged 12 years or above.

Often passengers are referred to as **PAX** this term covers all ages and gender and might be used in examination questions

Infants and Children

Where infants sit on an adults lap they are said to have no mass. When an infant sits in a passenger seat it is said to have a mass of 35 kg. Children irrespective of gender are said to have a mass of 35 kg and must have their own passenger seat. These masses are for use on all commercial flights where standard passenger masses are used irrespective of the number of passenger seats available.

Adults

Adult passenger mass depends on gender and on the number of passenger seats available. This information is given in the two tables below taken from JAR-OPS J 1.620(f).

Table 1

Passenger seats:	**20 and more**		**30 and more**
	Male	**Female**	**All adult**
All flights except holiday charters	88 kg	70 kg	84 kg
Holiday charters	83 kg	69 kg	76 kg
Children	35 kg	35 kg	35 kg

All flights except holiday charters	Schedule service etc.
Holiday charters	Part of holiday package travel.
All adult	Adult mass regardless of gender.

For aircraft with 19 passenger seats or less table two applies (see below). The smaller the seating capacity the greater the adult passengers mass becomes. Within these masses is an allowance for hand baggage.

On flights (table 2 only) where no hand baggage is carried in the cabin or where the hand baggage is accounted for separately **6 kg** may be deducted from the adult mass. Articles such as small cameras, overcoats and small handbags are not considered for the purpose of hand baggage.

Table 2

Passenger seats	**1 – 5**	**6 – 9**	**10 – 19**
Male	104 kg	96 kg	92 kg
Female	86 kg	78 kg	74 kg
Children	35 kg	35 kg	35 kg

Passenger Baggage Values

Where the total number of passenger seats available are 19 or less then all the passenger hold baggage has to be weighed individually to determine the actual baggage mass. Where the passenger seats available are 20 or more then standard weights can be applied to each individual item of luggage, the actual allowance is given in table 3, part of JAR-OPS J 1.620(f). (as shown below)

Table 3

Type of flight	**Baggage standard mass**
Domestic	11 kg
Within the European region	13 kg
Intercontinental	15 kg
All other	13 kg

For the purposes of **Table 3 JAR-OPS J 1.620(f)**:

Domestic Flight Domestic flight means a flight with origin and destination within the border of one state.

European Region Within the **European Region** means a flight made outside the domestic state, but remaining within the area as designated by JAR-OPS-1 .620 (f) and appendix 1 duplicated in fig 3.6 below.

Intercontinental flights Intercontinental flights, other than flights within the European region, means a flight with origin and destination in different continents.

For fig 3.6 the European area is bounded by rhumb lines between the following points

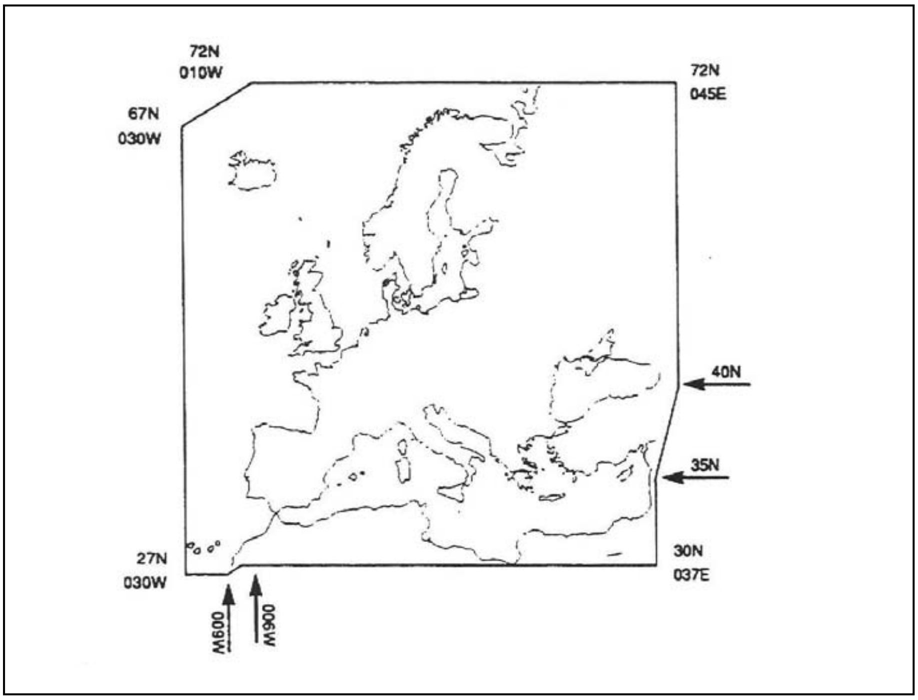


Figure 3.6

N7200 E04500	N3000 W00600	N7200 W01000
N4000 E04500	N2700 W00900	N7200 E04500
N3500 E03700	N2700 W03000	
N3000 E03700	N6700 W03000	

Load Shifting Formula

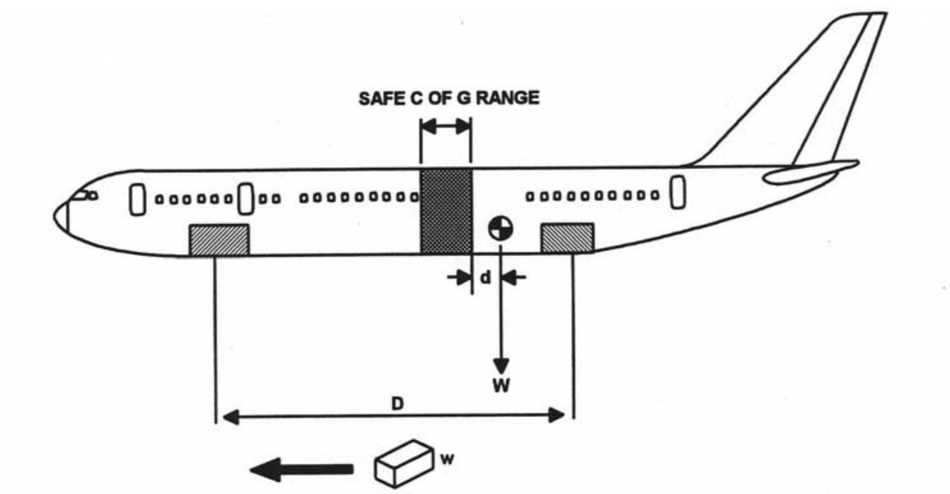


Figure 3.7

In part 1, examples of determining an aircraft's CG and altering the loads were shown using the basic method. While this will always give accurate answers its operation can be time consuming. To speed up the mathematical calculations a formula can be used.

This used to be known as the $^{w}/_{W} = ^{d}/_{D}$ method, it could as easily be termed the $^{m}/_{M} = ^{d}/_{D}$ method substituting mass for the term weight. This method is explained in Chapter 5

Useful Load and Laden

Useful Load is defined in the JAR Learning Objectives as Traffic Load and Usable Fuel

The term **laden** is old English and can be read "as loaded mass" or "the loaded mass".

S.I Units (Systeme International)

So far only pounds or kilograms have been used as units of mass and inches, feet, cm or metres as the distance for the worked examples
(10 kg % 5m = 50 kgfm. 10 lb % 5m = 50 lbfm etc.)

In the exam questions asked based on S.I units where:

- Force is given in "Newtons" (N)
- Mass is given as kilograms (kg)
- Distance in meters (m)
- Acceleration (a) as meters per second squared m/s^2
- Gravity is given as a constant of acceleration of **9.81** m/s^2

The constant for gravity 9.81 m/s^2 is the result of a 1 kilo mass acted on by a 1 kilo force. As force is expressed as F= m x a [Force = Mass X Acceleration], the Newton is the result of a body's mass acted upon by gravity.

Therefore the Newton is equal to 1kilo X 9.81 m/s^2 = 9.81N

Example

The following two tables are of the same aircraft, in the top table the reaction weight/mass is given in kilos in the bottom table it is given as a force in newtons

Item	**Mass (kg)**	**Balance Arm (m)**	**Moment (kgfm)**
Nose Wheel	100	+2	+200
Left Main Wheel	700	+4	+2800
Right Main Wheel	700	+4	+2800
Total Mass	**1500**	Total Moment	**+5800**

CG +5800 kgfm + 1500 kg = +3.867m

Item	**Force (N)**	**Balance Arm (m)**	**Moment (Nm)**
Nose Wheel	981	+2	+1962
Left Main Wheel	6867	+4	+27468
Right Main Wheel	6867	+4	+27468
Total Force	**14715**	Total Moment	**+56898**

CG +56898 Nm + 14715 N = +3.867m

There is a direct correlation between the two tables that can be found by multiplying or dividing by the constant of 9.81.

Questions for Chapter 4

1. What is the maximum time period between weighing for a single aircraft?
   a. 4 yrs
   b. 3 yrs
   c. 2 yrs
   d. 1 yr

2. Eight aircraft of the same type and configuration have been used to establish a fleet mass. How many aircraft must be weighed at each subsequent weighing?
   a. 5
   b. 6
   c. 7
   d. 8

3. What is the maximum time period between 2 fleet mean evaluations?
   a. 1yr
   b. 2 yrs
   c. 3 yrs
   d. 4 yrs

4. A fleet mass has been established for 25 aircraft as being BEM of 1500 kg with a CG of 27% MAC, the aircraft's

MTOM	33 56.7kg
MLM	2980 kg
MZFM	1990 kg

What is the tolerance level for this fleet?

   a. 14.9 kg 0.135 % MAC
   b. 29.8 kg 0.270 % MAC
   c. 14.9 kg 0.270 % MAC
   d. 29.8 kg 0.135 % MAC

5. For a fleet of aircraft where the fleet mass is 20,000 lb and the CG is 29% MAC, at evaluation weighing one aircraft is found to be within the mass tolerance but out of the MAC tolerance. How is this aircraft to be treated?
   a. removed from the fleet mass program and used with its own mass and balance documentation
   b. remain in the fleet mass program using its own CG location
   c. remain within the fleet until the complete fleet is reweighed
   d. grounded for technical investigation

6. To level an aircraft for weighing 90 lbs of ballast is located at – 3.5 ft. The reaction masses are given below. What is the BEM and CG?

Item	Mass (lb)	B.A (ft)
Nose wheel	350	-12
Left main wheel	4130	-7
Right main wheel	4123	-7

a. 8513 lb -7.3
b. 8603 lb -7.24
c. 8603 lb -7.3
d. 8513 lb -7.24 ft

7. An aircraft being weighed has the following reactions left main wheel 3750 kg at arm +16, right main wheel 3740 kg at arm +16 and tail wheel 300 kg at arm + 27. To level the aircraft a tail stand of 47 kg mass is used, the stand is located at arm + 27. All the arms are given in feet what is the reaction moment of the tail stand?

a. -1269 kg/m
b. –1269 kg/ft
c. +1269 kg/ft
d. +1269 kg/m

8. To level an aircraft for weigh on a weighbridge a negative moment 600 lb/ft is required to act anti clockwise around the datum. Choose the correct mass and arm to achieve this moment.

a. 81 lb at an arm of –7.5 ft
b. 70 lb at an arm of –-8.57 ft
c. 66.67 lb at an arm of –8.87 ft
d. 54 lb at an arm of 11 ft

9. An aircraft is loaded with 3 containers, the first container is 16ft long by 8 ft wide with a mass of 6090 lb, the second container is 12ft long by 8 ft wide with a mass of 4750 lb and the third container is 8 ft square with a mass of 3000 lb. What is the static load per square foot per container?

1. container one 47.58 lb per square foot
2. container one 49.48 lb per square foot
3. container two 49.48 lb per square foot
4. container two 46.88 lb per square foot
5. container three 46.88 lb per square foot
6. container three 47.88 lb per square foot

a. (1) (3) (4)
b. (2) (3) (5)
c. (2) (4)(6)
d. (1) (3) (5)

10. In an aircraft where the area of the floor is 2.75m by 4 m and is limited to a static load of 300 lb per m^2. What is the maximum mass that can be placed on this floor?

a. 300 lb
b. 3000 lb
c. 330 lb
d. 3300 lb

11. An aircraft of 19000 kg BEM is loaded for take-off to 43000 kg. The load consists of the following VL 1100 kg, fuel 7800 kg, tare 800kg and 14300 kg cargo. From the list below choose the correct statements

i. the traffic load is 22100 kg
ii. the tare is counted as revenue load
iii. the DOM is 20100 kg
iv. the payload is 15100 kg
v. the OM is 27900 kg
vi. the ZFM is 35200 kg

a. (I),(iii),(v)
b. (iii),(iv),(vi)
c. (ii),(iv),(v)
d. (iii),(v),(vi)

12. From the following choose the correct statements for the mass and balance documents.

a. the Commander must supervise the loading of his aircraft
b. the Commander must sign and retain the document
c. the Commander can use a PIN instead of a signature
d. the Commander can delegate responsibility for accepting the aircraft's load to the loading supervisor

13. Who decides on the limit for last minute changes?

a. the Commander
b. the CAA
c. the loading supervisor
d. the operator

14. The aircraft's CG is located at 29% MAC the MAC is 2.3 m and TeMAC is located + 13 m from the datum. What is the linear distance of the CG from the datum?

a. +11.36 m
b. +13.67 m
c. +11.37 m
d. +13.66 m

15. In the formula $\frac{A - B}{C} \times 100$

a. A = the distance from the datum to the CG
b. C = the distance from the datum to the CG
c. B = the distance from the datum to the CG
d. None of the above equals the distance from the datum to the CG

16. Express the CG of +15.93 m as a percentage MAC where MAC is 3.19 m and LeMAC is located at +14.67 m

a. 39 %
b. 39.5 %
c. 40 %
d. 40.5 %

17. An aircraft with an OM of 9897 kg and CG at 28 % MAC is to be loaded with 2000 kg of freight in the fwd hold and 1900 kg in the aft hold. The trip fuel is estimated to be 1500 kg. The bulk fuel load is 2500 kg. Each 150 kg of cargo in the Fwd hold has an effect of – 0.6% MAC, each 190 kg of cargo in the aft hold has the effect of + 1.2 % MAC and each 100 kg of fuel used has the effect of – 0 .7% MAC. When the gear is raised the effect is – 0.37 % MAC, lowering of flaps to landing has a + 2.8 % MAC. Select the correct statement from below.

i. for TO the CG will be 32%
ii. for TO the CG will be 21.5%
iii. for DOM the CG will be 10 % MAC
iv. for cruise the CG will be 31.63 % MAC
v. for landing the CG will be 34.8 % MAC
vi. for landing the CG will be 24.3 % MAC

a. (i),(iv),(vi)
b. (ii),(iii),(v)
c. (ii), (v), (vi)
d. (iii),(iv),(vi)

18. Choose the correct statements that apply to a female passenger aged 11 travelling on an aircraft that is using standard passenger weights.

i. She is counted as an adult for all flights except charters
ii. If the aircraft falls in table 2 and she has no hand baggage then 6 kg is deducted from her mass.
iii. She is counted as a child and has a mass of 35 kg for all flights
iv. She is counted as having a mass of 35 kg for all flights unless she sits on an adults lap.
v. She must be sat in her own seat

vi. No allowance is made from her mass if she does not take hand baggage on a flight that falls in table 2.

a. (i),(ii),(v)
b. (iii),(v),(vi)
c. (iv),(v),(vi)
d. (ii),(v), (vi)

19. A 27 seat aircraft is making a scheduled flight from Rome to Oslo and the operator is using standard passenger masses. A family of four book. They consist of a male aged 37, a female aged 35, a female aged 13 and a female aged 11, they also have three suitcases. Choose the correct statement for this family.

a. as payload the family + baggage = 326 kg
b. as payload the family + baggage = 267 kg
c. as payload the family + baggage = 302 kg
d. as payload the family + baggage = 320 kg

20. An aircraft's reactions after weighing are given as:

Item	**Force (N)**	**B.A (ft)**
Nose lifting jack	34370	- 1.7
Left lifting jack	759785	+ 16
Right lifting jack	759785	+ 16

Give the BEM and CG of this aircraft.

a. 158403.67 kg acting at + 15.61ft
b. 15840.37 kg acting at + 15.61ft
c. 158403.67 kg acting at –15.61ft
d. 15840.37 kg acting at – 15.61ft

Answers to Practice Questions from Chapter 4

1. A
2. B
3. D
4. A
5. B
6. D
7. C
8. B
9. D
10. D
11. D
12. C
13. D
14. C
15. A
16. B
17. A
18. B
19. C
20. A

Intentionally Left Blank

Chapter 5

Load shifting, Load addition and Load subtraction

Chapter 2 showed the basic theory and method of determining the location of the CG and how to determine the effect of adding subtracting or moving components of the load. As seen in Chapter 2 this becomes time consuming and given that for exam purposes [as well as real life] time is of the essences a formula can be used to calculate both the effect of altering the load or by how much a load must be altered to achieve a desired CG condition.

This formula is below and the rest of this chapter will deal with the practical aspects of manipulating this formula. If you find this formula is not user friendly please revert to the default method as per Chapter two or contact your tutor for a further method known as the ***X*** factor.

$$^{m}/_{M} = {}^{d}/_{D}$$

Where:

m = the mass **to be** moved, added or subtracted

M = the **total** mass of the aircraft

d = the distance the CG **will** move from its original position

D = the greatest distance that the mass 'm' is moved, added to or subtracted from.

Load Shifting

The act of transferring a mass from one location to another within an aircraft will have a double effect on the total moment. The first effect is from removing the mass from one location, placing this mass in a new location will create the second effect. These will complement each other, thus calculating the mass to be moved from one location to another will always produce a smaller answer than that of removing or adding mass to achieve the same change in CG.

Obviously the total mass of the aircraft will remain constant as the mass to be shifted is already part of the load. The CG location is likely to alter dependent on the mass being moved and the distance it is moved relative to the total mass of the aircraft. The CG will always move towards the position in which the load has been moved to. The formula allows us to find the amount of mass that needs to be shifted, to relocate the CG to a specified point. Or the amount by which the CG will move if a known mass is shifted

Worked examples 1+ 2 show the use of the formula for load shifting.

Load Addition

Adding any mass to an aircraft will have two effects, firstly the mass acting over the arm of its location will cause a change in the total moments and secondly the gross mass will increase. The combined effect will result in the CG moving in the direction of the additional load. The result will be proportional to the amount of extra load added, the lever arm dimension at which the mass is added and the total mass of the aircraft.

The formula allows us to find the amount of mass that needs to be added to a given location, to relocate the CG to a specified point. Or the amount by which the CG will move if a known mass is added to a given location.

Worked examples 3 + 4 show the use of the formula for load addition.

Load Subtraction

Subtracting a mass from an aircraft will have the reverse effect to adding extra load by reducing the total moment and total mass. This results in the CG moving away from the point where the load was removed. This movement will be proportional to the amount of the load removed, the lever arm dimension at which the mass had been acting and the total mass of the aircraft.

The formula is used to find the amount of mass that needs to be removed from a given location, to relocate the CG to a given point. Or the amount by which the CG will move if a known mass is removed from a given location.

Worked examples 5 + 6 show the use of the formula for load subtraction.

Following each example are three practice questions. At the end of the chapter following the practice questions are worked answers to each question.

Example 1. Finding the Mass to be Moved

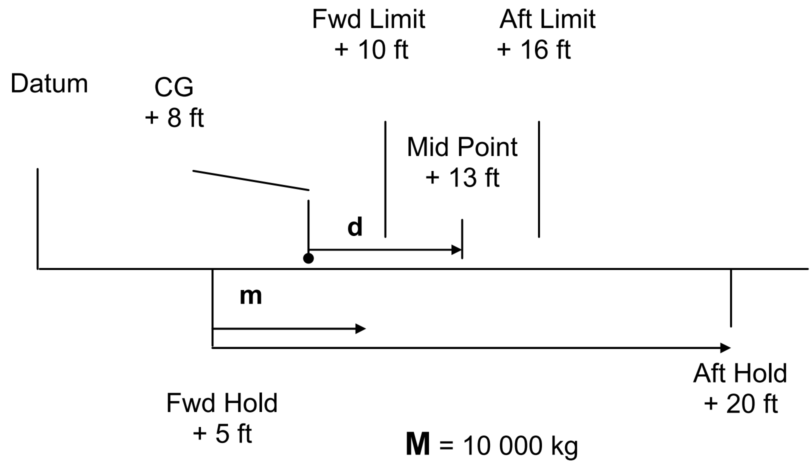
How much mass must be repositioned to place the CG in the middle of the safe range?

Given that:

Total mass	10 000 kg,
Loaded CG is located at	Stn +8
Fwd limit of the safe range is	Stn +10
Aft limit of the safe range is	Stn +16
Fwd Hold is located at	Stn + 5
Aft Hold is located at	Stn + 20
All Stn in feet	

1. Find the location of the intended CG and the distance between it and the existing CG and the direction in which it must move.
2. Find the distance between the location from which the mass is to be removed and the location in which the mass is to be placed.

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass to **be** moved
In this case unknown

M = the **total** mass of the aircraft	10 000 kg
d = the distance the CG **will** move from its original position	5 ft (13 ft – 8 ft)
D = the distance that the mass ‘m’ **is** moved	15 ft (20 ft – 5 ft)

The new CG location is to be aft of the original location, so **m** must be moved rearwards.

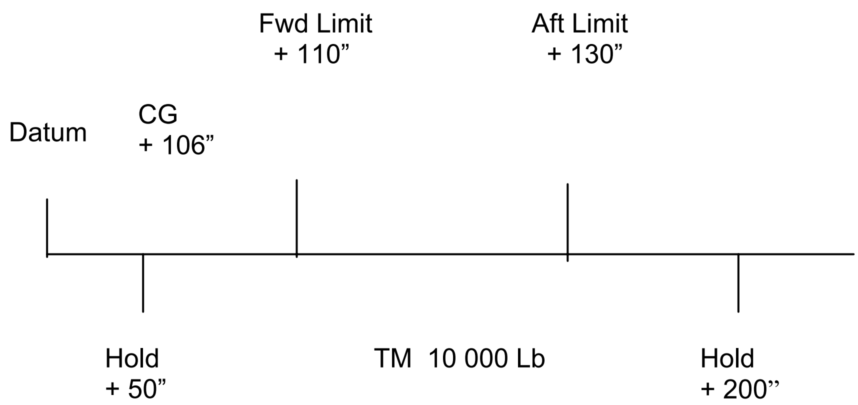
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10\,000\text{ kg}} = \frac{5\text{ ft}}{15\text{ ft}} \qquad m = \frac{5\text{ ft} \times 10\,000\text{ kg}}{15\text{ ft}}$$

$$m = \frac{50\,000\text{ kg ft}}{15\text{ ft}} \qquad \mathbf{m = } 3333.333\text{ kg}$$

3333.33 kg would have to be moved from the Fwd hold to the Aft hold.

Practice 1 – Finding the Mass to be Moved

Question 1. How much mass must be moved to put the CG into the middle of the safe range for the aircraft as shown below?



Question 2. How much mass must be transferred to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120 000 kg

Question 3. How much mass must be shifted from the front hold to the rear hold of this aircraft to place the CG on the rear limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

Example 2 **Finding the Effect of Moving a Known Mass**

The pilot of a light aircraft has loaded his plane with four passengers in the middle and aft row of seats. One of the passengers with a mass of 200 lb seated in the rear row expresses a wish to sit alongside the pilot. Where would the aircraft's CG be located if this is allowed?

Given that:

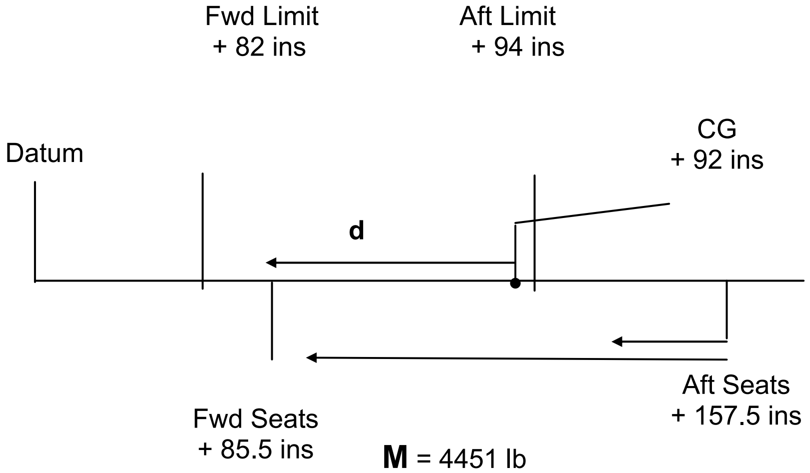
Total mass as loaded	4451 lb
Loaded CG is located at	+ 92.0 ins

Fwd limit of the safe range is	+ 82.0 ins
Aft limit of the safe range is	+ 94.0 ins
Fwd seats located at	+ 85.5 ins
Mid seats located at	+ 118.5 ins
Aft seats located at	+ 157.5 ins

Method

1. Find the distance between the location from which the known mass is to be removed and the location in which this mass is to be placed.
2. Note the direction in which the known mass is moving

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** moved	200 lb
M = the **total** mass of the aircraft	4451 lb
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass 'm' **is** moved	72 ins (157.5 ins – 85.5 ins)

The original location of mass **m** is aft of the new location for **m,** so **d** must be a forward movement. The value of **d** is the amount by which the CG will move forward.

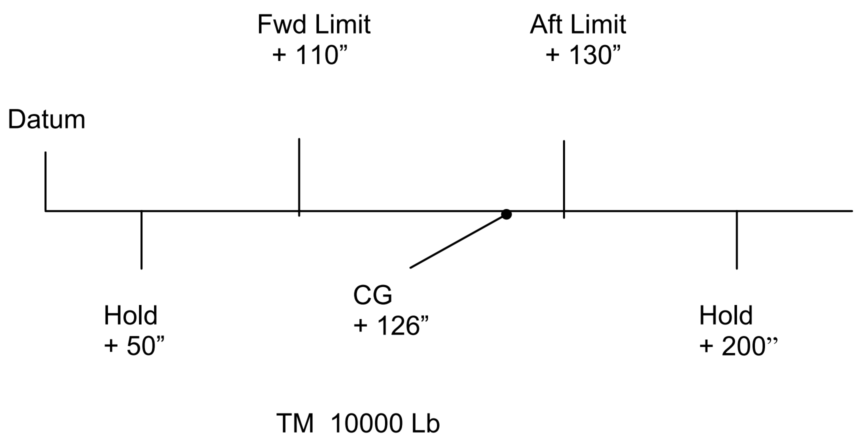
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{200\ \text{lb}}{4451\ \text{lb}} = \frac{d}{72\ \text{ins}} \qquad d = \frac{200\ \text{lb} \times 72\ \text{ins}}{72\ \text{ins}}$$

$$d = \frac{14400\ \text{lbins}}{4451\ \text{lb}} \qquad \mathbf{d} = 3.235\ \text{ins}$$

The CG will move forward by **3.24** ins from its original location to + 88.76ins.

Practice 2 - Finding the Effect on the CG when a Known Mass is Moved

Question 1. Find the new CG for this aircraft if 100 lb of freight is moved from the rear hold to the forward hold.



Question 2. 500kgs is to be relocated into the aft hold from the fwd hold. Will this place this aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 500.0
Rear Hold	Stn	+200.0
CG located	Stn	- 27.0
All Stn in inches		
Total mass		120000 kg

Question 3. A 1000 kg pallet of freight that was to be loaded into the Fwd hold is found to exceed the cargo door dimensions. It will now have to be loaded into the Aft hold. From the original loading data below determine the new CG.

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225000.00 kg ft
Total mass	50000 kg

Example 3 - Finding the Mass that Must be Added to Alter the CG Location

How much mass must be added to the rear hold to place the CG in the middle of the safe range?

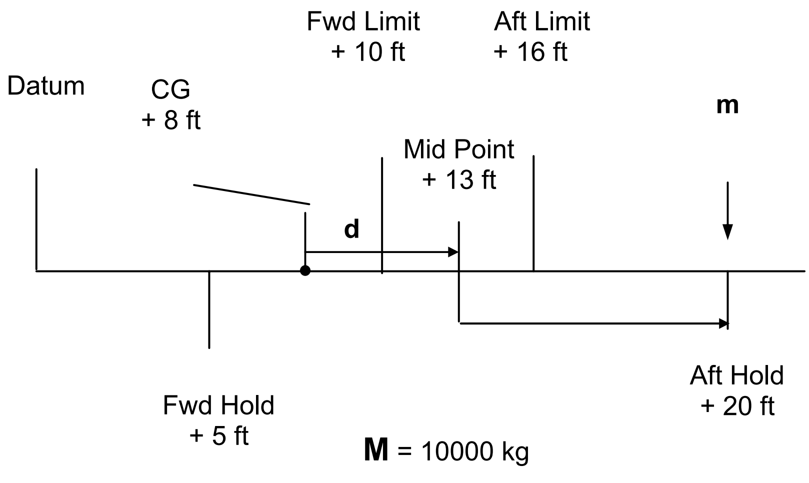
Given that:

Total mass of	10000 kg,
Loaded CG is located at	Stn +8
Fwd limit of the safe range is	Stn +10
Aft limit of the safe range is	Stn +16
Fwd Hold is located at	Stn + 5
Aft Hold is located at	Stn + 20
All Stn in feet	

Method:

1. Find the location of the intended CG, the distance between it and the existing CG and the direction in which it must move.
2. Find the distance between the new CG location and the hold in which the mass is to be added.
3. As the aircraft's new total mass will not be known until **m** is determined **M** the original total mass is used.

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** added - In this case unknown

M = the **total** mass of the aircraft - 10000 kg

d = the distance the CG **will** move from its original position - - - - 5 ft (13 ft – 8 ft)

D = the distance that the mass 'm' **is** added - - - - - - - - - - - - - - - 7 ft (20 ft – 13 ft)

As the new CG location is given, the arm **D** is the greatest distance from **this** location that **m** can be added in this case the aft hold is given.

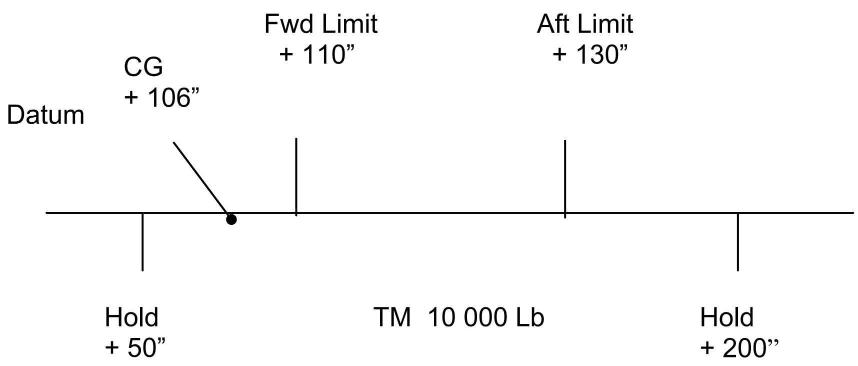
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10\,000\text{ kg}} = \frac{5\text{ ft}}{7\text{ ft}} \qquad m = \frac{5\text{ ft} \times 10\,000\text{ kg}}{7\text{ ft}}$$

$$m = \frac{50\,000\text{ kg ft}}{7\text{ ft}} \qquad m = 7142.85\text{ kg}$$

7142.9 kg would have to be added to the aft hold to reposition the CG.

Practice 3 - Finding the Mass to be Added

Question 1. How much mass must be added to put the CG into the middle of the safe range for the aircraft as shown below.



Question 2. How much mass must be added to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120 000 kg

Question 3. How much additional mass must placed in a hold of this aircraft to relocate the CG on the forward limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

Example 4 - Finding the Effect of Adding a Known Mass

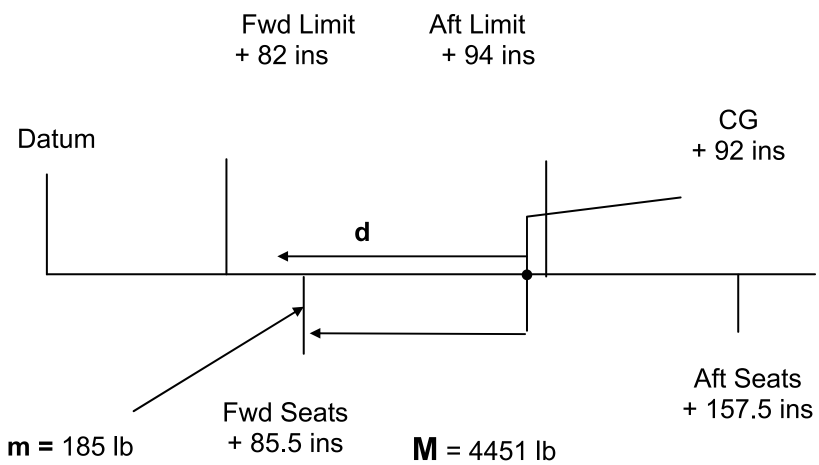
The pilot of a light aircraft has worked out the loading of his aircraft for a flight with four passengers in the middle and aft row of seats. Before take-off another pilot with a mass of 185 lb asks to occupy the front seat. Calculate the aircraft's new CG if the second pilot is taken.

Given that:

Total mass as loaded	4451 lb
Loaded CG is located at	+ 92.0 ins
Fwd limit of the safe range is	+ 82.0 ins
Aft limit of the safe range is	+ 94.0 ins
Fwd seats located at	+ 85.5 ins
Mid seats located at	+ 118.5 ins
Aft seats located at	+ 157.5 ins

1. Find the distance between the location of the mass to be added and the current CG
2. Work out the new total mass for the aircraft. As **m** is given the new total mass is **M** + **m**
3. Note the direction in which the known mass is being added relative to the existing CG

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** added	185 lb
M = the **total** mass of the aircraft	4636 lb (4451 lb + 185 lb)
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass 'm' **is** added	6.5 ins (92 ins – 85.5 ins)

As the original CG is known, **D** becomes the distance between it and the point at which **m** is being added. As this is in front of the original CG, **d** is the amount by which the CG will move forward.

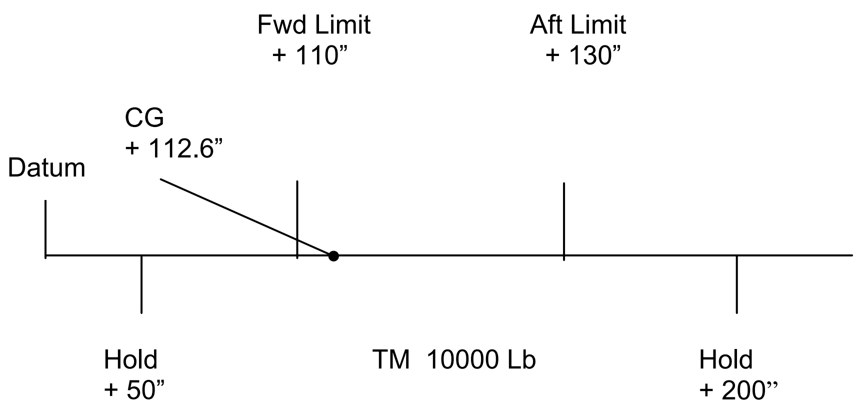
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{185\text{ lb}}{4636\text{ lb}} = \frac{d}{6.5\text{ ins}} \qquad d = \frac{185\text{ lb} \times 6.5\text{ ins}}{4636\text{ lb}}$$

$$d = \frac{1202.5\text{ lbins}}{4636\text{ lb}} \qquad \mathbf{d} = 0.259\text{ ins}$$

The CG will move forward by 0.26 ins from its original location to + 91.74 ins.

Practice
4 - Finding the New CG after a Known Mass is Added

Question 1. What will be the effect on this aircraft's CG if 300 lbs of baggage is stowed in the cabin at a location of + 120.5 ins.



Question 2. If a mass of 3000 kg is to be loaded into the aft hold will the aircraft be in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	- 1.0
All Stn in inches		
Total mass		120 000 kg

Question 3. An item of freight with a moment effect of –135000 kgft is added to the fwd hold, what will the be the new CG?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

Example 5 - Finding the Mass That Must be Removed to Alter the CG Location

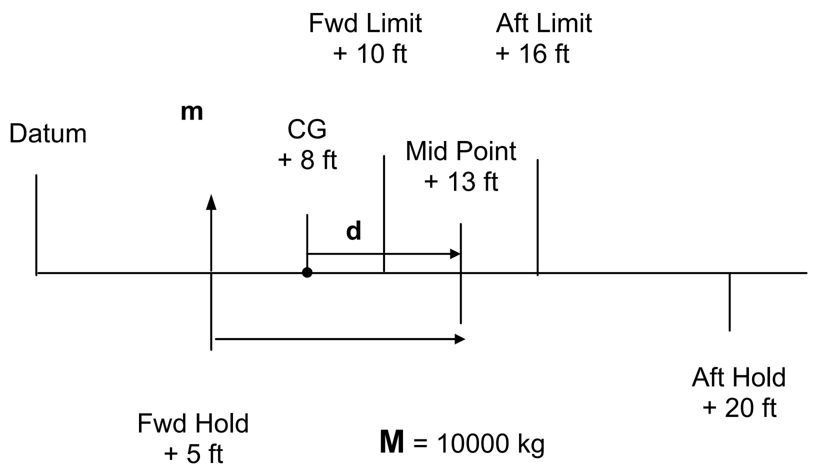
How much mass must be subtracted from the fwd hold to place the CG in the middle of the safe range?

Given that:

Total mass of	10 000 kg,
Loaded CG is located at	Stn +8
Fwd limit of the safe range is	Stn +10
Aft limit of the safe range is	Stn +16
Fwd Hold is located at	Stn + 5
Aft Hold is located at	Stn + 20
All Stn in feet	

1. Find the location of the intended CG, the distance between it and the existing CG and the direction in which the CG must move.
2. Find the distance between the new CG location and the hold in which the mass is to be removed from.
3. As the aircraft's new total mass will not be known until **m** is determined **M** the original total mass is used.

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** removed	In this case unknown
M = the **total** mass of the aircraft	10 000 kg
d = the distance the CG **will** move from its original position	5 ft (13 ft – 8 ft)
D = the distance that the mass ‘m’ **is** removed	8 ft (13 ft – 5 ft)

The result of moving a mass directly on to the CG is for the mass to have no moment effect. As the new CG location is given and the arm **D** is the distance between the location from where **m** is removed from and the new CG location.

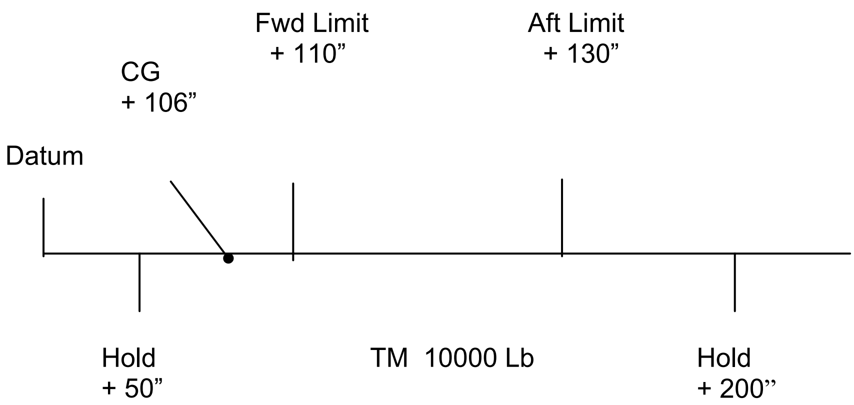
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10000\text{ kg}} = \frac{5\text{ ft}}{8\text{ ft}} \qquad m = \frac{5\text{ ft} \times 10000\text{ kg}}{8\text{ ft}}$$

$$m = \frac{50000\text{ kg ft}}{8\text{ ft}} \qquad m = 6250.0\text{ kg}$$

6250.0 kg would have to be removed from the fwd hold to reposition the CG.

Practice 5 - Finding the Mass to be Removed

Question 1. How much mass must be deducted to locate the CG into the middle of the SR of the aircraft as shown below.



Question 2. How much mass must be removed to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120 000 kg

Question 3. How much mass must be extracted from this aircraft to place its CG on the aft limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

Example 6 - Finding the Effect of Removing a Known Mass

The pilot of a light aircraft has calculated the loading of his aircraft for a flight with four passengers into the middle and aft row of seats. Before take-off the two passengers in the rear row cancel their trip. Their combined mass was 294 lb. Calculate the aircraft's CG if the other passengers remain in the middle seats.

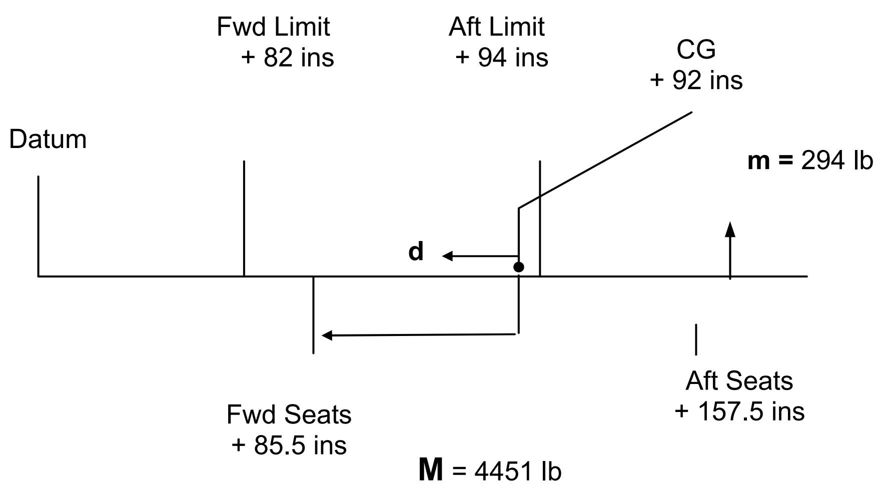
Given that:

Total mass as loaded	4451 lb
Loaded CG is located at	+ 92.0 ins
Fwd limit of the safe range is	+ 82.0 ins
Aft limit of the safe range is	+ 94.0 ins
Fwd seats located at	+ 85.5 ins
Mid seats located at	+ 118.5 ins
Aft seats located at	+ 157.5 ins

Method

1. Find the distance between the location of the mass to be removed and the current CG
2. Work out the new total mass for the aircraft. As **m** is given the new total mass is **M** - **m**
3. Note the direction in which **m** is being removed from relative to the existing CG

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** removed	294 lb
M = the **total** mass of the aircraft	4157 lb [4451- 294 lb]
d = the distance the CG **will** move from its original position	In this case unknown
D = the furthest distance that the 'm' **can** move	65.5 ins (157.5 - 92 ins)

As the original CG is known, **D** becomes the distance between it and the point from which **m** is being removed. As this is aft of the original CG, **d** is the amount by which the CG will move forward.

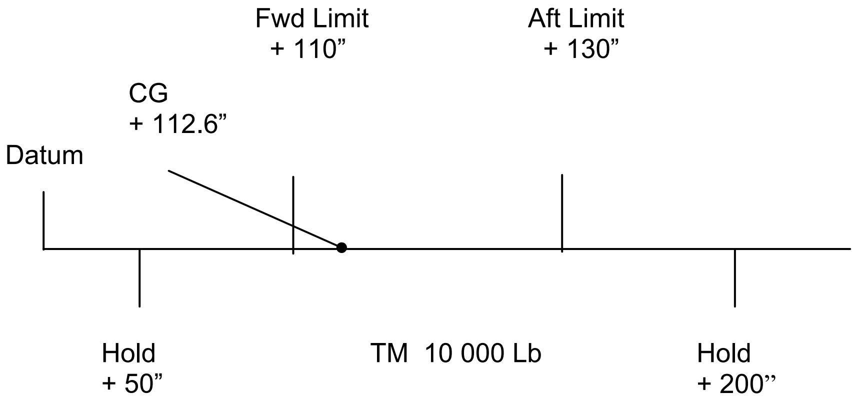
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{294 \text{ lb}}{4157 \text{ lb}} = \frac{d}{65.5 \text{ ins}} \qquad d = \frac{294 \text{ lb} \times 65.5 \text{ ins}}{4157 \text{ lb}}$$

$$d = \frac{19257 \text{ lbins}}{4157 \text{ lb}} \qquad \mathbf{d} = 4.632 \text{ ins}$$

The CG will move forward by 4.33 ins from its original location to + 87.67 ins.

Practice 6 - Finding the New CG After a Known Mass is Removed

Question 1. What will be the effect on this aircraft's CG if 250 lbs of baggage is off loaded from the aft hold.



Question 2. If a mass of 1000 kg is to be unloaded from the fwd hold will the aircraft be in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	- 1.0
All Stn in inches		
Total mass		120 000 kg

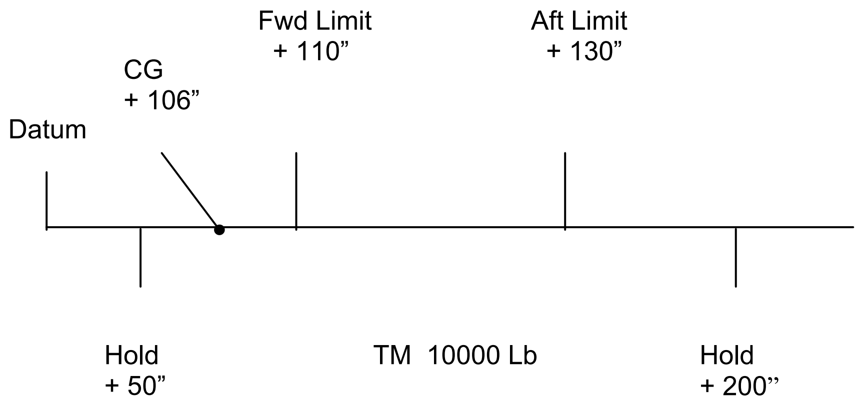
Question 3. An item of freight removed from the aircraft has a moment effect of –1670 kgft, what will be the new CG?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225000.00 kg ft
Total mass	50000 kg

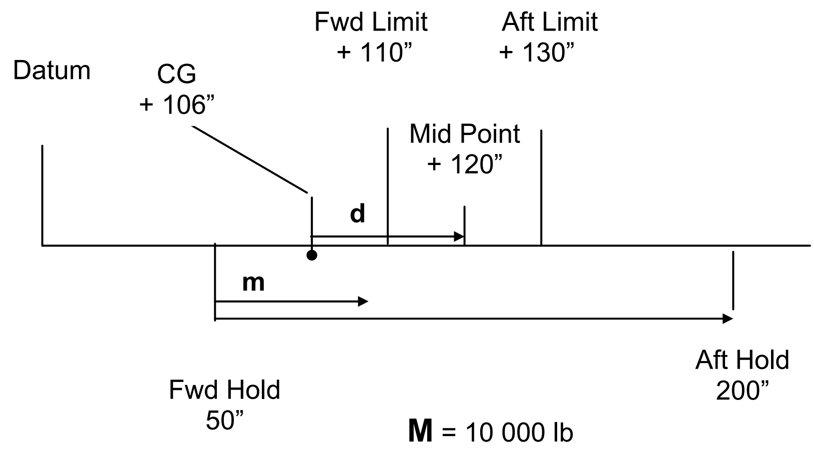
Answers for Practice Questions

Practice 1 Question 1

How much mass must be moved to put the CG into the middle of the safe range for the aircraft as shown below.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	10 000 lb
d = the distance the CG **will** move from its original position	14” (120”-106”)
D = the distance that the mass ‘m’ **is** moved	150” (200” – 50”)

The new CG location is to be aft of the original location, so **m** must be moved rearwards.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10000\text{ lb}} = \frac{14''}{150\text{ lb}} \qquad m = \frac{14'' \times 10000\text{ lb}}{150''}$$

$$m = \frac{140000\text{ lb}''}{150''} \qquad \mathbf{m} = 933.33\text{ lb}$$

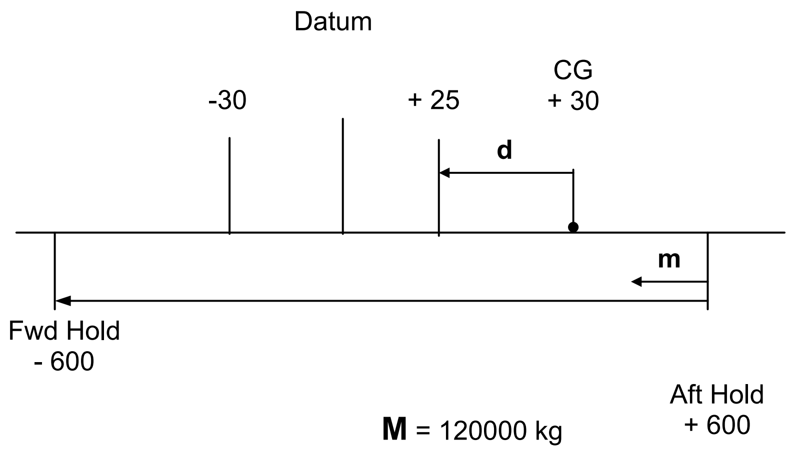
933.33 lb would have to be moved from the Fwd hold to the Aft hold.

Question 2

How much mass must be transferred to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	120 000 kg
d = the distance the CG **will** move from its original position	5” (30”- 25”)
D = the distance that the mass ‘m’ **is** moved	1200” (600” + 600”)

The new CG location is to be fwd of the original location, so **m** must be moved Fwd.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{120000\text{ kg}} = \frac{5''}{1200''} \qquad m = \frac{5'' \times 120\,000\text{ kg}}{1200''}$$

$$m = \frac{600\,000\text{ kg}''}{150''} \qquad \mathbf{m} = 500\text{ kg}$$

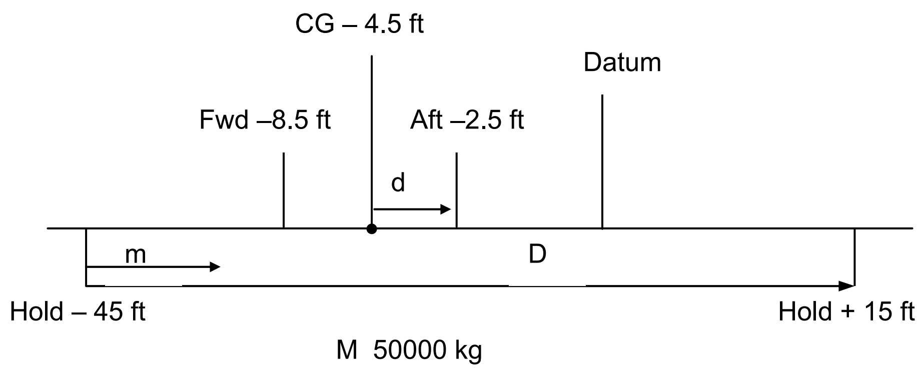
500 kg would have to be moved from the Aft hold to the Fwd hold.

Question 3

How much mass must be shifted from the front hold to the rear hold of this aircraft to place the CG on the rear limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	50 000 kg
d = the distance the CG **will** move from its original position	2 ft (4.5 ft- 2.5 ft)
D = the distance that the mass 'm' **is** moved	60 ft" (45 ft + 15 ft)

The new CG location is to be aft of the original location, so **m** must be moved Aft.

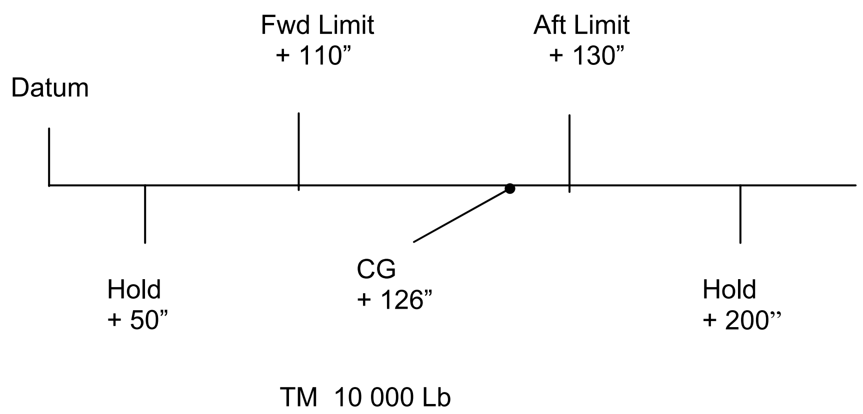
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{50000\ \text{kg}} = \frac{2\ \text{ft}}{60\ \text{ft}} \qquad m = \frac{2\ \text{ft} \ \% \ 50000\ \text{kg}}{60\ \text{ft}}$$

$$m = \frac{100000\ \text{kgft}}{60\ \text{ft}} \qquad \mathbf{m =} 1666.666\ \text{kg}$$

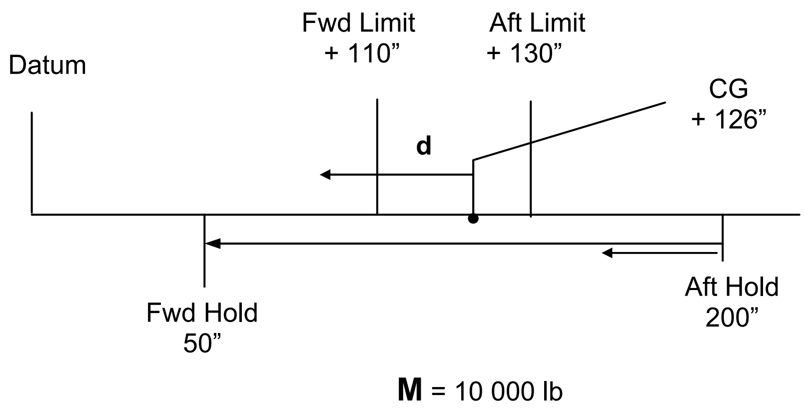
1666.67 kg would have to be moved from the Fwd hold to the Aft hold.

Practice 2 Question 1

Find the new CG for this aircraft if 100 lb of freight is moved from the rear hold to the forward hold.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	100 lb
M = the **total** mass of the aircraft	10 000 lb
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass ‘m’ **is** moved	150” (200” – 50”)

As a mass of 100 lb is being moved Fwd the new CG will be Fwd of the current position.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{100\ \text{lb}}{10\ 000\ \text{lb}} = \frac{d}{150\ \text{ins}} \qquad d = \frac{100\ \text{lb} \times 150\ \text{ins}}{10\ 000\ \text{lb}}$$

$$d = \frac{15\ 000\ \text{lbins}}{10\ 000\ \text{lb}}$$

d = - 1.5 ins CG = +124.5 ins (+126 ins – 1.5 ins)

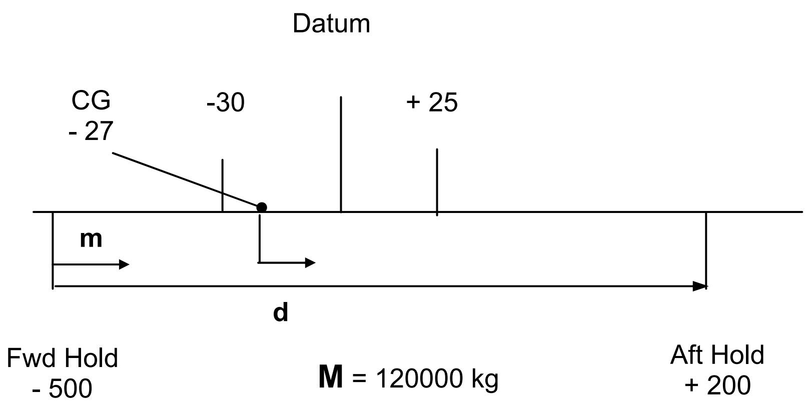
The new CG would move Fwd by 1.5 ins to a location of + 124.5 ins.

Question 2

500kgs is to be relocated into the aft hold from the fwd hold will this place this aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 500.0
Rear Hold	Stn	+200.0
CG located	Stn	- 27.0
All Stn in inches		
Total mass		120000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	500 kg
M = the **total** mass of the aircraft	120 000 kg
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass ‘m’ **is** moved	700” (500” + 200”)

A mass of 500 kg is to be moved into the Aft hold from the Fwd hold so the CG will move aft.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{500\text{ kg}}{120000\text{ kg}} = \frac{d}{700''} \qquad d = \frac{500\text{ kg} \times 700\text{ ins}}{120000\text{ kg}}$$

$$d = \frac{350000\text{ kgins}}{120000\text{ kg}} \qquad \mathbf{d =} +2.916 \quad \text{CG} = -24.08\text{ ins } (-27 + 2.916)$$

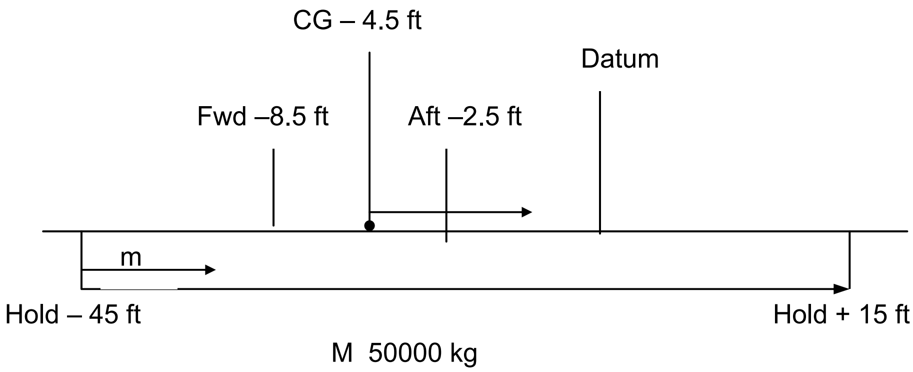
The New CG will be located 2.916 ins aft of the original CG position at – 24.08 ins

Question 3

A 1000 kg pallet of freight that was to be loaded into the Fwd hold is found to exceed the cargo door dimensions and has to be loaded into the Aft hold. From the original loading data below determine the new CG.

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	1000 kg
M = the **total** mass of the aircraft	50 000 kg
d = the distance the CG **will** move from its original position	In this case unknown

D = the distance that the mass 'm' **is** moved 60 ft" (45 ft + 15 ft)

As a 1000 kg is to be relocated from the fwd hold to the aft hold the CG will move Aft

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{1000\ kg}{50000\ kg} = \frac{d}{60\ ft} \qquad m = \frac{1000\ kg \times 60\ ft}{50000\ kg}$$

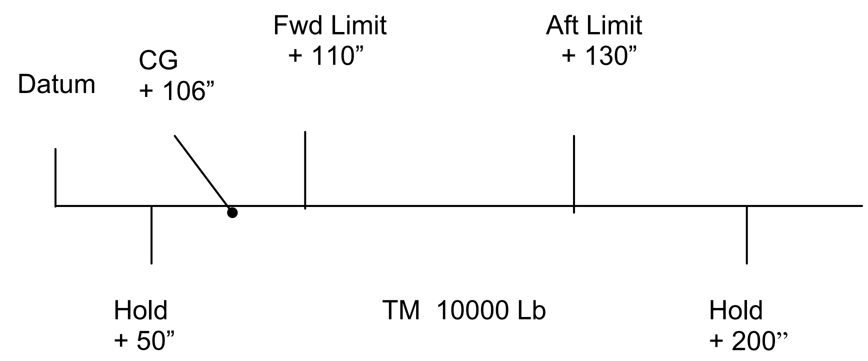
$$d = \frac{60000\ kgft}{50000\ kg}$$

d = + 1.2 ft CG = - 3.3 ft (- 4.5ft + 1.2 ft)

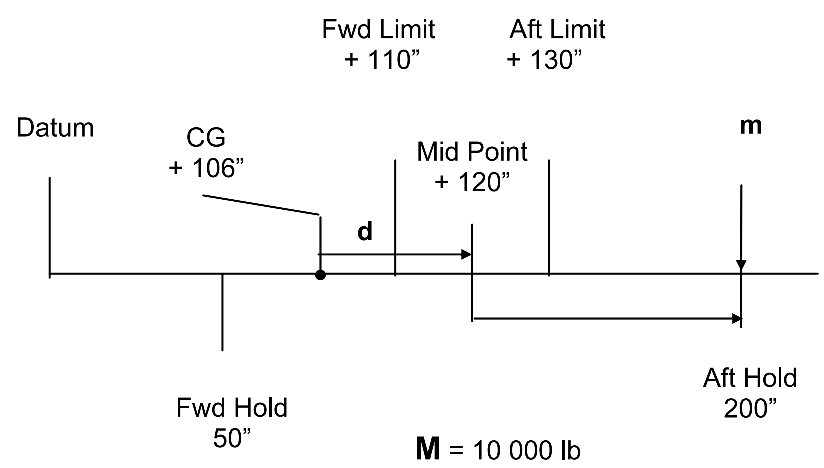
The new CG will be located 1.2 ft aft of the original CG at –3.3 ft which is in limits.

Practice 3 Question 1

How much mass must be added to put the CG into the middle of the safe range for the aircraft as shown below.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	10 000 lb
d = the distance the CG **will** move from its original position	14” (120”-106”)
D = the distance that the mass ‘m’ **is** moved	80” (200” – 120”)

The new CG location is to be aft of the original location, so **m** an unknown must be added to the rear hold, so **D** is between the new CG and the place **m** is added to.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10000\text{ lb}} = \frac{14''}{80\text{ ins}} \qquad m = \frac{14'' \times 10000\text{ lb}}{80''}$$

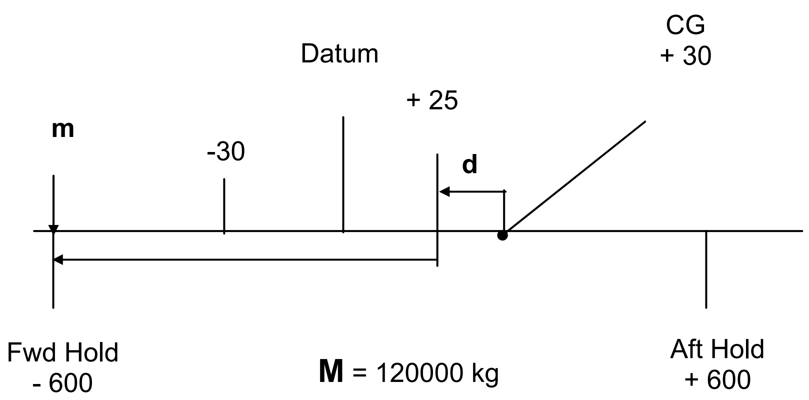
$$m = \frac{140000\text{ lb}''}{80''} \qquad \mathbf{m} = 1750\text{ lb}$$

1750 lb would have to be added to the Aft hold.

Question 2 How much mass must be added to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** added	In this case unknown
M = the **total** mass of the aircraft	120 000 kg
d = the distance the CG **will** move from its original position	5” (30” – 25”)
D = the distance that the mass ‘m’ **is** moved	625” (600” + 25”)

A mass **m** kg is to be added into the Fwd hold to move the CG on to the Aft Limit, D will be the distance between them.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{120000\ \text{kg}} = \frac{5}{625”} \qquad m = \frac{120000\ \text{kg} \% 5\ \text{ins}}{625\ \text{ins}}$$

$$m = \frac{600000\ \text{kgins}}{625\ \text{ins}} \qquad \mathbf{m} = 960\ \text{kg}$$

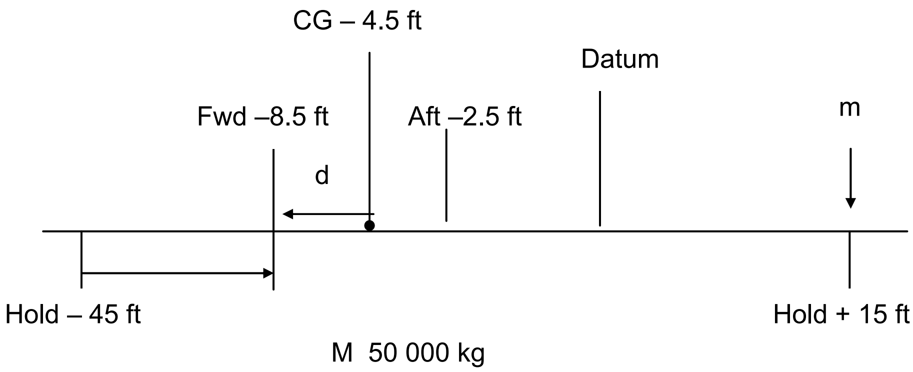
An addition of 960 kg to the Fwd hold will place the CG on the Aft limit

Question 3

How much additional mass must placed in a hold of this aircraft to relocate the CG on the forward limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	50 000 kg
d = the distance the CG **will** move from its original position	4 ft (8.5 ft –4.5 ft)
D = the distance that the mass 'm' **is** moved D	36.5 ft (45 ft – 8.5 ft)

As the CG is to be relocated fwd **m** must be added ahead of the original CG into the front hold.

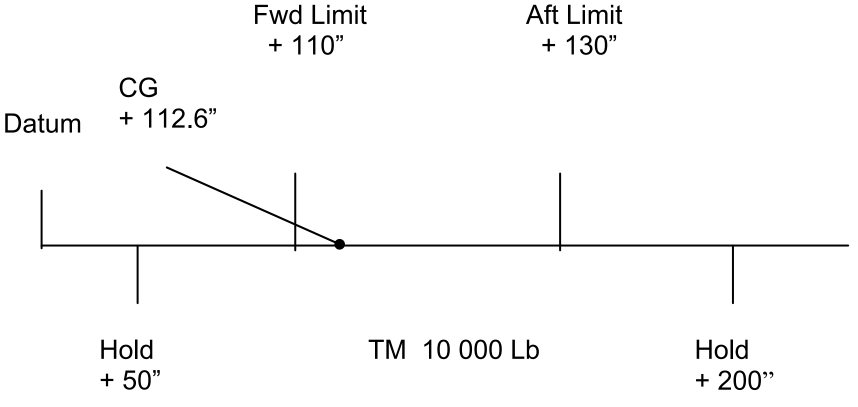
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{50000\text{ kg}} = \frac{4\text{ ft}}{36.5\text{ ft}} \qquad m = \frac{50000\text{ kg} \times 4\text{ ft}}{36.5\text{ ft}}$$

$$m = \frac{200000\text{ kgft}}{36.5\text{ ft}} \qquad \mathbf{m =} 5479.452\text{ kg}$$

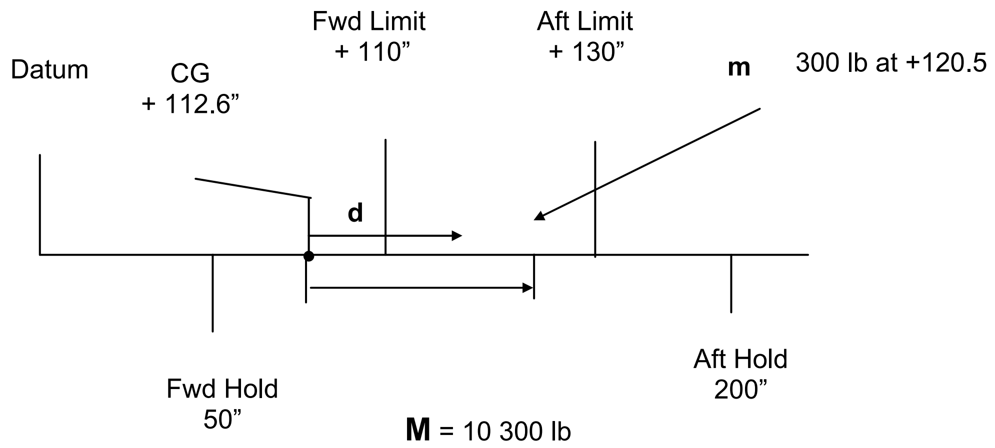
A mass of 5479.45 kg must be added to the Fwd hold to relocate the CG on the Fwd limit of the safe range

Practice 4 Question 1

What will be the effect on this aircraft's CG if 300 lbs of baggage is stowed in the cabin at a location of + 120.5 ins.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	300
M = the **total** mass of the aircraft	10 300 lb (10 000 lb + 300 lb)
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass ‘m’ **is** moved	7.9” (120.5” – 112.6”)

The new CG location will be aft of the original location as **m** a 300 lb mass added to a location behind it, so **D** is between the old CG and the place **m** is added to.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{300\text{ lb}}{10300\text{ lb}} = \frac{d}{7.9\text{ ins}} \qquad d = \frac{300\text{ lb} \times 7.9\text{ ins}}{10300\text{ lb}}$$

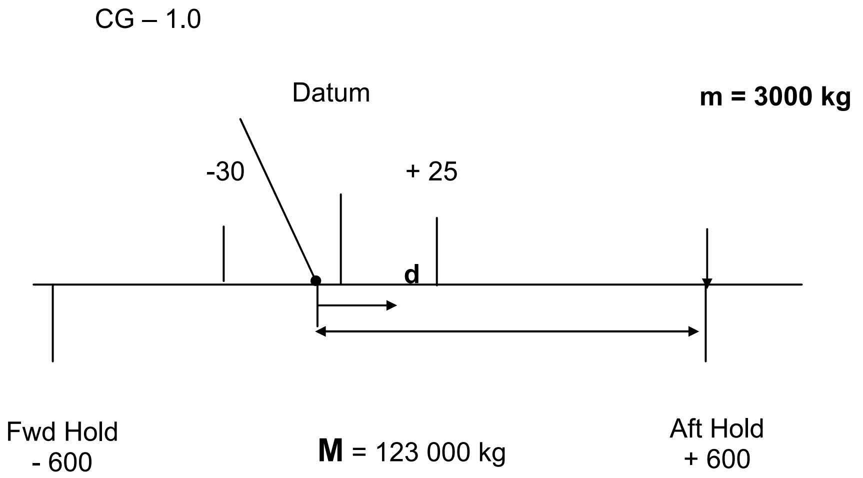
$$d = \frac{2370\text{ lbins}}{10300\text{ lb}}$$ **d =** + 0.230 CG = +112.83ins (112.6 ins + 0.23 ins)

The addition of 300 lb at +120.5 ins will result in the CG relocating to a position of + 112.83 ins.

Question 2 If a mass of 3000 kg is to be loaded into the aft hold will the aircraft be in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	- 1.0
All Stn in inches		
Total mass		120 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** added	3000 kg
M = the **total** mass of the aircraft	123 000 kg (120 000 + 3000)
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass ‘m’ **is** moved	601” (600” + 1”)

A mass **m** kg is to be added into the Aft hold the CG will move rearwards, D will be the distance between the original CG and aft hold.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{3000\ \text{kg}}{123000\ \text{kg}} = \frac{d}{601''} \qquad d = \frac{3000\ \text{kg} \times 601\text{ins}}{123000\ \text{kg}}$$

$$d = \frac{1803000\ \text{kgins}}{123000\ \text{kg}}$$

d = +14.658 ins CG = + 13.66 ins (+ 14.66 ins – 1.0 ins)

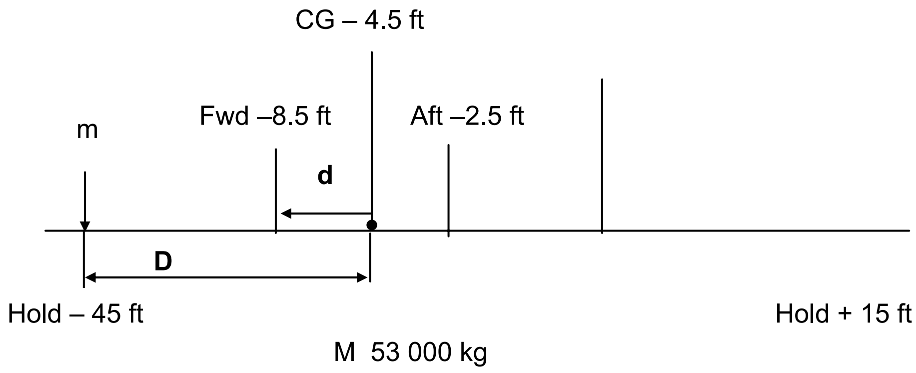
The addition of 3000 kg to the Aft hold will place the CG at + 13.66 ins

Question 3 An item of freight with a moment effect of –135000 kgft when added to the fwd hold, what will be the new CG?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft

Total mass 50 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	3000 kg
M = the **total** mass of the aircraft	53 000 kg
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass 'm' **is** moved	40.5 ft (45 ft – 4.5 ft)

As the mass to be added is given as a moment negative effect, the mass is this effect divided by the arm it is acting over. In this case –135 000 kgft ÷ - 45 ft = 3000 kg. This mass will cause the CG to relocate fwd of the original CG position.

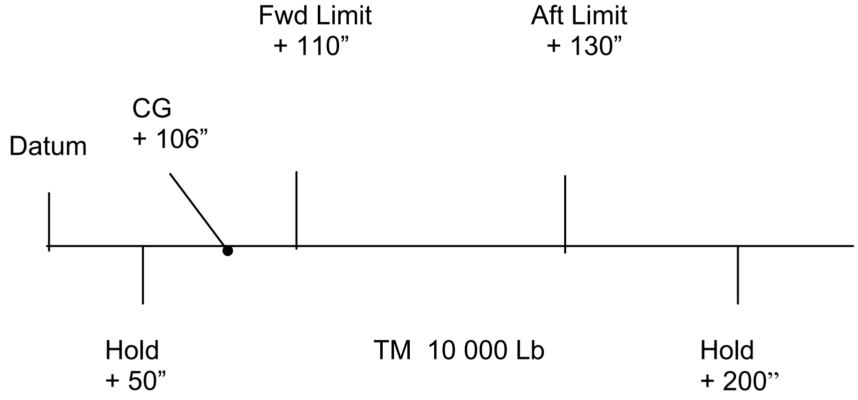
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{3000\ \text{kg}}{53000\ \text{kg}} = \frac{d}{40.5\ \text{ft}} \qquad d = \frac{3000\ \text{kg} \times 40.5\ \text{ft}}{53000\ \text{kg}}$$

$$d = \frac{121\ 500\ \text{kgft}}{53\ 000\ \text{kg}} \qquad \mathbf{d = -2.292\ ft} \quad CG = -\ 6.79\ \text{ft}\ (-4.5\ \text{ft} + -\ 2.29\ \text{ft})$$

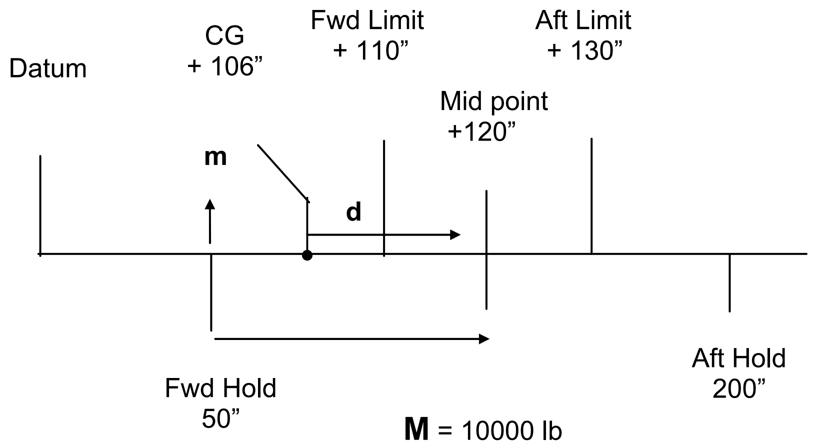
A mass of 3000 kg added to the Fwd hold will relocate the CG to a position of –6.79 ft.

Practice 5 Question 1

How much mass must be deducted to locate the CG into the middle of the SR of the aircraft as shown below.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	10 000 lb
d = the distance the CG **will** move from its original position	14” (120” – 106”)
D = the distance that the mass ‘m’ **is** moved	70” (120” – 50”)

The new CG location will be aft of the original location as **m** an unknown mass is removed from the Fwd hold to relocate the CG by **d** on to the mid point, so **D** is between the hold and new CG.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{10000\ lb} = \frac{14''}{70\ ins} \qquad m = \frac{10000\ lb \times 14''}{70\ ins}$$

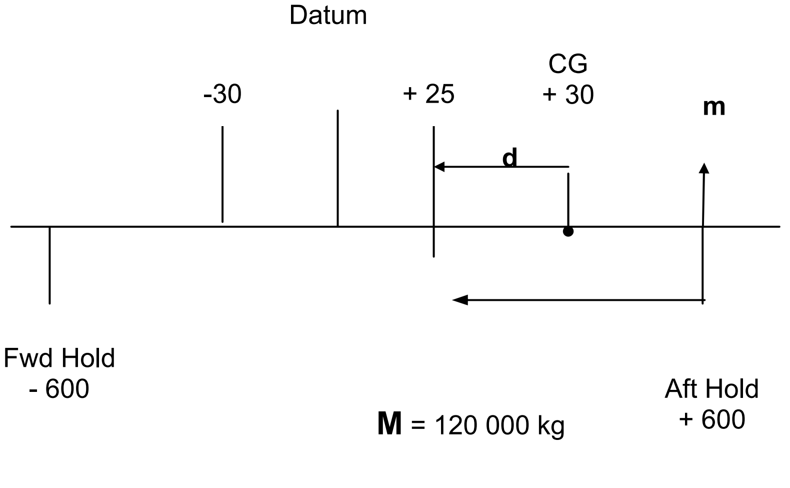
$$m = \frac{140000\ lbins}{70\ ins} \qquad \mathbf{m} = 2000\ lb$$

To relocate the CG to the mid point of the safe range a mass of 2000 lb would have to be removed from the Fwd hold.

Question 2 How much mass must be removed to place the following aeroplane in limits?

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	+ 30.0
All Stn in inches		
Total mass		120000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** added	In this case unknown
M = the **total** mass of the aircraft	120 000 kg
d = the distance the CG **will** move from its original position	5" (30" –25")
D = the distance that the mass 'm' **is** moved	575" (600" – 25")

A mass **m** kg is to be removed from the Aft hold the CG will move forwards, D will be the distance between the new CG and aft hold.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{120\,000\text{ kg}} = \frac{5''}{575''} \qquad m = \frac{120\,000\text{ kg} \times 5''}{575''}$$

$$m = \frac{600\,000\text{ kgins}}{575''} \qquad \mathbf{m} = 1043.478\text{ kg}$$

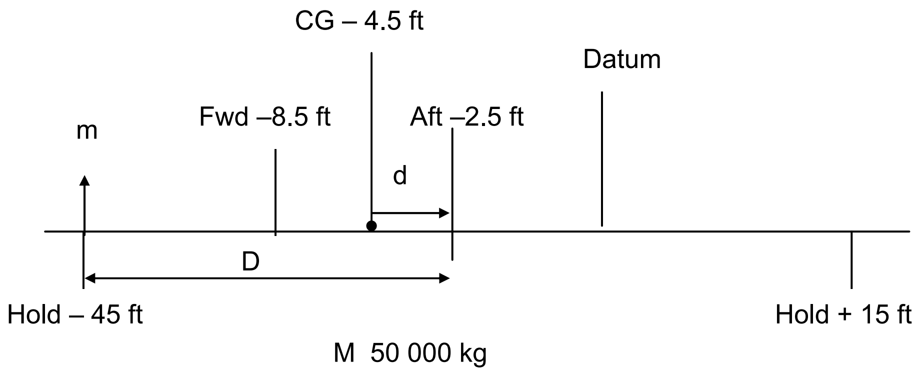
To relocate the CG to the rear limit of the SR a mass of 1043.48 kg must be removed from the Aft hold

Question 3

How much mass must be extracted from this aircraft to place its CG on the aft limit?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

The not to scale line diagram below denotes these distances and directions



In this example:

m = the mass **to be** moved	In this case unknown
M = the **total** mass of the aircraft	50 000 kg
d = the distance the CG **will** move from its original position	2 ft (4.5 ft – 2.5ft)

D = the distance that the mass 'm' **is** moved 42.5 ft (45 ft – 2.5 ft)

As the mass to be removed is not given but the new location is given the **D** in this case is between the hold and new CG position.

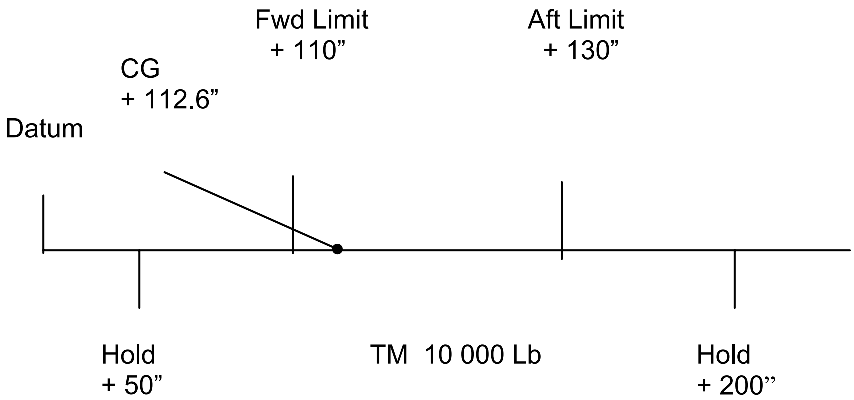
$$\frac{m}{M} = \frac{d}{D} \qquad \frac{m}{50\,000 \text{ kg}} = \frac{2 \text{ ft}}{42.5 \text{ ft}} \qquad m = \frac{50\,000 \text{ kg} \times 2 \text{ ft}}{42.5 \text{ ft}}$$

$$m = \frac{100\,000 \text{ kgft}}{42.5 \text{ ft}} \qquad \mathbf{m =} \ 2352.941 \text{ kg}$$

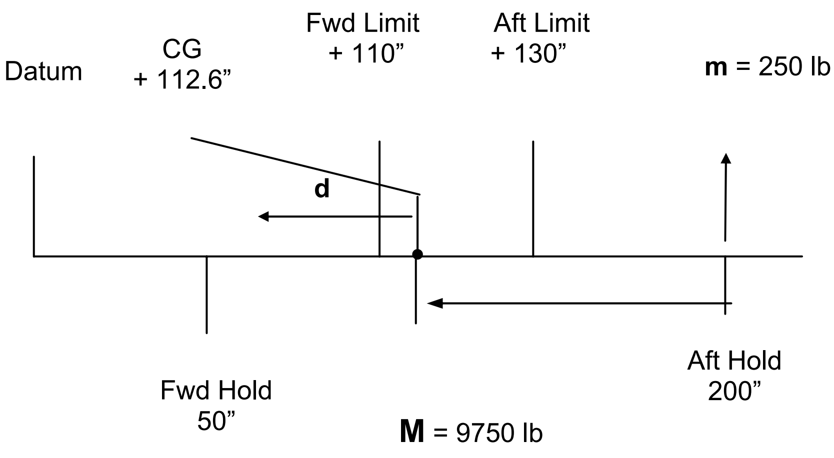
A mass of 2352.94 kg must be removed from the Fwd hold to relocate the CG on the Aft limit.

Practice 6 Question 1

What will the effect be on this aircraft's CG if 250 lbs of baggage is off loaded from the aft hold.



The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	250 lb
M = the **total** mass of the aircraft	9750 lb (10000 lb – 250 lb)
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass 'm' **is** moved	87.4" (200" – 112.6")

As a mass of 250 lb is being removed from Aft hold the new CG will be Fwd of the current position.

Question 2

If a mass of 1000 kg is to be unloaded from the fwd hold, will the aircraft be in limits?

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{250\text{ lb}}{9750\text{ lb}} = \frac{d}{87.4\text{ ins}} \qquad d = \frac{250\text{ lb} \times 87.4\text{ ins}}{9750\text{ lb}}$$

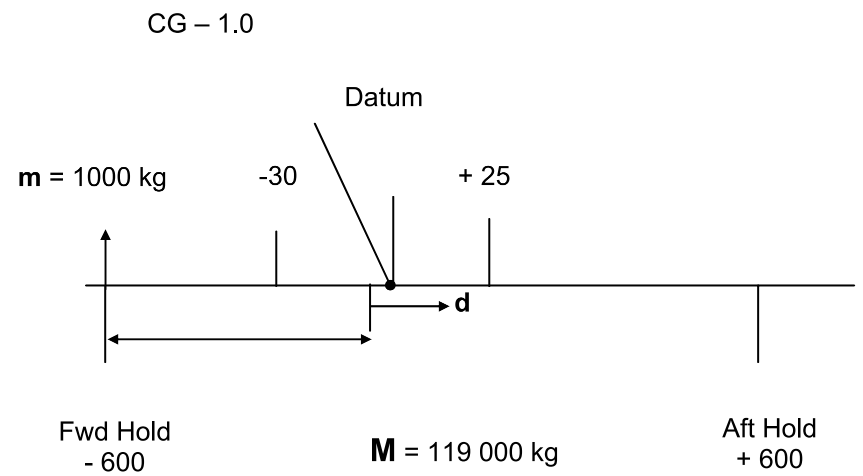
$$d = \frac{21\,850\text{ lbins}}{9750\text{ lb}}$$

d = - 2.241 ins CG = +110.36 ins (+112.6 ins – 2.24 ins)

The new CG would move Fwd by 2.24 ins to a location of + 110.36 ins.

Datum	Stn	0.0
Fwd limit	Stn	- 30.0
Aft Limit	Stn	+ 25.0
Fwd Hold	Stn	- 600.0
Rear Hold	Stn	+600.0
CG located	Stn	- 1.0
All Stn in inches		
Total mass		120 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** added	1000 kg
M = the **total** mass of the aircraft	119 000 kg (120 000 - 1000)
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass 'm' **is** moved	599" (600" - 1")

A mass **m** kg is to be removed from the Fwd hold the CG will move rearwards, D will be the distance between the original CG and Fwd hold.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{1000\text{ kg}}{119\,000\text{ kg}} = \frac{d}{599"} \qquad d = \frac{1000\text{ kg} \times 599\text{ ins}}{119\,000\text{ kg}}$$

$$d = \frac{599\,000\text{ kgins}}{119\,000\text{ kg}}$$

d = +5.033 ins CG = + 4.03 ins (+ 5.03 ins – 1.0 ins)

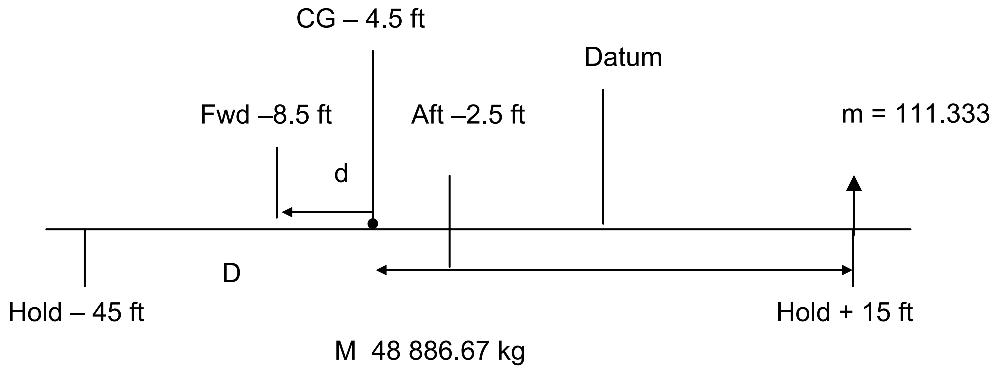
The subtraction of 1000 kg to the Fwd hold will place the CG at + 4.03 ins

Question 3

An item of freight removed from the aircraft has a moment effect of –1670 kgft, what will be the new CG?

Datum	0.0
Safe Range	6.0 ft
Aft Limit	- 2.5 ft
Fwd Hold	- 45.0 ft
Rear Hold	+ 15. 0 ft
Total moment	-225 000.00 kg ft
Total mass	50 000 kg

The not to scale line diagram below denotes these distances and directions



m = the mass **to be** moved	111.333 kg
M = the **total** mass of the aircraft	48 886.67 kg
d = the distance the CG **will** move from its original position	In this case unknown
D = the distance that the mass ‘m’ **is** moved	19.5 ft (15 ft + 4.5 ft)

As the mass to be removed has a negative moment effect, the mass is the effect divided by the arm it is acting over. In this case –1670 kgft + - 15 ft = 111.333 kg. This mass will cause the CG to relocate fwd of the original CG position.

$$\frac{m}{M} = \frac{d}{D} \qquad \frac{111.333\ \text{kg}}{48\ 886.67\ \text{kg}} = \frac{d}{19.5\ \text{ft}} \qquad d = \frac{111.333\ \text{kg x } 19.5\ \text{ft}}{48\ 886.67\text{kg}}$$

$$d = \frac{21709.935\ \text{kgft}}{48\ 886.67\ \text{kg}} \qquad \mathbf{d =} -0.444\ \text{ft} \quad \text{CG} = -4.94\ \text{ft}\ (-4.5\ \text{ft} + -0.444\ \text{ft})$$

A mass of 111.333 kg removed from the Aft hold will relocate the CG to a position of –4.54 ft.

Intentionally Left Blank

Chapter 6

Questionnaire for Data Sheet SEP 1

Use the conversion factors given in the CAP 696 page 4, reduced to 4 places decimal.
E.g. from kilos to pounds would read 2.2046

Work and answer to two places decimal, give final answer for CG and moments to two places decimal and convert masses to nearest whole number.

1. What is the MTOM of the aircraft?

2. What is the maximum load per square foot in Zone C?

3. What distance is the datum from the Reference Point?

4. What is the mass of a single gallon of fuel?

5. What is the moment of a single gallon of fuel?

6. What is the normal run up and taxi allowance of fuel?

7. What will be the DOM + CG for a crew of two pilots each weighting 182 lb?

8. What will be the aircraft's gross mass and CG if it is parked with full fuel tanks?

9. What is the OM for an aircraft crewed with two pilots each weighing 182 lb and fully fueled?

10. An aircraft is operated with six seats, one crew and five passengers using the standard masses where each passenger is a male adult without hand baggage. 200 lb of baggage is loaded into the Zone C, what would its ZFM and CG be?

11. What would be the TOM, LM and ZFM if the aircraft were to be operated in the two-seat configuration as loaded below for a flight of six hours duration?

    1 Crew (standard mass)
    1 adult female (standard mass) in front seat
    Full fuel load with a fuel burn of 5 gallons per hour.

12. A small ad hoc charter company operates an aircraft with a male and female crew who weigh 189 lb and 104 lb respectively. The aircraft is chartered to fly cargo between two airports, 2½ hours apart. The Company operations manual states that a contingency reserve must be carried for each operation that is the greater of either 10 % of the flight fuel or 3 gallons. The fuel consumption is estimated to be 6 galls per hour. Calculate the masses and determine the maximum payload that could be carried allowing a standard start fuel allowance.

13. An aircraft is operated with only the pilot’s seats fitted, fully fuelled with two female pilots at standard mass. What floor area would be required to support a payload of 416 lb loaded into area A?

14. An aircraft is to be loaded as below, calculate the aircraft's useful load.

Front seats - pilot weighing 112 lb pax weighs 196 lb.
The 3+4 seats -female of 105 lb and a child of 56 lb.
Baggage in zone B = 200 lb.
Baggage in zone C = 100 lb
Fuel load 360 lb
Trip fuel 180 lb
Start fuel 13 lb

	Mass	Arm	Moment(X100)
BEM	2415.00	77.7	
Front seats		79	
3+4 seats		117	
Baggage zone A		108	
5+6 seats		152	
Baggage zone B		150	
Baggage zone C		180	
ZFM			
Fuel Load			
Ramp mass			
Less Start			
Take Off Mass			
Trip			
Landing Mass			

15. Work out the CG and mass for the following conditions:
DOM, OM, ZFM, Taxi Mass, TOM and LM for an aircraft loaded as follows
Pilot 160 lb
Pax 238 lb in seats 3 + 4
Pax 126 lb in seats 5 + 6
Baggage 100 lb in zone C
Fuel load 25 gals, including reserve and standard start allowance.
Fuel burn 6.5 galls per hour. Trip time 2.5 hours.

	Mass	Arm	Moment(X100)
BEM	2415.00	77.7	
Front seats		79	
3+4 seats		117	
Baggage zone A		108	
5+6 seats		152	
Baggage zone B		150	
Baggage zone C		180	
ZFM			
Fuel Load			
Ramp mass			
Less Start			
Take Off Mass			
Trip			
Landing Mass			

Answers for Questionnaire Data Sheet SEP1

All page numbers refer to CAP 696

1.	**3650 lb.**	Page 5.	
2.	**100 lb per square foot**	Page 5	
3.	**39 inches**	Page 5	
4.	**6 lb**	Page 6	30 lb ÷ 5 = 6 lb per gallon.
5.	**460 lb/ins**	Page 6	23 lb/ins ÷ 5 = 4.6(moment/100)
6.	**13 lb**	Page 8	

7. DOM = 2779 lb @ + 77.87"

	Mass	Arm	Moment(X100)
BEM	2415	77.7	187645.5
Crew	364	79	28756
DOM	2779		216401.5
DOM CG	216401.5	Divided by	2779
CG =	+ 77.87	Inches	

8. **GM 2859 lb @ + 77.28"**

	Mass	Arm	Moment(X100)
BEM	2415	77.7	187645.5
Fuel	444	75	33300.0
Gross	2859		220945.5
DOM CG	220945.5	Divided by	2859
CG =	+ 77.28	Inches	

9. **OM 3223 lb**

	Mass
BEM	2415
Crew	364
Fuel	444
OM	3223

10. ZFM 3883 lb. @ "95.74"

From the standard passenger mass for a 1-5 passenger seat aircraft a male's mass = 104 kg. This includes 6 kg of hand baggage – each male in this question has a mass of 98 kg each. The crew has a standard mass of 85 kg. So convert the mass from kg to lb by multiplying it by the constant.

Crew 85 kg	X	2.2046 lb	187.39 lb
Pax 98 kg	X	2.2046 lb	216.05

	Mass	Arm	Moment(X100)
BEM	2415.00	77.7	187645.50
Front seats	403.44	79	31871.76
3+4 seats	432.10	117	50555.70
Baggage zone A	0	108	0
5+6 seats	432.10	152	65679.20
Baggage zone B	0	150	0
Baggage zone C	200.00	180	36000.00
ZFM	3882.64		371752.16

ZFM = 3883 lb.
ZFM CG is 371752.6 lb/in divided by 3883
CG = + 95.74 ins

11. ZFM 2792 lb @ 77.88"
TOM 3223 lb @ 77.76"
LM 3043 lb @ 77.93"

As pax is female but hand luggage is not mentioned you must assume it is there.

Female	86 kg	X	2.2046	= 189.60 lb
Crew	85 kg	X	2.2046	= 187.39 lb

Total mass 376.99 lb. as this is 0.01 less than a pound round it up for use in the table.

	Mass	Arm	Moment(X100)
BEM	2415.00	77.7	187645.50
Front seats	377.00	79	29783
3+4 seats	0.00	117	0.00
Baggage zone A	0	108	0
5+6 seats	0.00	152	0.00
Baggage zone B	0	150	0
Baggage zone C	0.00	180	0.00
ZFM	2792.00	**77.88**	217428.50
Fuel Load	444.00	75	33300.00
Ramp mass	3236.00	**77.48**	250728.50
Less Start	-13		-100.00
Take Off Mass	3223.00	**77.76**	250628.5
Trip 6 x 5 x 6]	-180.00	75	-13500.00

Landing Mass	3043.00	**77.93**	237128.5

12. **Maximum payload 821 lb.**

	Mass
BEM	2415.00
Front seats	293.00
3+4 seats	0.00
Baggage zone A	0
5+6 seats	0.00
Baggage zone B	0.00
Baggage zone C	0.00
ZFM	2708.00
Fuel Load	121.00
Ramp mass	2829.00
Less Start	-13
Take Off Mass	2816.00
Trip 2.5 x 6 x 6	-90.00
Landing Mass	2726.00

Trip fuel is calculated as 2.5 hrs X 6 Gals = 15 gallons. The mass for this fuel is found in fig 2.3 or calculated at 6 lb per gallon. 15 gals X 6 lb = 90 lbs. The fuel load has to be increased by the greatest of either 10% of the trip fuel or 3 gallons. 10% of 15 gallons is 1.5 gallons; therefore the fuel reserve to be used is 3 gallons, equaling 18 lbs. A start allowance of 13 pounds is also required. Giving a total fuel load of 121 lb. [90+18+13].

The data sheet for this aircraft shows that the MTOM 3650 lb. is equal to MLM and with reference to the CG envelope there is no extra allowance for ramp mass. Given this the maximum payload the aircraft can carry is found by subtracting the ramp mass from 3650 lbs.

Max payload is: 3650 lb – 2829 lb = 821 lb

This will account for the start fuel allowance on board the aircraft, if the actual take-off mass of 2816 lb is used, it would give a value of 834 lb for the payload. This would make the aircraft 13 lb overloaded at the ramp.

13. **8.32 square feet**.

This type of question gives unwanted information to catch the unwary. The actual question asked is what square area is required to support a load of 416 lb given the structural limitation for zone A (50 lb per sq. ft.)

416 lb ÷ 50 lb/sqft = 8.32 square ft

14 **1017 lb Useful load**

The JAA definition of useful load is only given in the theory syllabi and is the combined masses of fuel and payload.

Pax Mass	Baggage	Fuel
196	'B' 200	Bulk 360
105	'C' 100	
56		
Sub total 357	Sub total 300	Sub total 360

Total 1017 lb

15.

DOM	2575.00	at 77.78 ins	**Taxi Mass**	3189.00	at 86.71 ins
OM	2712.00	at 77.96 ins	**TOM**	3176.00	at 87.04 ins
ZFM	3039.00	at 87.29 ins	**LM**	3078.50	at 87.42 ins

	Mass	Arm	Moment (x 100)
BEM	2415.00	77.7	1876.46
Front seats	160.00	79	126.4
3+4 seats	238.00	117	278.46
Baggage zone A	0.00	108	0
5+6 seats	126.00	152	191.52
Baggage zone B	0.00	150	0
Baggage zone C	100.00	180	180
ZFM	3039.00	**87.29**	2652.84
Fuel Load	150.00	75	112.50
Ramp Mass	**3189.00**	**86.71**	2765.34
Start fuel	-13.00	75	-10.00
TOM	**3176.00**	**87.04**	2764.34
Trip (2.5 x 6.5 x 6)	-97.50	75	-73.13
LM	**3078.50**	**87.42**	2691.21

	Mass	Arm	Moment(X100)
BEM	2415.00	77.7	1876.46
Crew	160.00	79.00	126.4
DOM	**2575.00**	**77.78**	2002.86
TOF	137.00	75.00	102.75
OM	**2712.00**	**77.96**	2114.36

Chapter 7

Questionnaire for Data Sheet MEP 1

1. What is the maximum load for Zone 2?

2. What is the MTOM?

3. What is the MZFM?

4. If standard passenger masses from table two of JAR-OPS 1 subpart J are used for this aircraft what is the moment for a female adult and male child sitting in the rear row of seats?

5. Calculate the mass of the aircraft given an arm of 89.5 ins aft of the datum and a moment of 416175 inchpounds and with reference to the CG limits state whether it is in or out of limits.

6. What mass is allowed for each US gallon of fuel?

7. Where is the reference point for the aircraft?

8. What distance is the nose wheel from the main wheel?

9. What effect does raising the undercarriage have?

10. Why does the forward CG limit decrease from 82" to 91"?

11. What is the performance class of this aeroplane?

12. What is the MLM?

13. What is the difference in mass for the specimen aircraft at a gross mass of BEM and full fuel and the MTOM?

14. If the CG plot falls on the line it is?

15. What is the fwd limit of the safe range at 4300 lb mass?

16. Calculate the take off mass, landing mass and CG positions for a specimen aircraft operated as a freighter, which has the following load:

    100 lb Zone 1 360 lb Zone 2
    400 lb Zone 3 100 lb Zone 4
    Crew 183 lb
    Bulk fuel 21 US galls
    Trip fuel 15 US galls
    Start fuel 16 lbs

    a. TOM in limits take off CG out of limits, landing mass and CG out of limits
    b. TOM out of limits take off CG in limits, landing mass and CG in of limits
    c. All Limits exceeded
    d. All masses within limits, CG limits exceeded

17. For the specimen aircraft loaded as below calculate the following masses and CG DOM, ZFM, TOM and LM

ITEM	**Mass (Lbs.)**	Arm Aft Of Datum (IN)	MOMENT (IN/Lbs)
Basic Empty Mass	3210	88.5	
Pilot and Front Passenger	182	85.5	
Passengers (Centre Seats) or Baggage Zone 2 (360 LB Max.)	294	118.5	
Passengers (Rear Seats) or Baggage Zone 3 (400 LB Max.)		157.6	
Baggage Zone 1 (100 LB Max.)	60	22.5	
Baggage Zone 4 (100 LB Max.)	100	178.7	
Zero Fuel Mass (4470 LB Max - Std)			
Fuel (123 Gal. Max) **79 Gals**			
Ramp Mass (4773 LB Max)			
Start Fuel	-30		
Take-off Mass (4750 LB Max.)			
Minus trip fuel **32 Gals**			
Landing Mass (4513 LB Max.)			

18. A specimen aircraft where Zone 3 is being used as a 'freight bay' is chartered to transport two pax and a package from Airport A to Airport B a distance of 350 nm. Airport B is unable to refuel the aircraft. The fuel load at TOM from airport A must include all the fuel required for start, trip and reserve.

Flight 360 nm @ 120 kt
Fuel consumption 10 US galls per hour out bound and 7.5 US galls per hour inbound
A start taxi allowance for the departure airport of 16 lbs and 10 lbs for the start from the destination airport. The aircraft must land with a diversion fuel allowance of 1.5 hour

Pilots Capt. 138 lb Training Capt. 203 lb
Freight Baggage zone 2 Freight marked 160 kg Dimension 1m X 0.5m X 0.5m
Freight Baggage zone 3 Freight marked 83 Lb Dimension 2.75ft X 1.5 ft X 0.5 ft

a. the aircraft can make both the outbound and return flight
b. the aircraft is over the limits for the outbound landing
c. the aircraft is over the limits for the out bound take-off
d. the aircraft can make the outbound, but not return flight

19. An aircraft is loaded as follows:

Pilot	158 lb	1st row pax	198 lb
2nd row pax	126 + 130 lb	3rd row pax	0 lb
Bulk fuel	100 US gals	Baggage	100 lb Zone A and 4
Trip fuel	73 galls.	Fuel allowance for start	-15 lb

Is the aircraft:

a. in limits for take off
b. in limits for landing
c. in limit for take off and landing
d. not in limit for take off and landing

20. Below is a load manifest that has been prepared for a planned flight to transport three items of freight and one passenger. Check the manifest and select the correct statement from those listed below.

ITEM	Mass (Lbs)	Arm Aft of Datum (In)	Moment (IN/Lbs)
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	340.00	85.5	29070.00
Passengers (Centre Seats) or Baggage Zone 2	360.00	118.5	42660.00
Passengers (Rear Seats) or Baggage Zone 3	240.00	157.6	37824.00
Baggage Zone 1	100.00	22.5	2250.00
Baggage Zone 4	77.00	178.7	1375.99
Zero Fuel Mass	**4327.00**	**91.8**	**397264.99**
Fuel	444.00	93.6	41558.40
Ramp Mass	**4771.00**	**92.0**	**438823.39**
Start Fuel	-22	93.6	-2059.20
Take-off Mass	**4749.00**	**92.0**	**436764.19**
Minus trip fuel	-400.00	93.6	-37440.00
Landing Mass	**4349.00**	**91.8**	**399324.19**

a. The aircraft is in limits for ZFM, RM, TOM and LM
b. The aircraft is in limits for take off but not for ZFM and LM
c. The aircraft is in limits for ZFM and RM but not for TOM and LM
d. The aircraft is in limits for ZFM, RM TOM but not LM

Answers for Self Test Questionnaire Data Sheet MEP1

Page numbers refer to CAP 696

1. 360 lb Page 13
2. 4750 lb Page 12
3. 4470 lb Page 12
4. 42041.38 inlbs

Standard Pax Mass from table 2 for 1 - 5 Pax seats

	KG	Conversion	Pounds
Female	86	2.2046	189.60
Child	35	2.2046	77.16
Total Mass	121	2.2046	266.76

	Mass	Arm	Moment
Passengers Rear Seats	266.76	157.6	**42041.38**

5. 416175 inlbs ÷ 89.5 = 4650 lbs which is fwd of the fwd limit for the mass Page 15
6. 6 lb per US gallon Page 13
7. Leading edge of the wing at inboard edge of inboard fuel tank Page 12
8. 84.5” distance B– A (109.8” – 25.3”) Page 12
9. “no significant effect" Page 12
10. Due to the increase in mass the aircraft’s fwd limit of the CG is reduced to prevent the aircraft becoming too stable and requiring excessive force and excessive deflection to operate the controls.
11. Performance class B Page 12
12. 4513 lb Page 12
13. 802 lb

Basic Empty Mass	3210.00
Fuel (123 Gals x 6 lb)	738.00
Gross Mass	3948.00
MTOM	4750.00
Gross Mass	-3948.00
Difference	**802.00**

14. “ in limits”

15. **+ 87.1 ins.** Using the CG envelope on page 15 find mid point between the 4200 and 4400 in two places, then project a horizontal line across the Fwd safe limit where they intersects drop a line down to the CG location scale that parallels the nearest grid line.

16. All masses within limits, CG limits exceeded

ITEM	Mass (Lbs)	Arm Aft of Datum (In)	Moment (IN/Lbs)
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	183.00	85.5	15646.50
Passengers (Centre Seats) or Baggage Zone 2 (360 LB Max.)	360.00	118.5	42660.00
Passengers (Rear Seats) or Baggage Zone 3 (400 LB Max.)	400.00	157.6	63040.00
Baggage Zone 1 (100 LB Max.)	100.00	22.5	2250.00
Baggage Zone 4 (100 LB Max.)	100.00	178.7	17870.00
Zero Fuel Mass (4470 LB Max - Std)	**4353.00**	**97.8**	**425551.50**
Fuel (123 Gal. Max)	126.00	93.6	11793.60
Ramp Mass (4773 LB Max)	**4479.00**	**97.6**	**437345.10**
Start Fuel	-16	93.6	-1497.60
Take-off Mass (4750 LB Max.)	**4463.00**	**97.7**	**435847.50**
Minus trip fuel	-90.00	93.6	-8424.00
Landing Mass (4513 LB Max.)	**4373.00**	**97.7**	**427423.50**

17.

DOM 3392 lb at + 88.3 ins TOM 4290 lb at + 92.1 ins
ZFM 3846 lb at + 92.0 ins LM 3079 lb at + 92.1 ins
RM 4320 lb at + 92.1 ins

ITEM	Mass (Lbs)	Arm Aft of Datum (In)	Moment (IN/Lbs)
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	182.00	85.5	15561.00
Passengers (Centre Seats) or Baggage Zone 2 (360 LB Max.)	294.00	118.5	34839.00
Passengers (Rear Seats) or Baggage Zone 3 (400 LB Max.)	0.00	157.6	0.00
Baggage Zone 1 (100 LB Max.)	60.00	22.5	1350.00
Baggage Zone 4 (100 LB Max.)	100.00	178.7	17870.00
Zero Fuel Mass (4470 LB Max - Std)	**3846.00**	**92.0**	**353705.00**
Fuel (123 Gal. Max)	474.00	93.6	44366.40
Ramp Mass (4773 LB Max)	**4320.00**	**92.1**	**398071.40**
Start Fuel	-30	93.6	-2808.00
Take-off Mass (4750 LB Max.)	**4290.00**	**92.1**	**395263.40**
Minus trip fuel	-192.00	93.6	-17971.20
Landing Mass (4513 LB Max.)	**4098.00**	**92.1**	**377292.20**
BEM	3210.00	88.5	284085.00
Crew	182.00	85.5	15561.00
DOM	**3392.00**	**88.3**	**299646.00**

18. '**The aircraft can make both the outbound and return flight**'

First check that the freight is within the floor load limit of 120 lb per Sq Ft (Page 12)

	kg	Conversion	lb
Freight	160.00	2.2046	352.74

Item 1 Dimensions 1m x 0.5m x 0.5m

Meters	Conversion	Feet	Sq feet	Load lb	Lbs per sqft
1m	0.3048	3.28	5.38	352.74	65.57
0.5m	0.3048	1.64	2.69	352.74	131.08
0.5m	0.3048	1.64			

Item 2 Dimensions 2.75ft x 1.5ft x 0.5ft

		2.75	4.13	83	20.09
		1.5	0.75	83	110.67
		0.5			

Both items are in floor load limits

Calculate the fuel load for take–off from the departure airport by calculating the flight time etc. On landing at B the aircraft has the return trip fuel on board so the reserve fuel is calculated at the consumption rate for the return flight.

Distance	Speed	Flight Time		
360	120	3.00		
			Gallons	Mass
Trip fuel Out Bound	3hr at 10 gals at 6 lb		30.00	180.00
Trip fuel In Bound	3hr at 7.5 gals at 6 lb		22.50	135.00
Total Trip Fuel			52.50	315.00
Start allowance A	16 lb		2.67	16.00
Start allowance B	10 lb		1.67	10.00
Reserve	1.5 x 7.5 GPH x 6 lb		11.25	67.50
Fuel Load at 'A'	Max 123 gal 738 lb		68.09	408.5

As both the fuel and the freight are in limits, calculate the outbound manifest

For Flight from A to B	Mass lbs	Arm (ins	Moment In/lb
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	341.00	85.5	29155.50
Passengers (Centre Seats) or Baggage Zone 2 (360 LB Max.)	352.74	118.5	41799.22
Passengers (Rear Seats) or Baggage Zone 3 (400 LB Max.)	83.00	157.6	13080.80
Baggage Zone 1 (100 LB Max.)	0.00	22.5	0.00
Baggage Zone 4 (100 LB Max.)	0.00	178.7	0.00
Zero Fuel Mass (4470 lb max)	**3986.74**	**92.3**	**368120.52**
Fuel (123 Gal. Max)	408.50	93.6	38235.60
Ramp Mass (4773 LB Max)	**4320.00**	**94.1**	**406356.12**
Start Fuel	-16.00	93.6	-1497.60
Take-off Mass (4750 LB Max.)	**4304.00**	**94.1**	**404858.52**
Minus trip fuel	-180.00	93.6	-16848.00
Landing Mass (4513 LB Max.)	**4124.00**	**94.1**	**388010.52**

Check the outbound actual masses against the structural maximum masses.
Check the calculated CG position against the CG envelope.

As the outbound flight is in limits calculate the inbound flight

For Flight from B to A	Mass lbs	Arm (ins)	Moment In/lb
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	341.00	85.5	29155.50
Passengers (Centre Seats) or			
Baggage Zone 2 (360 LB Max.)	0.00	118.5	0.00
Passengers (Rear Seats) or			
Baggage Zone 3 (400 LB Max.)	0.00	157.6	0.00
Baggage Zone 1 (100 LB Max.)	0.00	22.5	0.00
Baggage Zone 4 (100 LB Max.)	0.00	178.7	0.00
Zero Fuel Mass (4470 lb max)	**3551.00**	**88.2**	**313240.50**
Fuel (123 Gal. Max)	212.50	93.6	19890.00
Ramp Mass (4773 LB Max)	**3763.50**	**88.5**	**333130.50**
Start Fuel	-10.00	93.6	-936.00
Take-off Mass (4750 LB Max.)	**3753.50**	**88.5**	**332194.50**
Minus trip fuel	-135.00	93.6	-12636.00
Landing Mass (4513 LB Max.)	**3618.50**	**88.3**	**319558.50**

Check the inbound actual masses against the structural maximum masses.
Check the calculated CG position against the CG envelope.

19. In limit for take off and landing

ITEM	Mass	Arm Aft of	Moment
	(Lbs)	Datum (In)	(IN/Lbs)
Basic Empty Mass	3210.00	88.5	284085.00
Pilot and Front Passenger	356.00	85.5	30438.00
Passengers (Centre Seats) or			
Baggage Zone 2 (360 LB Max.)	256.00	118.5	30336.00
Passengers (Rear Seats) or			
Baggage Zone 3 (400 LB Max.)	0.00	157.6	0.00
Baggage Zone 1 (100 LB Max.)	100.00	22.5	2250.00
Baggage Zone 4 (100 LB Max.)	100.00	178.7	17870.00
Zero Fuel Mass (4470 LB Max - Std)	**4022.00**	**90.7**	**364979.00**
Fuel (123 Gal. Max)	600.00	93.6	56160.00
Ramp Mass (4773 LB Max)	**4622.00**	**91.1**	**421139.00**
Start Fuel	-15.00	93.6	-1404.00
Take-off Mass (4750 LB Max.)	**4607.00**	**91.1**	**419735.00**
Minus trip fuel	-450.00	93.6	-42120.00
Landing Mass (4513 LB Max.)	**4157.00**	**90.8**	**377615.00**

20. The aircraft is in limits for take off but not for ZFM and LM

Purposeful error made in Baggage zone 4 line [77 X 178.7 = 13759.9] The JAA use this type of question to check that you are checking the computation of others rather than accepting a manifest and just signing for it.

ITEM	Mass (Lbs)	Arm Aft of Datum (In)	Moment (IN/Lbs)	True (IN/Lbs)	True CG
Basic Empty Mass	3210.00	88.5	284085.00	284085	
Pilot and Front Passenger	340.00	85.5	29070.00	29070	
Passengers (Centre Seats) or Baggage Zone 2 (360 LB Max.)	360.00	118.5	42660.00	42660	
Passengers (Rear Seats) or Baggage Zone 3 (400 LB Max.)	240.00	157.6	37824.00	37824	
Baggage Zone 1 (100 LB Max.)	100.00	22.5	2250.00	2250	
Baggage Zone 4 (100 LB Max.)	77.00	178.7	1375.99	*13759.9*	
Zero Fuel Mass (4470 LB Max)	**4327.00**	**91.8**	**397264.99**	**409648.9**	**94.7**
Fuel (123 Gal. Max)	444.00	93.6	41558.40	41558.4	
Ramp Mass (4773 LB Max)	**4771.00**	**92.0**	**438823.39**	**451207.3**	**94.6**
Start Fuel	-22	93.6	-2059.20	-2059.2	
Take-off Mass (4750 LB Max.)	**4749.00**	**92.0**	**436764.19**	**449148.1**	**94.6**
Minus trip fuel	-400.00	93.6	-37440.00	-37440	
Landing Mass (4513 LB Max.)	**4349.00**	**91.8**	**399324.19**	**411708.1**	**94.7**

Intentionally Left Blank

Chapter 8

Medium Range Jet Transport – MRJT 1

Introduction

This chapter introduces the MRJT 1 as per CAP 696 JAR FCL Examinations Loading Manual. The aircraft is a medium range twin jet, certified under FAA/JAR-25 in performance class A.

The MRJT 1 data sheets in the CAP 696 (pages 19 to 31) show in an abbreviated format the type of loading manual documentation that you are likely to encounter on a large transport aircraft.

Read these notes in conjunction with the CAP 696 in order to make yourself familiar with the presentation and use of the data. The notes will use extracts from the CAP 696. Where these are used the Figure Number or Table Number along with the page number are given.

Contents (Page 19)

The manual is split into 7 sections:

1. Aircraft Description
2. Aircraft Data Contents
3. Mass and Balance Limitations
4. Fuel Data
5. Passengers and Personnel Data
6. Cargo Data
7. Mass and Balance Calculations

Aircraft Description (Page 20)

A brief description is given:

- Monoplane
- Twin high-bypass gas turbine engines
- Retractable undercarriage
- Certified under FAA/JAR –25
- Performance Class A

Locations Diagram Figure 4.1 (Page 20)

This diagram shows the aircraft viewed from the right wing tip. The datum's location in the nose of the aircraft is found by measuring 540 inches forward from the front spar. On the diagram this is marked FS below the fuselage and 540 above the fuselage.

From the diagram the nose is shown as being –22 inches forward of the datum and the tail of the aircraft as being 1365 inches aft of the datum. Giving a fuselage length of:

- 1387 inches or
- 115 ft 7 ins or
- 35.23 m.

Table to Convert Body Stations to Balance Arm Figure 4.2 (Page 20)

This table gives the method of converting Body Stations into inches.

Body Station	**Conversion**	**Balance Arm - in**
130 to 500	B.S. -152	-22 to 348

Subtract 152 ins from the Body Station (BS) to get the Balance Arm (BA) in inches.

Example

BS 130	130 – 152 ins = BA of –22 Ins
BS 500	500 – 152 ins = BA of 348 ins

For the block of body stations 500A to 500G the system changes. In the conversions column for each of the body stations the arm of 348ins is given plus a number of inches to be added.

Example

Body Station	**Conversion**	**Balance Arm - in**
500A	348 + 22 in	370

The table shows that in the 500A to 500G range each change in BS increases the BA by 22 ins.

For the BS 540 to 727 the BS converts directly into inches.

BS 727 converts directly across into a balance arm of 727 inches. For the BS 727A to 727G range a number of inches are added to the constant of 727 inches, each change is 20 ins.

For the final row BS 747 to 1217 a constant of 148 ins is added to the BS to read the BA.   While the data sheet does not make further reference to the body stations it is **possible** for the examiner to form questions around them.

Landing Gear Retraction (Page 21)

Paragraph 2.2 states that the landing gear has negligible effect on the CG.

Effect of Flap Retraction (Page 21)

Paragraph 1.3 Flap retraction should have been printed as paragraph 2.3.

In Figure 4.3 the effect of raising the flaps is shown as an index number, the effect is:

- Negative when the flaps are retracted
- Positive when they are lowered.

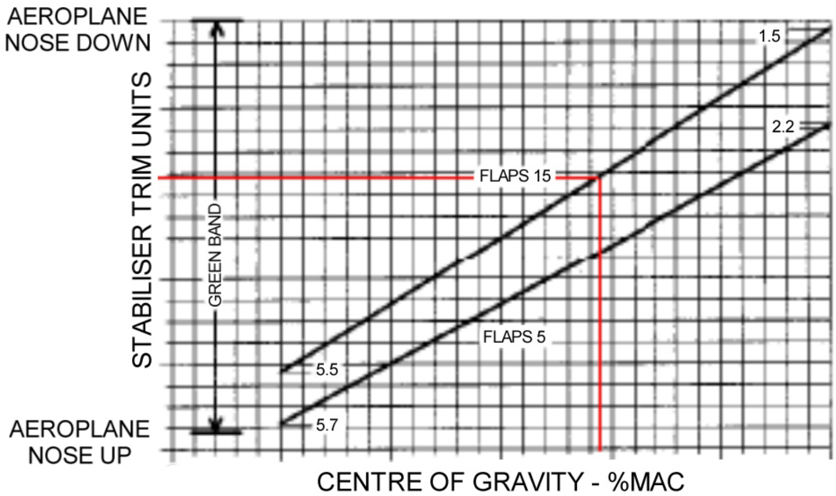
Take-Off Horizontal Stabiliser Trim Setting (Page 21)

Paragraph1.4 Take-Off horizontal Stabiliser Trim Setting should have been printed as paragraph 2.4

Obtaining Trim Units

Figure 4.4 is a graph showing horizontal stabiliser trim settings for 5° and 15° of flap against CG positions given in % MAC. This graph is used to find the stabiliser trim required depending on the CG position and flap setting. A horizontal stabiliser is a movable tailplane, this will be fully explained in Principles of Flight.

CAP 696 Figure 4.4 Graph of trim units for CG position (Page 21)



Example Use the graph figure. 4.4 in the data sheet to determine the stabiliser setting with 15° flap and CG at 19.5% MAC.

STEP 1 Enter graph at 19.5 % MAC and draw a vertical line to intersect the 15° of flap line

STEP 2 Then draw a horizontal line again parallel to the grid to the left axis.

STEP 3 Read off the side scale to obtain the correct stabiliser trim units, in this case 2.8.

Conversion of BA to or from % MAC

The Mean Aerodynamic Chord for the aircraft is given as 134.5 inches with its leading edge 625.6 ins aft of datum.

The conversion of a linear CG position uses the standard formula:

$$\frac{A - B}{C} \times 100 = \% \text{ MAC}$$

For the MRJT 1 insert the values of 625.6 for B and 134.5 for C, as shown in the formula below:

$$\frac{A - 625.6}{134.5} \times 100 = \% \text{ MAC}$$

Example The aeroplane is weighed in order to determine the Basic Empty Mass (BEM) and related CG. The following readings are obtained (in kilo Newton):

Location	**BA (inches)**	**Force Kn)**
Nose Wheel	158	29.95
L Main wheel	698	152.45
R Main wheel	698	153.10

Determine the BEM (Kg. assuming G = 981 cms/sec^2)

Determine the CG as a % MAC

STEP 1 Determine total force and total moment as shown in the table below

Location	**BA**	**Force**	**Moment**
Nose	158	29.95	4732.1
Left Main	698	152.45	106410.1
Right Main	698	153.10	106863.8
	Totals	**335.50**	**218 006.0**

BEM = 335.5 X1000 ÷ 9.81= 34,199.796 kg.
The Basic Empty Mass of the aircraft to the nearest kg is 34,200 kg.

STEP 2 Finding the CG as % MAC

CG = Moment ÷ Total force

= 218 006 ÷ 335.5

= 649.8 inches

$$\% \text{ MAC} \qquad \frac{649.8 - 625.6}{134.5} \times 100 = 17.99 \% \text{ MAC}$$

Mass and Balance Limitations (Page 21)

The following are given:

Maximum structural taxi mass	63,060 kg
Maximum structural take-off mass	62,800 kg
Maximum structural landing mass	54,900 kg
Maximum structural zero fuel mass	51,300 kg

Maximum Structural Taxi Mass can also be referred to as Maximum Ramp Mass or MRM.

Centre of Gravity Limits (Page 22)

The CG limits are shown in a graphical form in Figure 4.11 CG Envelope (Page 27).

Fuel (Page 22)

Fuel loads and limits for the aircraft are given in paragraph 4.

Figure 4.5 shows fuel tank locations and capacities, giving balance arms (inches) and quantities in both US Gallons and Kilograms. The SG is 0.8 for the figures given.

Note: The caution below the table about the centre tank, and
The mass of fuel is given as **3.03 kg** per US gallon.

During flight the weight in the fuselage combined with lift produced by the wings (airload) causes them to bend upwards. To counter this it is standard practice to:

- Use the fuel from the centre tanks first
- Then feed the engines from the inboard wing tanks and then
- Work progressively outwards.

This:

- Reduces the fuselage mass which
- Reduces the amount of lift required and balances this lift with the weight of fuel in the wing tanks
- Reducing the bending effect on the wing structure.

Figure 4.6 shows the same information as Figure 4.5 for **unusable** fuel. The order of the columns is changed.

A tank location diagram is shown at the bottom of the page.

Passengers (PAX) and Personnel (Page 23)

Details on passenger (pax) and personnel are given on page 23.

Paragraph 5.1 gives maximum passenger load, and the breakdown into club or business and economy classes:

Maximum Passenger Load	141 kg
Club/Business	33 kg
Economy	108 kg

Paragraph 5.2 and the associated diagrams Figure 4.7 and Figure 4.8 detail the passenger distribution in the cabin.

Note: In paragraph 5.2 the comment about seating for low passenger loads.

In Figure 4.8 the table details the max capacity, and balance arm "the centroid" of each zone. The BA given being the arm length for the mid-zone position.

Passenger Mass

In paragraph 5.3 the data sheet states that unless otherwise stated to assume the passenger mass as 84 kg which includes 6 kg hand baggage. As there is no mention of passenger age in this section of the data sheet assume that every passenger weighs 84 kg

Passenger Baggage

The passengers baggage mass is given as 13 kg

Personnel

Personnel are listed in paragraph 5.5

Standard Crewing	**Number**	**BA**	**Standard Mass Kg**
Flight Deck	2	78.0	90
Cabin Staff - Forward	2	162.0	90
Cabin Staff - Aft	1	1107.0	90

.

These masses vary from the standard masses given in JAR-OPS Subpart J 1.165 and 1.620 listed in Chapter 4 of these notes.

You must read the questions carefully to see if they are asking you to use the information from the data sheet or the standard passenger weights as per the JAR-OPS - 1.

Example

Establish the passenger load for the aeroplane carrying a total of 120 pax using the data given in the manual at paragraph 5.3:

80 male adults

35 female adults

5 children

120 pax X 84 kg = 10080 kg

Now establish the passenger load for the same aircraft using the data in JAR-OPS –1 for a non-holiday charter flight:

80 males	X 88 kg	7040
35 females	X 70 kg	2450
5 children	X 35 kg	175
		9665 kg.

Cargo

Page 24 details the aircraft's front and rear cargo compartment limitations, these take the form of 2 tables in figure 4.9 which is reproduced below in part.

Note: The full table is referred to as a hold, and the forward and aft areas are compartments.

Figure 4.9 Cargo Compartment Limitations

Forward Cargo Compartment

BA – IN 228	**286**	**343**	**500**
MAXIMUM COMPARTMENT RUNNING LOAD IN KG PER INCH	13.15	8.47	13.12
MAXIMUM DISTRIBUTION LOAD INTENSITY KG PER SQUARE FOOT	68		
MAXIMUM COMPARTMENT LOAD KG	762	483	2059
COMPARTMENT CENTROID B.A -IN	257	314.5	421.5
MAXIMUM TOTAL LOAD KG	3305		
FWD HOLD CENTROID B.A.- IN	367.9		
FWD HOLD VOLUME CUBIC FEET	607		

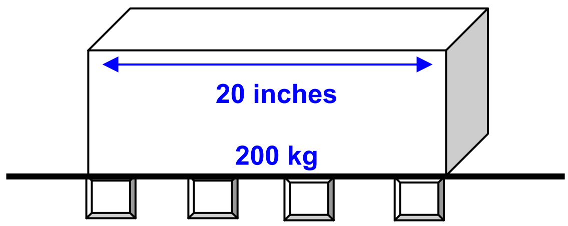
From the table it can be seen that the Forward cargo hold is divided into three compartments each with a different running load limit, but with the same static load limit (intensity).

Running Load This running load limitation protects the aircraft frame from excessive loads. This is the total load permitted in any length of the aircraft – the load width does not matter.

Example and

Assume that a container is 10 inches wide and 20 inches long weighs 200 kg. The maximum allowable running load is 10 kg/in

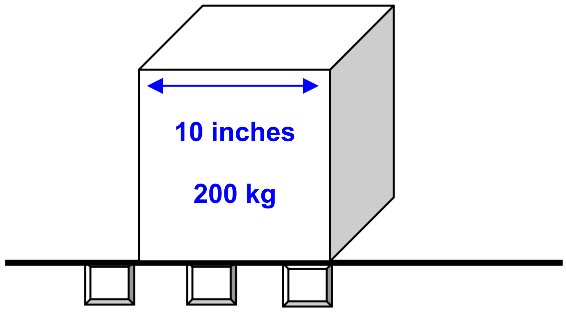
Case 1 Assume that the container is placed along the floor members



The load is 200 ÷ 20 = 10 kg/in

Which is well within the limits of 10 kg/in.

Case 2 Rotate the container by 90°



In this case the load is 200 ÷ 10 = 20 kg/in

Outside the running load limit.

The first compartment is between balance arms 228 to 286 a distance of 58 ins (286 – 228). This length of the area % running load equals the compartment load.

58 ins X 13.15 kg per inch = 762.7 kg, which is given as **762 kg** in the table.

This mass acts through the balance arm of **257** aft of the datum. If all the compartments are fully loaded then the mass acts through the hold centroid.

A further constraint is the total volume of the hold. Dimensions of cargo may have to be considered.

Note: That the table kilogram masses for the maximum compartment loads have been rounded up and down by the compiler of this data. The centroids given are not the exact centres of the compartments.

You as the examination candidate must **USE** the numbers given in the data sheet.

Loading Manifest (Page 25)

Paragraph 7.1 details how to calculate the mass and balance for the aircraft using the loading manifest figure 4.10 on page 26 and the CG envelope figure 4.11 on page 27. Read the list, because this will ensure that the aircraft's mass and balance is be checked against the limits.

You will note in figure 4.10 the manifest does not give the balance arms for the fuel tanks as this varies depending on the volume (mass) of fuel in the tank, refer to figures 4.5 and 4.6 on page 22 taking the left wing main tank.

Example

When the tank is full the fuel mass is 4542 kg at a BA of 650.7ins.

When empty of **usable** fuel it has a remaining fuel mass of 14 kg at a BA of 599.0 ins.

Thus the BA moves aft by 51.7 ins (650.7 – 599) from empty tanks to full tanks and vice versa. This works out at 87.85 kg of fuel per inch change in BA

(4542 kg + 51.7 ins)

In Figure 4.11 the CG envelope, shows both forward and aft limits in terms of % MAC at Gross Masses from 30 000 kg to 63 060 kg, the limits for MLM and MZFM.

Note: The change in shape of the envelope and the sharp reduction in the aft CG limit as the gross mass drops below 44250 kg.

Example For the following worked example figure 4.A a loading manifest has been completed to illustrate its use. The data for the structural limits have been taken from the data sheet. The passenger, cargo and fuel loads have been made up and are given in the table. Fuel consumption is given below:

Centre Tank has 4916 Kg at start-up and is used first. The taxi allowance of 260 kg is subtracted leaving 4656 Kg in the tank for take off.

Trip fuel, the centre tank is the used until empty the remaining trip fuel is drawn from the wing tanks (9500 – 4656) = 4844 Kg from wing tanks.

Figure 4.A Loading Manifest – MRJT 1

Max Permissible Aeroplane Mass Values:

TAXI MASS - 63 060 kg ZERO FUEL MASS - 51 300 kg

TAKE OFF MASS - 62 800 kg LANDING MASS - 54 900 kg

ITEM	MASS (KG.)	B.A. I.N	MOMENT KG-IN/1000	C.G. %MAC
D.O.M	34500	649.00	22390.5	
2. PAX Zone A	840.00	284.00	238.60	-
3. PAX Zone B	1512	386.00	583.60	-
4. PAX Zone C	2016	505.00	1018.1	-
5. PAX Zone D	2016	641.00	1292.3	-
6. PAX Zone E	2016	777.00	1566.4	-
7. PAX Zone F	1512	896.00	1354.8	-
8. PAX Zone G	1092	998.00	1089.8	-
9. CARGO HOLD 1	650.00	367.9	239.10	-
10. CARGO HOLD 4	2120	884.5	1875.1	-
11. ADDITIONAL ITEMS	NIL	N/A	NIL	-
ZERO FUEL MASS	48274	655.60	**31648.3**	**22.30**
12. FUEL TANKS 1 & 2	9084	650.70	5911	-
13. CENTRE TANK	4916	600.40	2951.6	-
TAXI MASS	62274	650.50	**40510.9**	**18.50**
LESS TAXI FUEL	- 260.00	600.40	- 156.10	-
TAKE OFF MASS	62014	650.70	**40354.8**	18.70
LESS FLIGHT FUEL	4844 4656 Total 9500	650.7 600.4	- 3152 - 2795.5	-
EST. LANDING MASS	52514	655.20	**34407.3**	22.53

Each of the structural limitations is checked against totals of:

MZFM – ZFM	+51 300 – 31 648.3 = 19 651.7	in limits
MSTM – TM	+63 060 – 62 274 = 786	in limits
MTOM –TOM	+62 800 – 62 014 = 786	in limits
MLM – Est LM	+54 900 – 52 514 = 2386	in limits

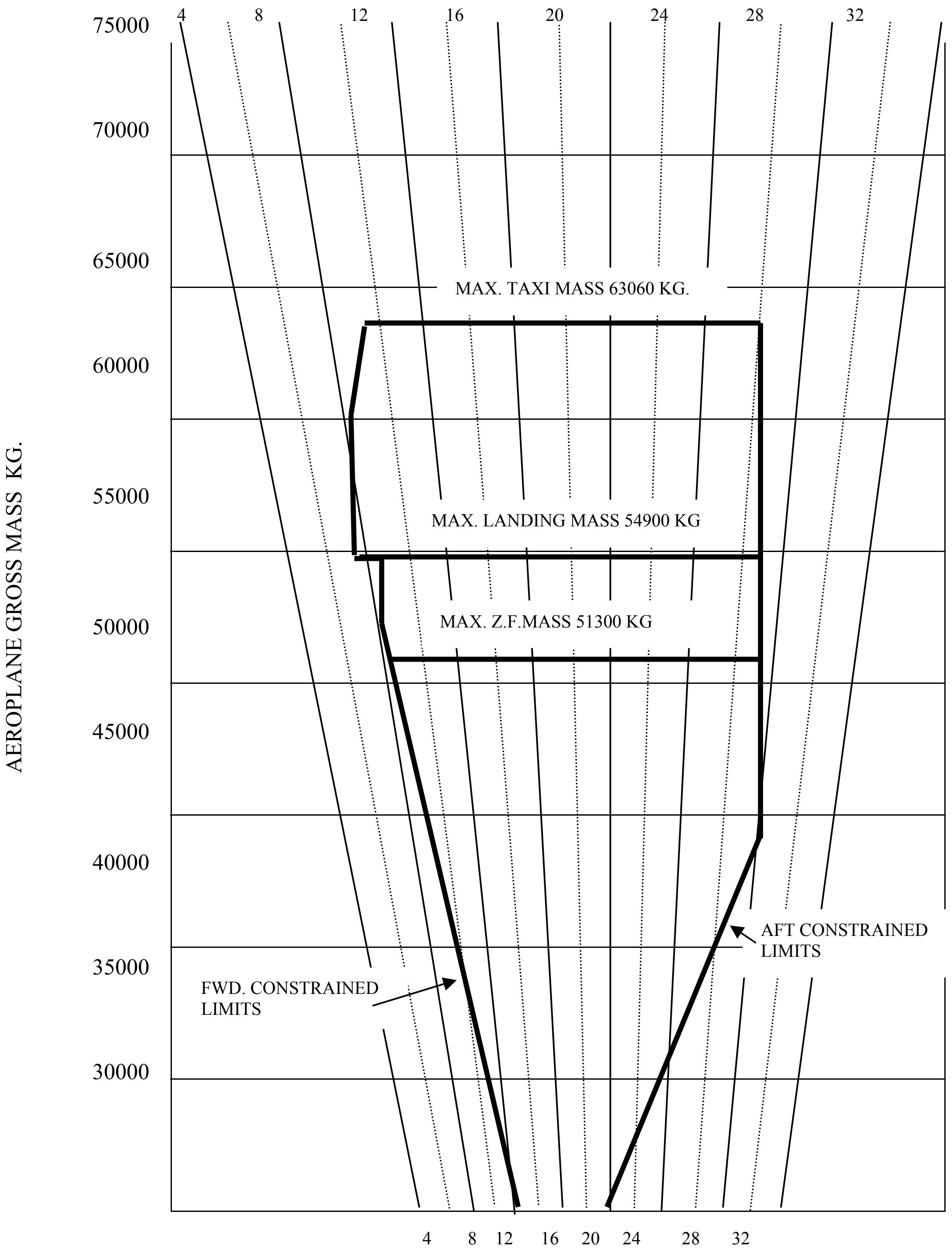
The CG location as a % MAC which has been calculated for each of these masses is plotted on the CG envelope.

When all are found to be in limits the aircraft is safe to fly. Plot the points on the following CG envelope Figure 4.B – is the aircraft in limits?

For the worked example above the limits are the maximums given in the data sheets. Care must be taken in reading the questions in case a performance or regulating limit applies

Figure 4.B

C.G. ENVELOPE (MRJT1)



CENTRE OF GRAVITY LIMITS % MAC

The Load and Trim Sheet

Load and trim sheets are a method of calculating an aircraft's mass and balance. They are used by operators of larger transport aeroplanes to:

- Speed up the process of Mass and Balance calculations
- Provide the flight crew with the essential information in 'an easy use' format
- Provide the necessary documentation as required by the Authorities.

The load sheet required by JAR-OPS, Subpart J includes the following mandatory information:

- Aeroplane registration and type
- Flight number
- PIC
- The identity of the loader
- The DOM and CG position
- Mass of take-off fuel and trip fuel
- Mass of consumables other than fuel
- Traffic load, passengers, baggage and freight
- TOM, LM and ZFM
- Load distribution
- Aeroplane CG positions
- Limiting mass and CG values

Typical of such documentation is the Load and Trim Sheet, an example of which appears in the CAP 696 as figure 4.14.

The procedure for using the Load and Trim Sheet in CAP 696 is given in paragraph 7.2, page 28, with a worked example on page 29 as figure 4.12.

From the example load and trim sheet, figure 4.12, the Load and Trim Sheet breaks down into two areas:

- Part A is the loading summary and is used to derive all the weights from DOM to LM
- Part B is the trim portion on which movements of CG may be derived for each weight from DOW to LW and includes elements for each portion of the load.

Part A is divided into 3 sections

Section 1 Use to establish the limiting TOM, maximum allowable traffic load and underload before any last minute changes.

The term "underload" means the amount by which the aircraft is below **the actual** take- off mass.

Section 2 Gives the distribution of the Traffic Load. Note the abbreviation codes.

TR	Transit
B	Baggage
C	Cargo
M	Mail
Pax	Passengers
Pax F	First Class passengers
Pax C	Club/Business Class passengers
Pax Y	Economy Class passengers

Section 3 Is a summary of the loading and is a cross check that limiting values are not exceeded.

The abbreviation used include:

DOI	Dry Operating Index
MLDGM	Maximum Landing Gross Mass

Note: For the following examples using the load and trim sheet in the CAP 696 and these notes the baggage is given a standard mass of **14 kg**; for the loading manifest data 13 kg is used.

Fuel Index Correction

Figure 4.13 is a correction table tabulating index movement against fuel mass.

Note: The comments below the table are important when attempting any questions

In the following pages illustrations of the load and trim sheets and a step by step approach on how to use them is given.

At first sight, it may appear to be a very complicated presentation. With practice, they do become “user friendly”.

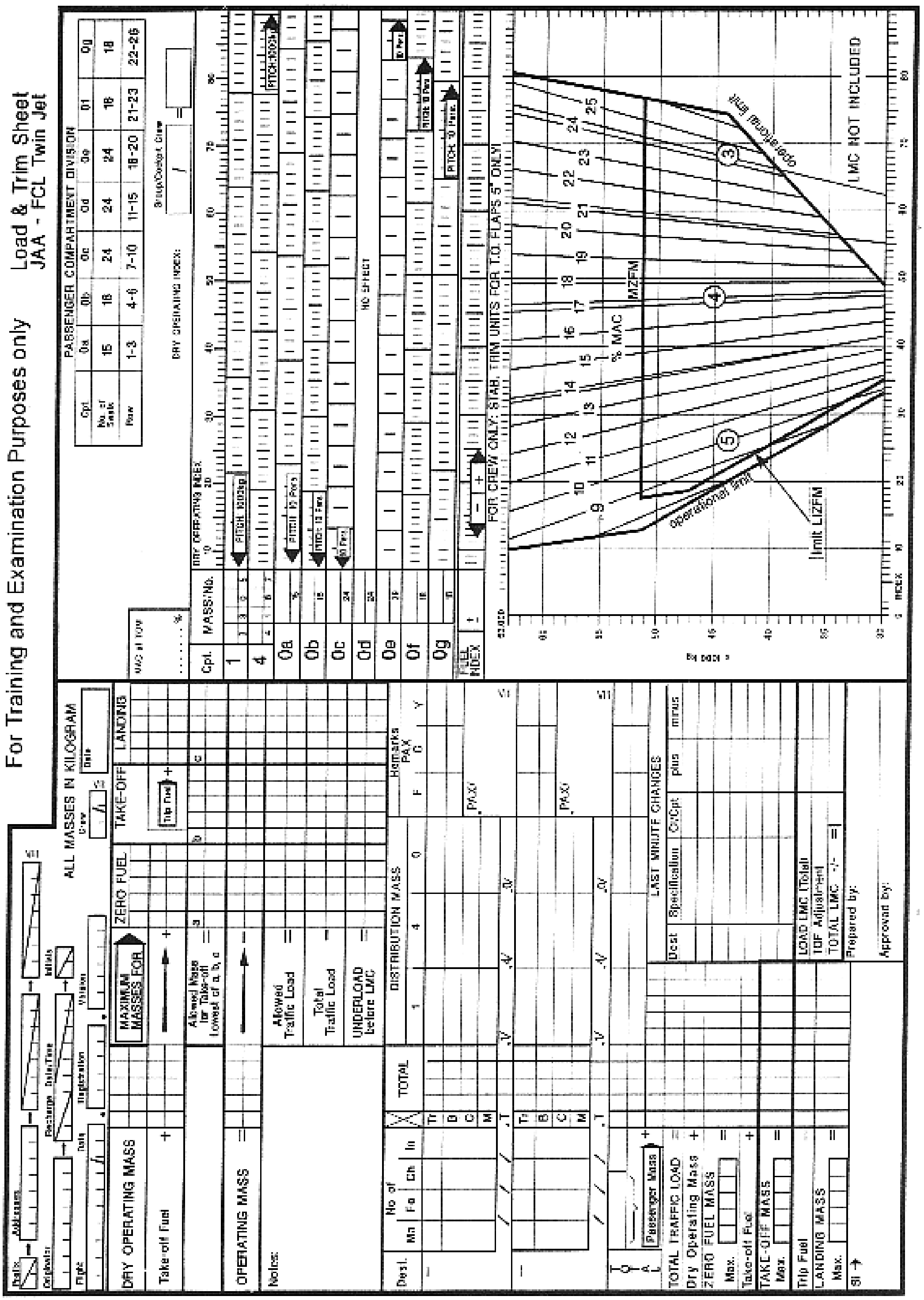
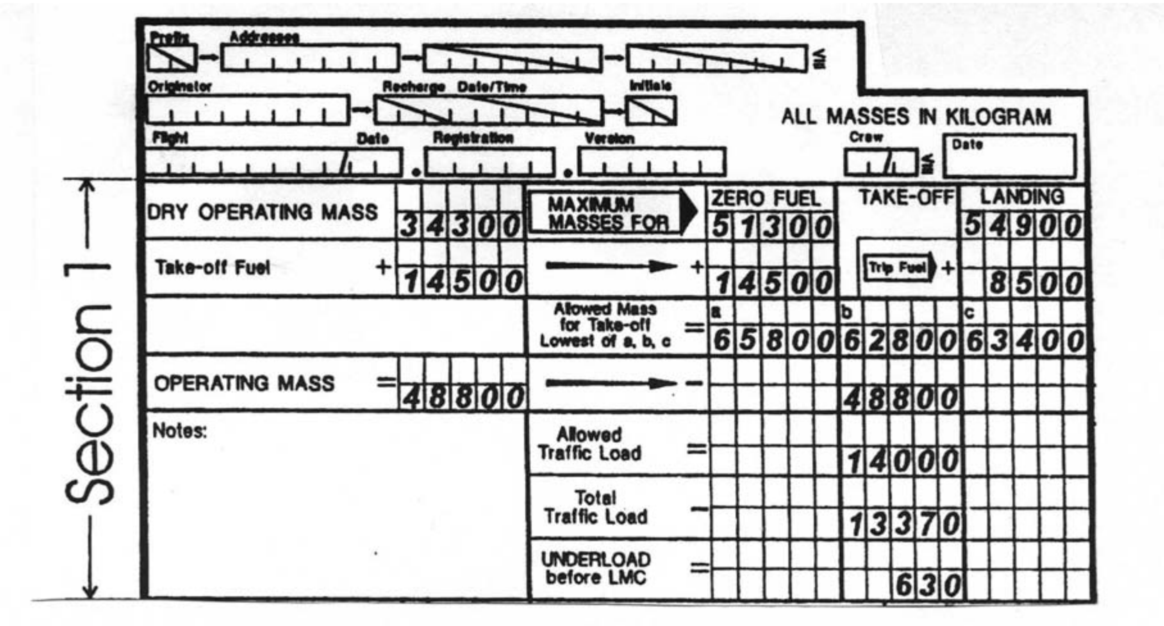


Figure 4.C Load and Trim Sheet

The Load Sheet

To complete the load sheet follow the instructions in-conjunction with the enlarged excerpts of Figure 4.12, CAP 696. We have divided the original diagram into the three sections for clarity and labelled them as figures 4D, 4E and 4F. Values used are those of figure 4.12.

Section 1 figure 4.D This section of the load sheet is divided into 4 columns, in the second column there are two arrows pointing to the right, these show where values from the first column are repeated in other columns. In this section there are + and – signs printed and the calculations run vertically downwards



1st column

1. Enter the DOM 34 300 kg

2. Below the DOM enter the Take Off Fuel 14 500 kg

3. Add the DOM and the TOF together to find the OM 48 800 kg enter this value against the operating mass

2nd column

4. Enter the MZFM 51 300 kg and carry across and enter the TOF 14 500 kg below it

5. Add the MZFM and TOF together 65 800 kg enter this in the next line down below the (a) against the heading Allowed Mass For Take-Off. The lowest of a, b, c

3rd column

6. Below the (b) in the row against Allowed Mass For Take-Off Lowest of a, b, c heading enter the lowest of either MTOM, PLTOM or RTOM. This has been given as 62 800 kg

4th column

7. Under the heading landings the lowest value of either MLM, PLLM or RLM is entered. This has been given as 54 900 kg. Below this is entered the trip fuel mass given as 8500 kg.

8. Add the landing mass to the trip fuel mass 63400 kg and enter this value below the (c) in the row against Allowed Mass For Take-Off Lowest of a, b, c

9. Select the lowest value in the row Allowed Mass For Take-Off, in this case it is (b) 62 800 kg and is referred to as MATOM - Maximum Allowed Take Off Mass.

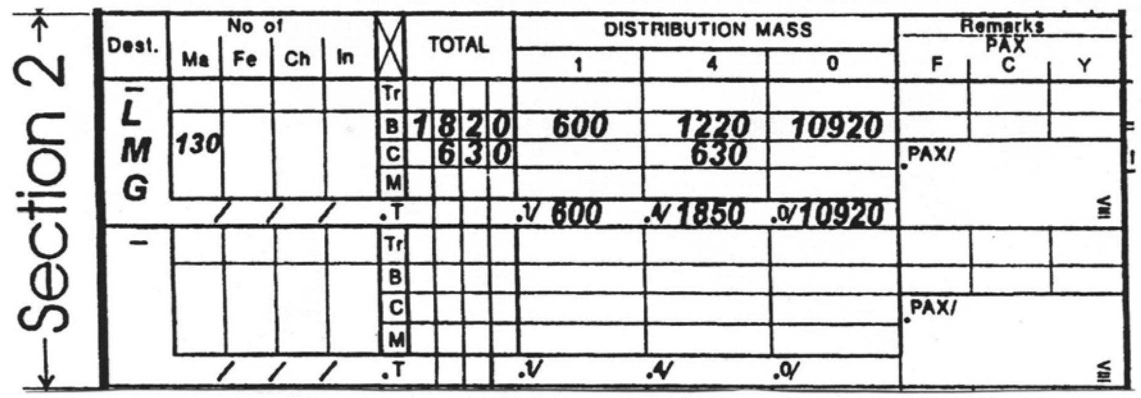
10. Use the following calculations to find the allowed traffic load, total traffic load and under load. These are carried out in the MATOM column, in this case b.

11. The OM 48 800 kg is carried across and entered in the column and subtracted from the MATOM 62 800 kg, the difference 14 000 kg is entered below against the Allowed Traffic load. This is maximum traffic mass for an aircraft of this DOM, TOF taking off from this departure airport and landing at the destination airport.

12. The actual traffic load 13 370 kg is entered in the next row down against the Total Traffic Load

13. The Total Traffic Load value 13 370 kg is subtracted from the Allowed Traffic Load Value 14000 kg. The 630 kg difference is the amount of under load, this mass could change if there are any Last Minute Changes such as passengers or freight being loaded or off loaded.

Section 2 figure 4.E The distribution of the traffic load is calculated in this section, note that the area is divided into three main columns



Dest.	No of Ma	Fe	Ch	In		TOTAL	DISTRIBUTION MASS 1	4	0	Remarks PAX F	C	Y
LMG	130				Tr							
					B	1820	600	1220	10920			
					C	630		630		PAX/		
					M							
	/	/	/		.T		.1/ 600	.4/ 1850	.0/ 10920			≤
–					Tr							
					B							
					C					PAX/		
					M							
	/	/	/		.T		.1/	.4/	.0/			≤

1st Column

14. In the first column the passenger details are given in seven sub-columns, the first is labelled Dest for destination. The three letter code for the destination airport is entered here in this case LMG.

    Across from Dest are four sub columns headed Ma, Fe, Ch and In; for Males, Females, Children and Infants The number of each is entered in the appropriate sub-column, in this case it is 130 under Ma.

    The sixth sub-column gives the code letters Tr, B, C and M as per page 28 of the CAP 696 against the appropriate code letter the mass is entered in the seventh sub-column. In this case 1820 kg for baggage and 630 kg for cargo.

2nd column

15. The second column is headed distribution of mass and divided into 3 sub-columns headed 1, 4 and 0. Sub-column 1 is the forward hold, sub-column 4 is the aft cargo hold and sub-column 0 is the passenger cabin.

    In this example the baggage 1820 kg has been divided between the two holds with 600 kg placed in the fwd hold and 1220 kg in the aft hold. The cargo of 630 kg is also placed in the rear hold. The passenger mass for cabin is entered as 10 920 kg.

    130 pax % 84 kg = 10920 kg.

Below code letter M in the first column is ∃**T** this is the total line for the rows above

∃1/ 600 kg, ∃ 4/ 1850 kg and ∃ 0/ 10 920 kg

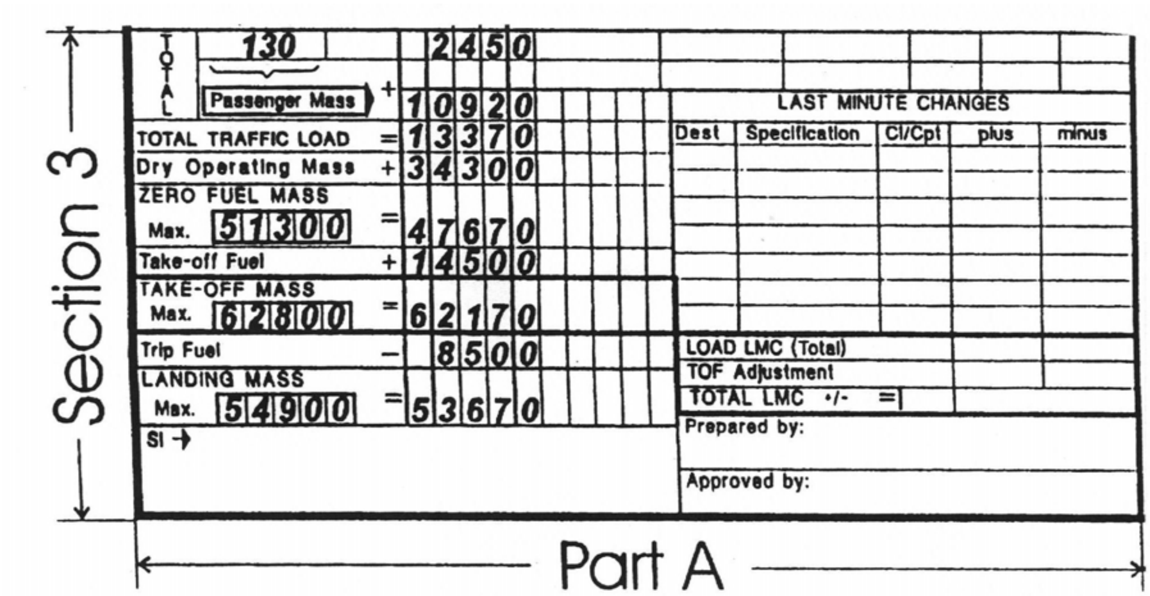
16. If any small mass other than pax is to be carried in the main cabin then it would be entered in the 0 sub-column, the pax load mass can be entered by gender and age to assist in checking the calculation.

3rd column

17. The third column headed remarks/pax, is divided into three sub-columns F, C, Y. These are the class codes as per page 28 of the CAP 696.

Section 3 figure 4.F This section is used to compare the mass totals with the limits to ensure that they are not exceeded. The section is divided into two main areas:

Left side	As loaded
Right side	Details any last minute changes and has the signature blocks.



18. In the first column the total number of passengers is entered - 130. To the right in the second column this is a total mass of the baggage and cargo etc from section 2. In this case 2450 kg.

19. Below this the passenger mass [10 920 kg] from section 2 is entered. These totals are added together to find the traffic load [2450 kg + 10 920 kg = 13 370 kg], this is entered on the next line down.

20. The aircraft's DOM 34 300 kg is entered on the next line down

21. The MZFM 51 300 kg is entered in the first column, then the Total Traffic Load and the DOM are added to find the aircraft's ZFM [13 370 kg + 34 300 kg = 47 670 kg] which is entered in the second column.

22. The Take-Off fuel mass 14 500 kg is entered below the ZFM in the second column and added to the ZFM [14 500 + 47 670 = 62 170 kg] to find the TOM 62 170 kg

23. The MATOM 62 800 kg is entered in the first column.

24. The trip fuel 8500 kg is entered in the second column and subtracted from the TOM to find the LM [62 170 kg – 8500 kg = 53 670 kg]. This is entered in the second column.

25. The Maximum allowed landing mass 54 900 kg is entered in the first column.

All the limitations entered in the 1st column of Section 3 are thosethat have been worked out in Section 1.

The masses for the Total Traffic Load are worked out from those masses entered in Section 2 and the Take off Fuel and Trip Fuel are those given in Section 1.

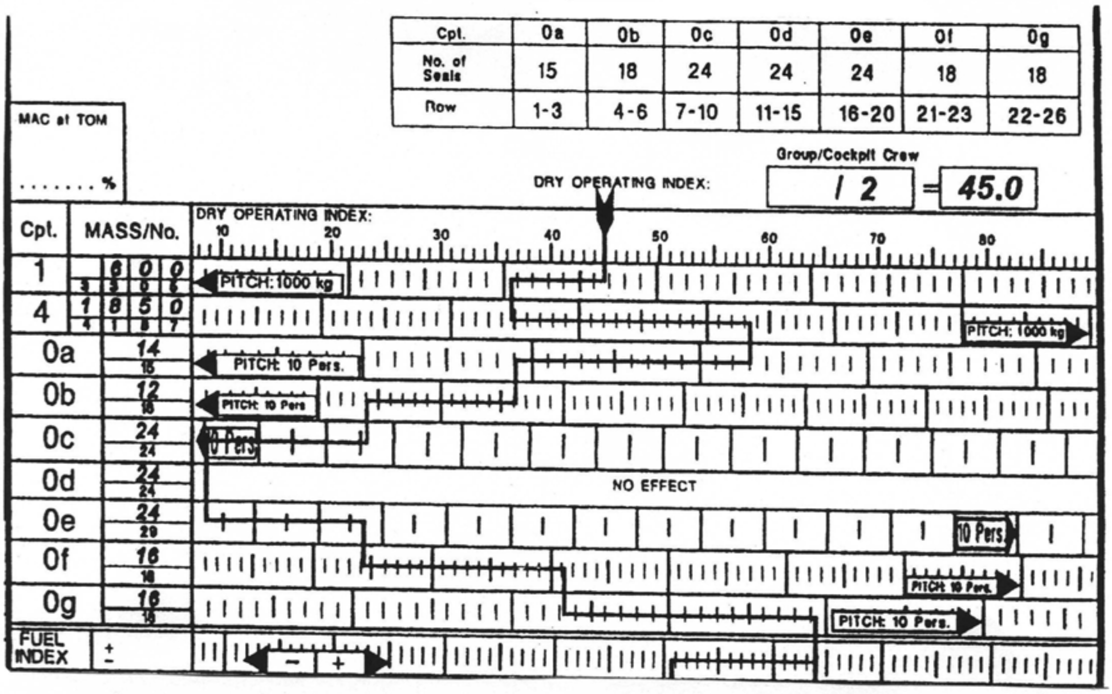
This allows the compiler and Commander to cross check the data.

Last Minute Changes Enter the total mass of LMC (LMC payload + change to TOF); then check to ensure that the figure does not exceed the allowable extra mass.

Trim Sheet The Trim sheet, figure 4.12 consists of two main areas:

The top half is effectively a series of horizontal scales above a CG envelope. The trim sheet uses moment index numbers to keep the figures used within manageable limits.

To demonstrate the method of using the trim sheet the CAP 696 example figure 4.12 has been divided into the two component parts and are shown here as figures 4.G and 4.H.



Before using the Trim Sheet a few details need to be highlighted.

The table at the top right of the page shows the break down of the passenger cabin into areas Oa, Ob etc. (refer to figure 4.7 of the CAP 696 for a pictorial view of the aircraft). Under each area is the maximum number of seats and the number of rows. For Oa there are 15 seats in rows 1 to 3.

Below the passenger compartment table is a box titled Group/Cockpit Crew. The group code or number of flight crew is entered into this box and the DOI is entered into the second box.

Note: "Group" refers to the operator's configurations and is unlikely to be used in examination

You will be given a DOI value if required by the question

To the left is a box titled MAC at TOM, this % will be found when the trim sheet is completed.

Below the MAC at TOM box are two columns titled Cpt and MASS/No respectively. Cpt is an abbreviation for Compartment.

In the first column Cpt each row indicates a compartment centroid arm, 1 being the fwd hold, 4 being the aft hold and then progressing rearwards through the cabin.

In the second column each row is sub-divided horizontally the lower portion has the limiting mass or limiting number for the compartment, as shown below in figure 4.G.1 for compartment Oa.

Oa	
	15

Figure 4.G.1

To the right of these columns are the main scales for Cpt1 to Og. Each scale varies from line to line. This reflects the effect that a given mass has in each compartment.

> **Note:** That compartment Od has no effect on the CG (refer to paragraph 5.2 on page 23 CAP 696)

In each row there is an arrow denoting the direction in which the CG moves as mass is added. The pitch scale is printed in the body of the arrow, for Cpts 1+ 2 it is in kilograms, for Cpts Oa to Og it is the number of passengers.

Example

1. Enter all the known details from the load sheet for Cpt 1 + 2. 600 and 1850

2. Enter the number of passengers per compartment for Oa to Og given as:

Oa	14
Ob	12
Oc	24
Od	24
Oe	24
Of	16
Og	16

3. Check to ensure that mass and pax limits are not exceeded, and that the total number of pax agrees with the number given in section 2 of the load sheet. For the worked example 130.

4. Enter the number of cockpit crew in the box marked Group/Cockpit Crew. For the example the crew is given as 2.

5. In the box to the right enter the Dry Operating Index DOI. In this case the Index is given as 45.0 as per the data sheet page 28.

6. In the top scale titled Dry Operating Index find the DOI and mark it. In this case it is 45.0.

7. Drop a vertical line from the mark 45.0 DOI into the centre of the horizontal scale below Cpt 1.

8. In this scale the arrow is pointing left and the pitch is given as 1000 kg per large division therefore each small division is equal to 100 kg. The cargo mass of 600 kg is equal to a horizontal movement to the left of six small divisions.

9. Where the vertical line dropped from a previous scale does not directly match the scale line, the compiler must measure from the point of entry the exact distance to be moved. As can be seen from the line in figure 4.G on completing the measurement a vertical line is dropped into the centre of the next row.

10. The operator continues the sequence and where the mass or number of pax differ from the given scale the operator has to interpolate to find the exact distance to move horizontally.

11. On completing the compartments the aircraft's ZFM CG can be found by dropping a vertical through the fuel index row into the CG envelope. See figure 4.H below.

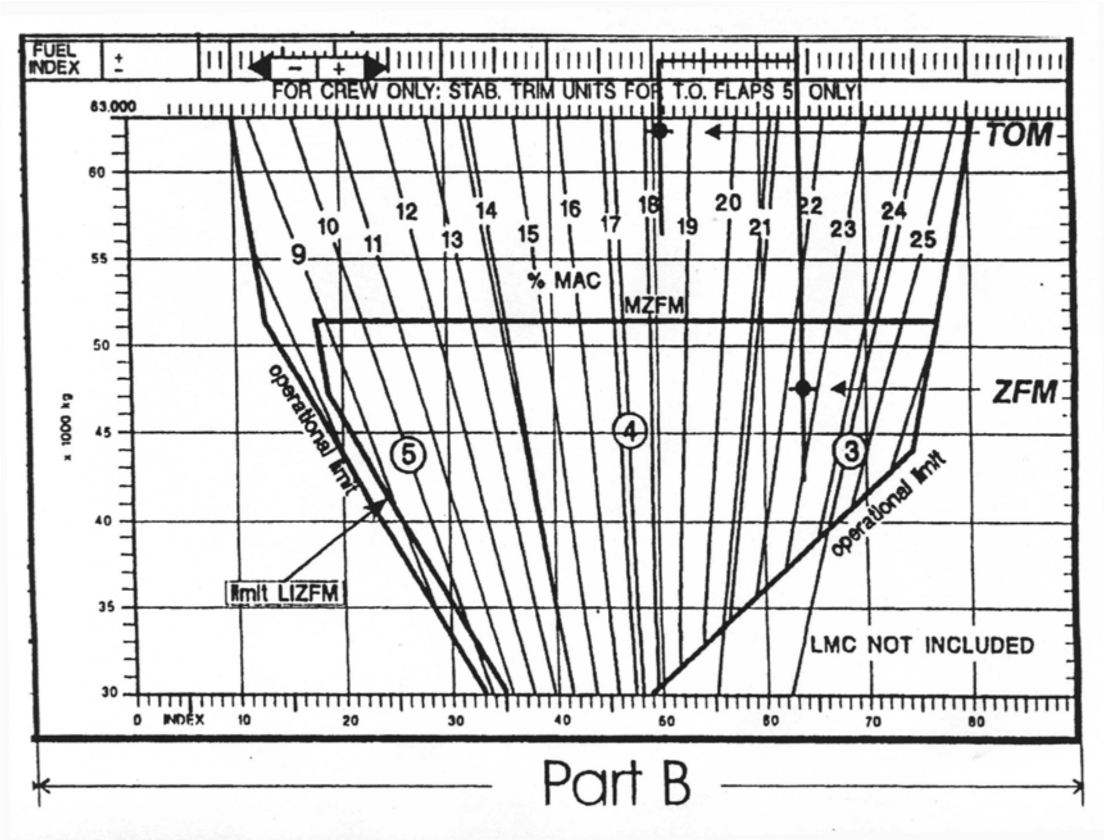


Figure 4.H CG envelope of Trim Sheet

12. Take the ZFM from the load sheet in this case 47 670 kg and find this point on the vertical scale at the side of the envelope. Draw a horizontal line from this point through the vertical index line, The ZFM CG is located where these lines intersect and can be read off as a % MAC from the envelope's scale.

13. Check that this intersection is within the LIZFM limits. (Load Index ZFM) and the MZFM limit

Note: For this aircraft the Fwd limit for the ZFM is less than the operational limits (front and rear limit of the safe range)

14. To add the fuel and account for its effect the compiler has to refer to the Fuel Index Correction Table figure 4.13 on page 30 of the CAP 696. In the worked example the take off fuel load is 14 500 kg as this cannot be found directly the compiler reads the next higher mass 14580 kg giving an index of – 12.9.

15. The fuel index row has a double arrow to the left for negative index units and to the right for positive index units. The scale has a pitch of 10 units per large division.

16. To find the take off index the fuel index units are added or subtracted from the ZFM index. In the case of the worked example the units are negative, therefore a horizontal line is drawn for 12.9 divisions to the left. A vertical line is dropped into the CG envelope where a horizontal line for the TOM is draw to intersect the vertical this shows the TOM CG.

17. Check that the TOM CG is within the operational limits

If a line is drawn connecting the centres of gravity for the TOM and ZFM conditions the CG should move progressively down this line as the usable fuel is consumed.

To find the Landing Mass CG take the trip fuel mass from the Take-Off fuel mass to find the fuel remaining in the aircraft's tanks on landing.

In this case 6000 kg [14 500 kg - 8500 kg = 6000 kg] and convert it into an index unit value using the table figure 4.13 on page 30.

For 6000 kg this is – 6, this is plotted in the fuel index scale from the ZFM vertical line, then a vertical line is dropped into the CG envelope. The Landing Mass CG is located were the vertical line bisects a horizontal line plotted for the Landing Mass 54 900 kg. This should also bisect the line joining the TOM and ZFM.

Note: The CG locations in the envelope do not include any LMCs.

Other uses for the trim sheet are:

- Finding the index number for an aircraft at a given CG condition.
- Finding the exact CG as a % MAC.
- Finding the OM CG location.
- Adjusting the CG's location.

Finding the Index Number for an Aircraft at a Given CG Condition

To find the index number for any CG location drop a vertical line from the CG's position in the envelope to the index scale below it and read of the value.

Finding the Index Number for an Aircraft at a Given CG Condition

Where the CG falls between two given values of MAC, in the case of the worked example between 18 and 19 % MAC for the TOM. Measure the distance between these two lines level with the CG's location, and the distance between the CG and line before it [18 % MAC in this case] work the fraction into a decimal eg 2/6mm = 33%. The CG is therefor located at 18.33 % MAC (obviously the larger the actual size of the envelope the more accurate the reading). You are not likely to have to be this accurate.

Finding the OM CG Location

If the operating mass CG is to be found, enter the DOI at the DOI scale, then drop a vertical line down into the fuel index scale. Add or subtract the fuel index value to move horizontally then drop a vertical into the envelope, bisect this with a horizontal for the OM.

Adjusting the CG's Location

If there is a need to relocate the CG from its current position to a new location, the trim sheet can be used to work out the amount of cargo, baggage or passengers that is required to be moved or off loaded, etc. The great advantage of the trim sheet is that the effect can be seen. It is easier to see the workings for removal or addition before looking at load shifting.

The method used is: Draw a vertical from the current CG position to the bottom of the DOI scale, draw another vertical line from the intended CG location again to the bottom of the DOI scale

> **Note:** Do not fall into the trap of aligning your rule with the % MAC lines as these diverge. Use the grid lines.

Read off the difference between the lines at each scale. Note the direction in which the arrow points. This will indicate the amount that must either be removed from the aircraft or added to the aircraft for that compartment to alter the CG's location

Using the worked example, if we wanted to relocate the CG from its current position to a new location of 18 % MAC. After drawing the two vertical lines it can be seen that we would have to:

- Add 100 kg to the fwd hold
- Add a 100 kg to the aft hold.
- Add 1 Pax to Cpt Oa
- Add 1 Pax to Cpt Ob
- Add 1 Pax to Cpt Oc
- Alterations in Cpt Od have no effect
- Remove 1 Pax from Cpt Oe
- Remove 1.5 Pax from Cpt Of
- Remove 1 Pax from Cpt Og

Any single alteration from the above list will cause the CG to relocate to 18 % MAC.

Where removing or adding is not practicable or commercially desirable the load would have to be relocated. To determine how much load is to be shifted (and to which location it is to be shifted) in order to effect a change of trim.

> **Note:** Additions and subtractions will alter the Gross Mass for all the load conditions.

Method:

- Note the direction in which the CG is to move, if this is fwd, then the mass to be relocated will be taken from the rear hold and placed in the fwd hold and vice versa.
- As before draw verticals from the two points in the envelope up through hold 4 and hold 1 scales. – Note the weight differences given on each scale.
- Find the average of these differences and then divide this figure in half.
- This is the amount that has to be removed from one hold and relocated in the other hold thus giving the overall effect.
- Where the mass is to be relocated from the rear hold to the fwd hold. From the vertical line raised from the current CG location into Cpt 4, count to the left the amount to be removed from this hold then raise a vertical Line into the fwd hold [Cpt 1]
- From this line count to the left the new mass to be located in this hold [original + relocated] then drop a vertical into Cpt 4.
- From this vertical count to the right the new mass to be located in the rear hold [original – relocated] the last unit of this should coincide with the vertical raised from the new CG position.
- For cargo baggage relocations in the opposite direction start at Cpt 1 and continue.

This system can be used for passenger relocation

Note : The relocation of masses will not alter the gross mass but will alter all the CG locations

Solving a Scale Space Problem

Where a load for a compartment is within the limiting values of the compartment but there is insufficient space on the row the horizontal line would exit the scale. For example:

- DOI was 40.0
- 3000 kg for Cpt 1
- 4000 kg for Cpt 4

1. Enter the DOI drop a vertical into Cpt 4 and add the scale component for the 4000 kg, then raise a vertical into Cpt 1.
2. Add the scale component for Cpt 1 to this vertical, then drop the following vertical into Cpt Oa.
3. This can be done for any of the loads provided they are within the Compartment's limits.

Other Methods of Deriving the CG's Location

There are several further methods of working out an aircraft's CG, the methods these use do not have to be learnt. You must be aware of their existence.

Computer generated load and trim sheets All data is entered and the computer calculates and prints the load and trim sheet.

Slide rules There are dedicated slide rules for finding the CG and GM for various conditions and calculating the effect of load transfer, fuel consumption etc and are either rotary or linear.

Practice Questions Based on the MRJT 1 Data Sheet

Using the loading manifest and CG envelope in the data sheet answer the following five questions for an aircraft loaded as detailed below.

Aircraft MRJT	DOM	33000 kg	CG @ Stn 650
Crew	standard		
Pay load	Pax	141	
	Baggage	282 item at standard allowance loaded equally between holds	
Fuel load	Wing tanks	full	
	Centre tank	600 kg	
	Start fuel	600 kg	
	Trip fuel	6000 kg	
Flap settings	Take- off 15^{o}		
	Landing 40^{o}		

1. What is the BEM and CG for this aircraft?
   a. 32 580 kg @ 21.56% MAC
   b. 32 580 kg @ 21.33% MAC
   c. 32 550 kg @ 21.56% MAC
   d. 32 550 kg @ 21.33% MAC

2. What is the total payload for the aircraft?
   a. 15 510 kg
   b. 13 677 kg
   c. 11 844 kg
   d. 3666 kg

3. What is the aircraft's CG when it lands?
   a. 16.88 % MAC
   b. 16.68% MAC
   c. 16.55% MAC
   d. 16.51% MAC

4. What is the stabilator trim required for take-off
   a. 3.75
   b. 3.5
   c. 3.25
   d. 3.0

5. If there are no performance limitations for the flight, what is the underload.
   a. 29800 kg
   b. 5489 kg
   c. 5149 kg
   d. 3306 kg

For the following two questions use the Load and Trim sheet for the aircraft as detailed below.

The aircraft has a DOM of 36 588 kg and a DOI of 50.0, it will make a flight to a destination XYZ where it is regulated to a landing mass of 50 900 kg. The trip fuel is 1950 kg but for contingency, reserve and return fuel the aircraft must land with 3000 kg of fuel remaining.

6. What is the allowed traffic load for this flight?
   a. 7012 kg
   b. 7412 kg
   c. 7400 kg
   d. 7000 kg

7. What is the aircraft's OM and CG
   a. 15% MAC @ 39 588 kg
   b. 15.25% MAC @ 39 588 kg
   c. 15.5% Mac @ 41 538 kg
   d. 15.75% MAC @ 41 538 kg

8. An aircraft has a DOM of 34000 kg and DOI of 43.0 is to take a pay load of 60 adult male pax each with 13 kg of baggage, and a cargo of 600kg.

The aircraft is performance limited to a MTOM of 57000 kg and due to regulations at the destination must land with 2000 kg of fuel remaining, the trip fuel is 7000 kg.

The aircraft is loaded as follows:

Baggage in Fwd hold

Cargo in Aft hold

12 Pax in Cpt Ob

24 Pax in Cpt Oc

24 Pax in Cpt Od

From the following choose the correct statements

i.	the underload is	7580 kg
ii.	the traffic load is	14000 kg
iii.	the ZFM is	40420 kg
iv.	the baggage mass is	780 kg
v.	the Pax mass is	5060 kg
vi.	the ZFM CG is	in limits
vii.	the fuel index is	– 0.1

a. i, iii, iv, vii.

b. i, ii, iv, v.

c. ii, v, vi, vii.

d. Iii, iv, v, viii.

9. For an aircraft loaded as follows

Aircraft	DOM	34000 kg	DOI	43.0
Payload				
Pax @ 84 kg	Cpt Ob	12		
	Cpt Oc	24		
	Cpt Od	24		
Baggage @ 13 kg	Cpt 1	60 items		
Cargo	Cpt 4	600 kg		
Fuel	Bulk	10000 kg		
	Start	1000 kg		
	Trip	7000 kg		

Calculate the ZFM CG as loaded, if the CG is out of limits relocate the Pax in Cpt Od to Cpt Oe. Give the answer to the nearest % MAC

a. 11%
b. 12%
c. 13%
d. 14%

b. For an aircraft that has a DOM of 33 470 kg and a DOI of 47.5 which is to make a flight where the only restrictions are those that are structural limitations.

The crewing is standard

The payload is the difference MZFM and DOM

Choose the correct statements for this flight.

i. Payload 17830 kg
ii. Take off fuel equivalent to a fuel index of – 5.7
iii. Take off fuel equivalent to a fuel index of – 6.3
iv. Useful load for this flight is 29330 kg
v. Useful load for this flight is 29780 kg
vi. Mass of fuel in the centre tank at take-off is 2410 kg
vii. Mass of fuel in the centre tank at take-off is 2416kg
viii. Mass of fuel available for start, run up and taxi is 260 kg
ix. Take –off fuel in US gallons is 349001

a. ii, iii, vi, vii, ix.
b. i, ii, v, vii, viii.
c. i, iv, vi, vii, viii.
d. ii, iv, vi, vii, ix.

For questions 1-5

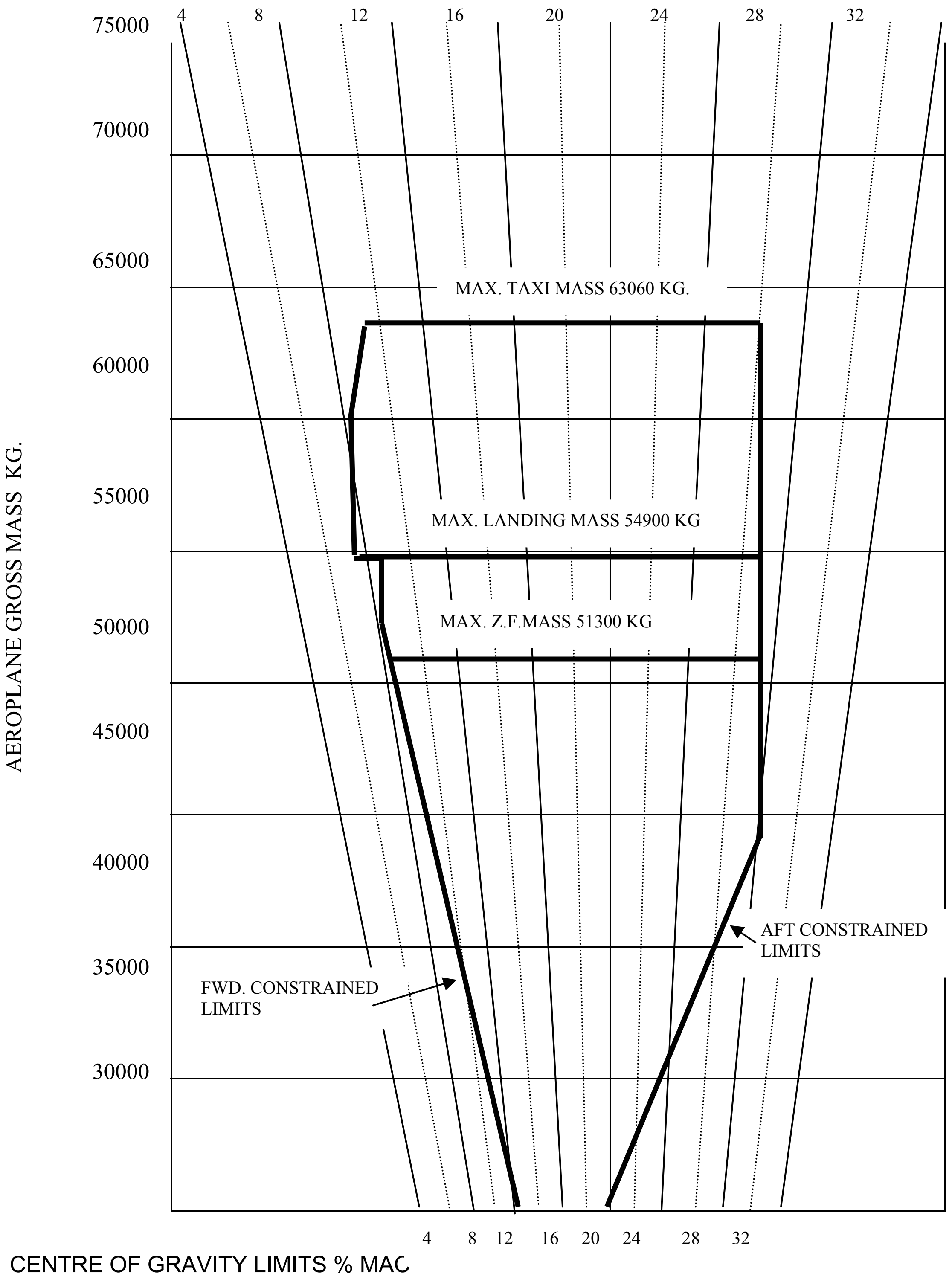
Max Permissible Aeroplane Mass Values: -

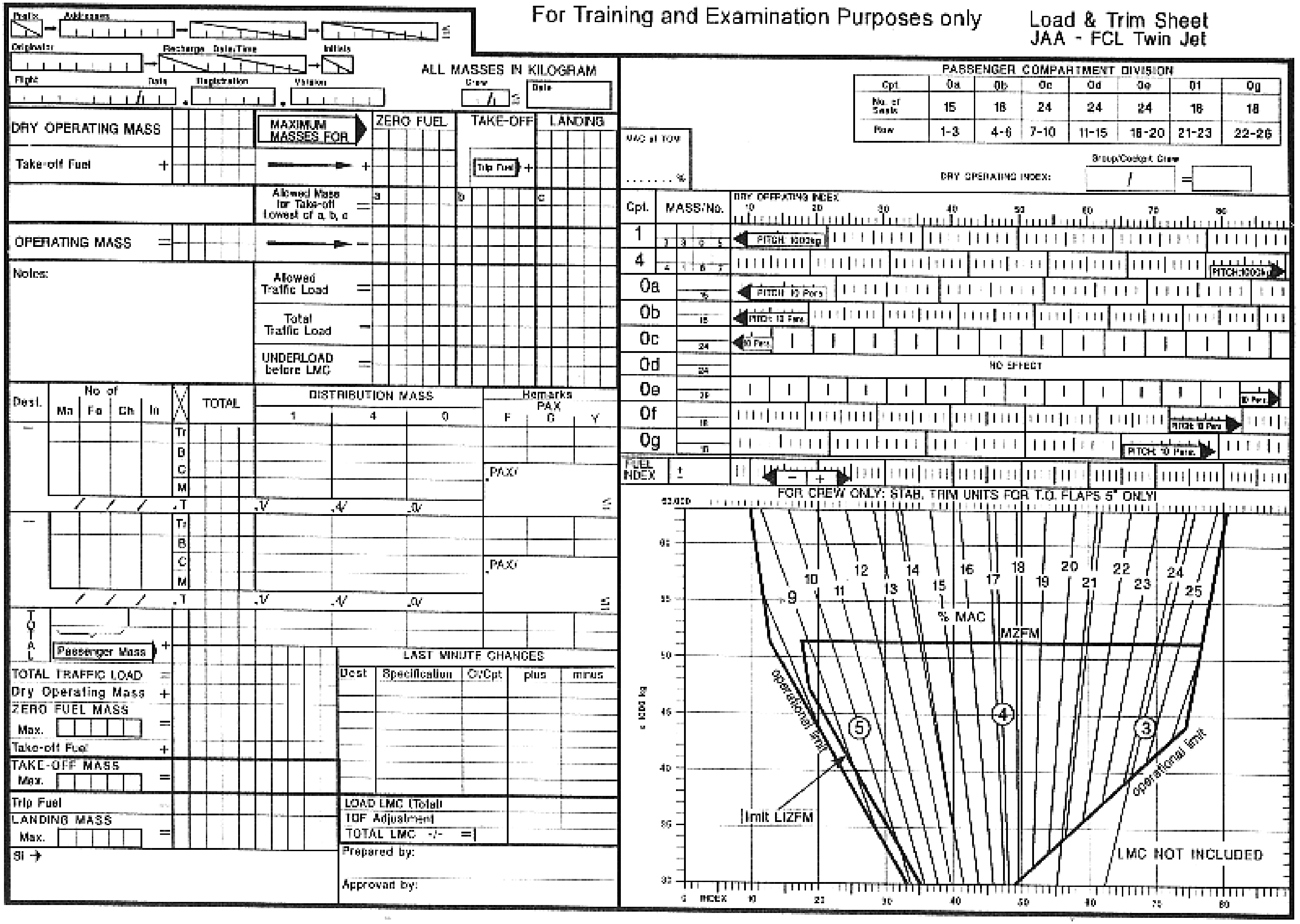
TAXI MASS - ZERO FUEL MASS -

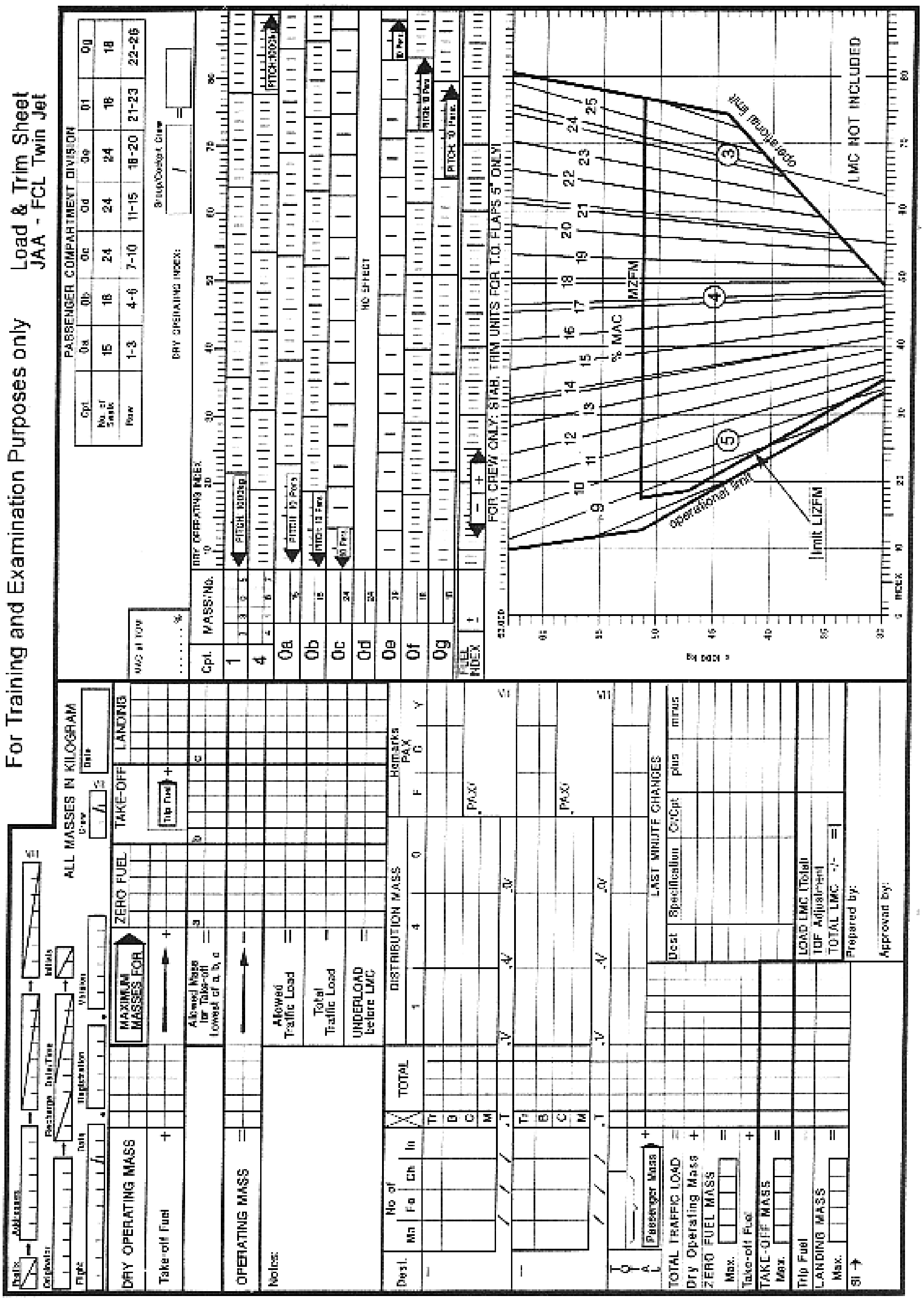
TAKE OFF MASS - LANDING MASS -

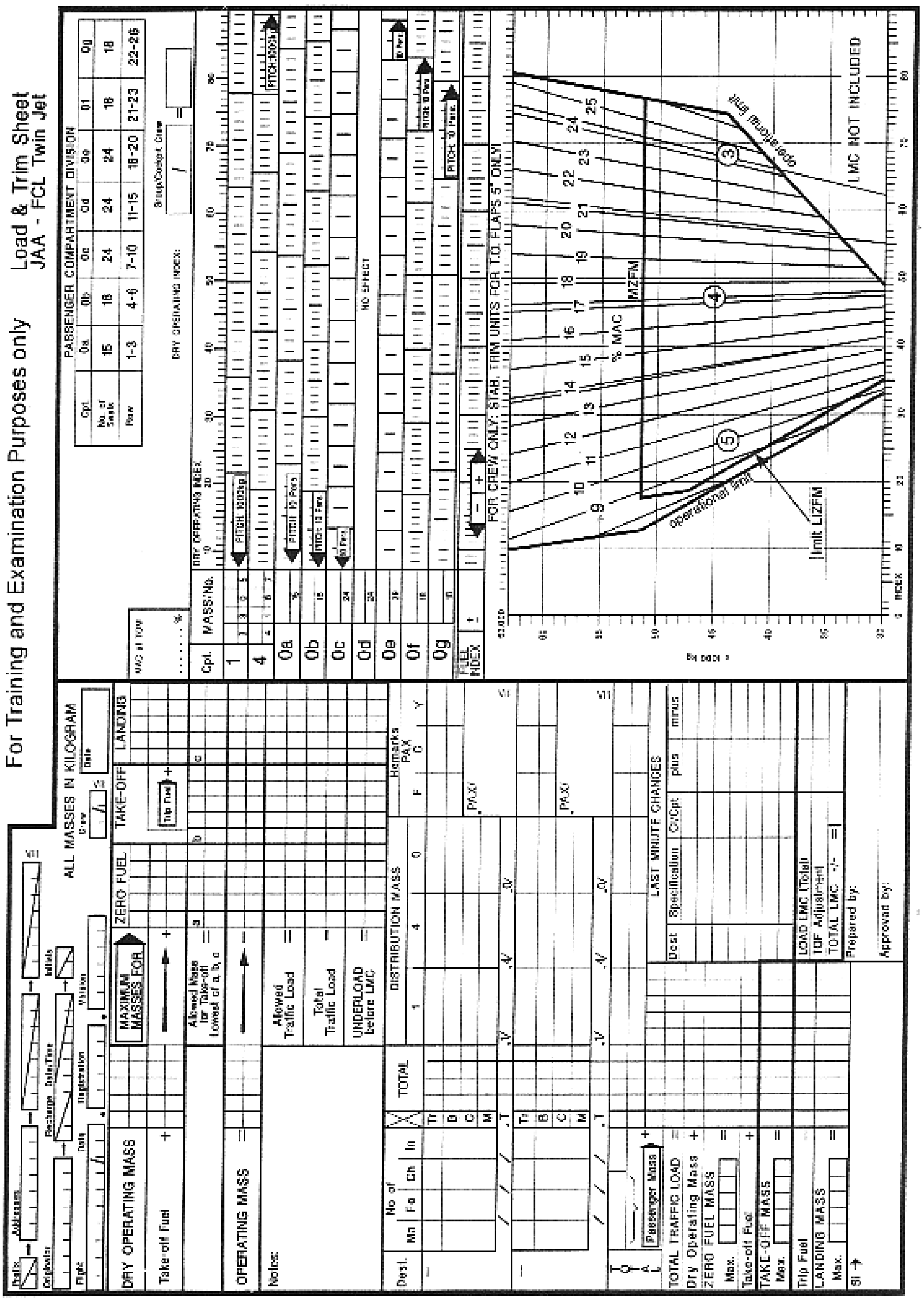
ITEM	**MASS** (KG.)	**B.A. I.N**	**MOMENT KG-IN/1000**	**C.G. %MAC**
D.O.M				
2. PAX Zone A		284.00		-
3. PAX Zone B		386.00		-
4. PAX Zone C		505.00		-
5. PAX Zone D		641.00		-
6. PAX Zone E		777.00		-
7. PAX Zone F		896.00		-
8. PAX Zone G		998.00		-
9. CARGO HOLD 1		367.9		-
10. CARGO HOLD 4		884.5		-
11. ADDITIONAL ITEMS				-
ZERO FUEL MASS				
12. FUEL TANKS 1 & 2				
13. CENTRE TANK				
TAXI MASS				
LESS TAXI FUEL				
TAKE OFF MASS				
LESS FLIGHT FUEL				
EST. LANDING MASS				

C.G. ENVELOPE (MRJT1)




For Training and Examination Purposes only
Load & Trim Sheet
JAA - FCL Twin Jet
ALL MASSES IN KILOGRAM
DRY OPERATING MASS
Take-off Fuel
MAXIMUM MASSES FOR
ZERO FUEL
TAKE-OFF
LANDING
Trip Fuel
Allowed Mass for Take-off Lowest of a, b, c
OPERATING MASS
Notes:
Allowed Traffic Load
Total Traffic Load
UNDERLOAD before LMC
Dest.
No of
Ma
Fe
Ch
In
TOTAL
DISTRIBUTION MASS
Remarks
PAX
PAX/
Passenger Mass
TOTAL TRAFFIC LOAD
Dry Operating Mass
ZERO FUEL MASS
Max.
Take-off Fuel
TAKE-OFF MASS
Trip Fuel
LANDING MASS
SI
LAST MINUTE CHANGES
Dest
Specification
Cl/Cpt
plus
minus
LOAD LMC (Total)
TOF Adjustment
TOTAL LMC
Prepared by:
Approved by:
PASSENGER COMPARTMENT DIVISION
Cpt
0a
0b
0c
0d
0e
0f
0g
No. of Seats
15
18
24
24
24
18
18
Row
1-3
4-6
7-10
11-15
16-20
21-23
22-26
DRY OPERATING INDEX:
Cpt.
MASS/No.
DRY OPERATING INDEX
PITCH: 1000kg
PITCH: 10 Pers
NO EFFECT
FUEL INDEX
FOR CREW ONLY: STAB. TRIM UNITS FOR T.O. FLAPS 5° ONLY!
% MAC
MZFM
operational limit
limit LIZFM
LMC NOT INCLUDED
INDEX


For Training and Examination Purposes only
Load & Trim Sheet
JAA - FCL Twin Jet
ALL MASSES IN KILOGRAM
PASSENGER COMPARTMENT DIVISION
DRY OPERATING MASS
Take-off Fuel
OPERATING MASS
Notes:
MAXIMUM MASSES FOR
ZERO FUEL
TAKE-OFF
LANDING
Allowed Mass for Take-off lowest of a, b, c
Allowed Traffic Load
Total Traffic Load
UNDERLOAD before LMC
DISTRIBUTION MASS
LAST MINUTE CHANGES
TOTAL TRAFFIC LOAD
Dry Operating Mass
ZERO FUEL MASS
TAKE-OFF MASS
Trip Fuel
LANDING MASS
LOAD LMC (Total)
TOF Adjustment
TOTAL LMC +/-
Prepared by:
Approved by:
DRY OPERATING INDEX
FOR CREW ONLY: STAB. TRIM UNITS FOR T.O. FLAPS 5° ONLY!
operational limit
limit LIZFM
MZFM
% MAC
LMC NOT INCLUDED



For Training and Examination Purposes only

Load & Trim Sheet
JAA - FCL Twin Jet

ALL MASSES IN KILOGRAM

DRY OPERATING MASS

Take-off Fuel

OPERATING MASS

Notes:

MAXIMUM MASSES FOR

ZERO FUEL | TAKE-OFF | LANDING

Allowed Mass for Take-off (lowest of a, b, c)

Allowed Traffic Load

Total Traffic Load

UNDERLOAD before LMC

DISTRIBUTION MASS

TOTAL

Remarks PAX

LAST MINUTE CHANGES

Dest | Specification | Cl/Cpt | plus | minus

TOTAL TRAFFIC LOAD

Dry Operating Mass

ZERO FUEL MASS

Max.

Take-off Fuel

TAKE-OFF MASS

Max.

Trip Fuel

LANDING MASS

Max.

LOAD LMC (Total)

TOF Adjustment

TOTAL LMC

Prepared by:

Approved by:

PASSENGER COMPARTMENT DIVISION

Cpt	0a	0b	0c	0d	0e	0f	0g
No. of Seats	15	18	24	24	24	18	18
Row	1-3	4-6	7-10	11-15	16-20	21-23	22-26

DRY OPERATING INDEX

Cpt. | MASS/No.

1, 4, 0a, 0b, 0c, 0d, 0e, 0f, 0g, FUEL INDEX

FOR CREW ONLY: STAB. TRIM UNITS FOR T.O. FLAPS 5° ONLY

% MAC

MZFM

operational limit

limit LIZFM

LMC NOT INCLUDED

INDEX

Answers to Practice Questions

1. B
2. C
3. B
4. C
5. D
6. B
7. D
8. A
9. B
10. B

Intentionally Left Blank