DOCUMENT
GSM-G-CPL.026

DOCUMENT TITLE

NAVIGATION 1

CHAPTER 7 – NAVIGATION COMPUTER (CALCULATOR SIDE)

Version 2.0
October 2017

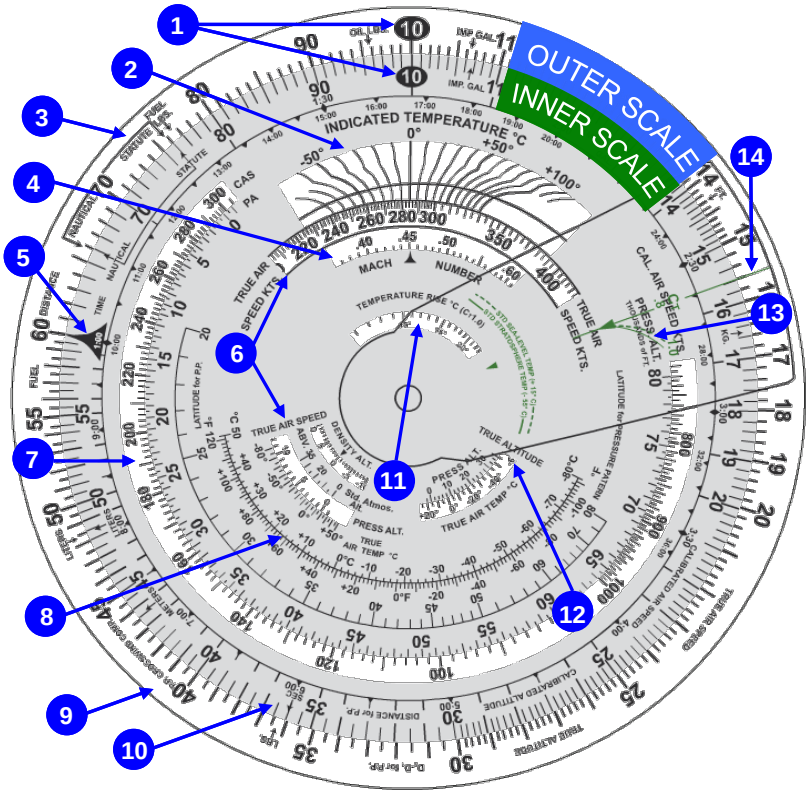
CONTENTS

NAVIGATION COMPUTER (CALCULATOR SIDE)

7.1 Circular Slide Rule

Navigation requires the solution of simple arithmetic calculations for time, speed, distance, etc. Various computers have been designed for this purpose; the Jeppesen CR-3 is the computer of choice for this chapter. The instruction manual can be downloaded from:

http://www.jeppesen.com/download/misc/crinstructions.pdf



1	Unit Index	**8**	Temperature Conversion Scale
2	Indicated Temperature Window	**9**	Base Disc (Outer Scale)
3	Nautical / Statute Conversion Arrows	**10**	Top Disc (Inner Scale)
4	Mach Number Window	**11**	Temperature Rise Scale
5	Time Index	**12**	True Altitude Window
6	True Airspeed Windows	**13**	Recovery Factor/Coefficient 1.0
7	Calibrated Airspeed Window	**14**	Index Cursor Hairline

7.1.1 Uses

Values may be expressed using a variety of units. The relationship between units of measurement is a fixed ratio and the CR3 circular slide rule provides a convenient method for conversion.

The CR-3 computer allows for the following calculations:

- Basic arithmetic
- Quantity, time and rate type calculations
- Unit conversions
- Airspeed corrections.

7.1.2 Logarithmic Scale

The slide rule side has two discs/scales, an inner and outer disc/scale, each graduated with adjacent logarithmic scales to present a circular slide rule. Logarithmic scale is the displacement between numbers that are not constant.

The numbers presented on either scale of the computer are the values as printed or the power of 10. Do a mental calculation to estimate the magnitude of the answer before reading the answer from the computer:

For example, 11 x 13 = _____

Simplify the values to determine the magnitude, 10 x 13 = 130. The magnitude of the answer is therefore in the hundreds and the computer's value will be in the same magnitude, i.e. 143 and not 14.3 or 1430.

Slide-rule type calculators do not give the magnitude of an answer and provide an answer to **three significant digits.**

Example	12 can represent its face value 12, or 1.2 (12×10^{-1}), or 120 (12×10^{1}), or 1,200 (12×10^{2}) etc.

It is up to the user to determine the magnitude of the answer.

7.2 Basic Arithmetic

Four basic arithmetic techniques are discussed:

- Multiplication
- Division
- Percentage
- Proportion.

These methods serve as an introduction and will assist the user to understand the logarithmic scale, interpolation and correctly interpreting the magnitude of an answer.

7.2.1 Multiplication

Multiplication is performed by using the unit index and setting values on the inner and outer scale.

Example: Multiply 11 by 13.

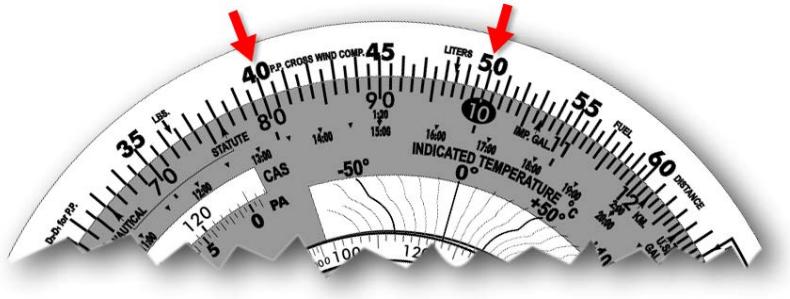
- Set 11 on the outer scale opposite the unit index (black 10) on the inside scale.
- Read the answer on the outside scale opposite 13 = **143.**

7.2.2 Division

Set the numerator and denominator values on the outer and inner scales and using the unit index for the answer.

Example: Divide 40 by 8.

- Set the divisor 8 on the inside scale opposite the dividend 40 on the outside.
- Read the answer on the outside scale opposite the unit index (black 10) = **5**



7.2.3 Percentage

The outer and inner scales are used to set the fraction and the answer as a percentage is read at the unit index. The process is similar to division.

Example: 45 out of 75 as a percentage.

- Set 45 on outside scale opposite 75 on inside scale.
- Read the answer on the outside scale opposite the unit index (black 10) on the inside scale.
- Since 45 is greater that 37.5 (50% of 75) the magnitude of the answer is greater 50% = **60%**, (and not 0.6%, 6% or 600%).

7.2.4 Proportion

The outer and inner scales are utilised to set the ratio and the answer is read from the unit index.

Example: The ratio 45:75 as a ratio of 40.

- Set the ratio 45:75 by aligning 45 on the outer scale opposite 75 on the inner scale.
- Read answer on the outside scale opposite 40 on the inside scale = **24**.

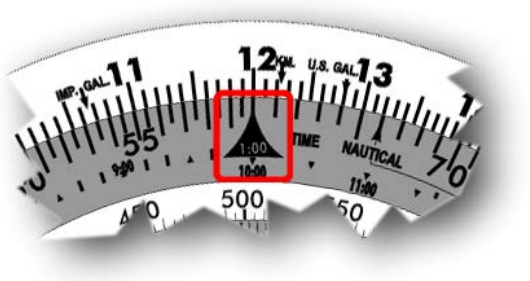
7.3 Quantity, Time and Rate Calculations

Quantity, time and rate calculations:

- Distance, time and speed calculations
- Fuel quantity, endurance and fuel flow calculations.

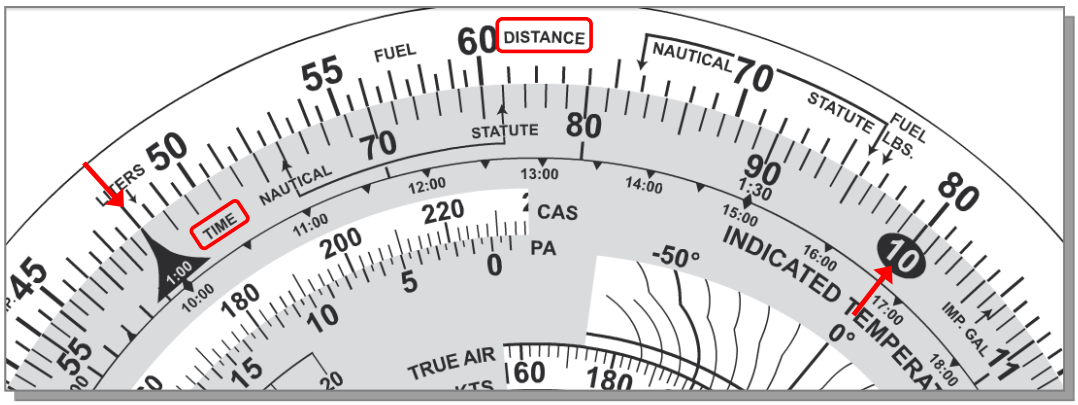
Both methods are performed during pre-flight planning and as part of en-route navigation tasks. Values are set using the inner and outer scales:

- Set **quantity val**ues, distance and fuel, on the outer scale.
- Set **time values** (e.g. minutes) on the **inner scale**.
- **Rate values**, speed and fuel flow, are set or read from the outer scale **opposite the large black arrowhead**.



7.3.1 Distance, Time and Speed

Time is displayed on the inner scale and distance is on the outer scale. Place the '60' Time Index opposite '480'. A speed of 480kts equals 480nm in 60 minutes, or 8 miles per minute. With this setting the distance travelled for any given time interval at the speed set can be obtained. View on the outer scale, the distance corresponding to the time interval on the inner scale. Alternatively we can view the time required for any given distance.



The groundspeed of an aircraft can be calculated, with the distance travelled known, in a given amount of time. Therefore, with the distance remaining to the next waypoint, the elapsed time, and estimated time of arrival (ETA) can be determined.

7.3.1.1 Distance

Example: Find the distance travelled in 75 minutes at a groundspeed of 135kts.

- Set the groundspeed 135 kts on the outside scale opposite 60 minutes (large black 1:00 triangle) on the inner scale.
- Read the distance travelled, on the outer scale, opposite 75 minutes flown on the inner scale.
- The aircraft would travel 135 nm in an hour at 135 nautical miles per hour (knots), the distance calculated must be more than 135 nm, since the time is more than an hour. Therefore, the magnitude of the answer is in the hundreds and can't be 16.8 or 1680.

Answer: 168.75nm

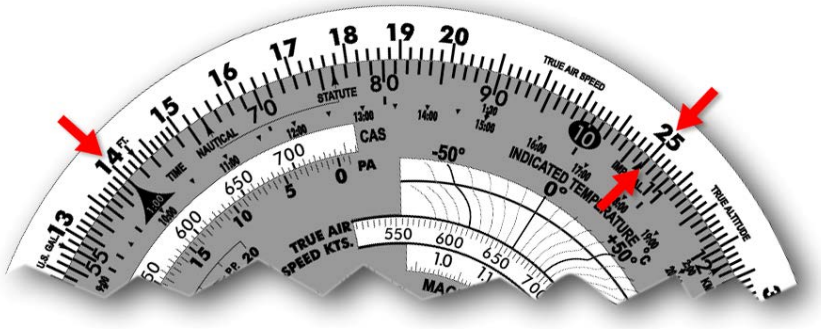
7.3.1.2 Time

There are two parts to the time scale. The outer portion of the inner scale has markings for time in minutes. Slightly inward of the outer edge of the inner scale is a solid line time scale. The solid line time scale represents hours and minutes. The minute markings on the outside edge of the inner scale can be used on the solid line scale to aid interpolation.

Example: Find the time (in minutes) it will take to fly 250 nm at a groundspeed of 140kts.

- Set the groundspeed of 140 kts on the outer scale opposite 60 min (the large black 1:00 triangle) on inner scale.

- Locate the distance of 250 nm on the outer scale and read the time opposite on the inner scale.
- Since the distance is almost double the speed, it will take almost two hours (120 min) to fly the distance. The magnitude of the answer will therefore be between 60 and 120mins.

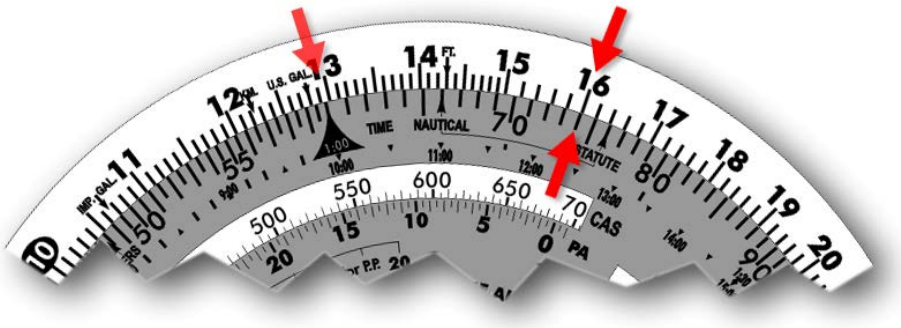


Answer: 107.14 minutes

7.3.1.3 Speed

> **Example:** Find the groundspeed to fly 160nm in 74 minutes.

- Set the distance 160 nm on the outer scale opposite the time in minutes (74mins) on the inner scale.
- Read the groundspeed on the outer scale opposite the rate index (black 60 minute arrow).
- If it took 60 min to fly 160nm, the speed would be 160 kts. Since it is taking longer than 60 minutes to fly this distance, the speed is less than 160 kts. If the flight took 2 hours, then the speed would have been 80 kts. Therefore, the answer is between 80 and 160 kts.



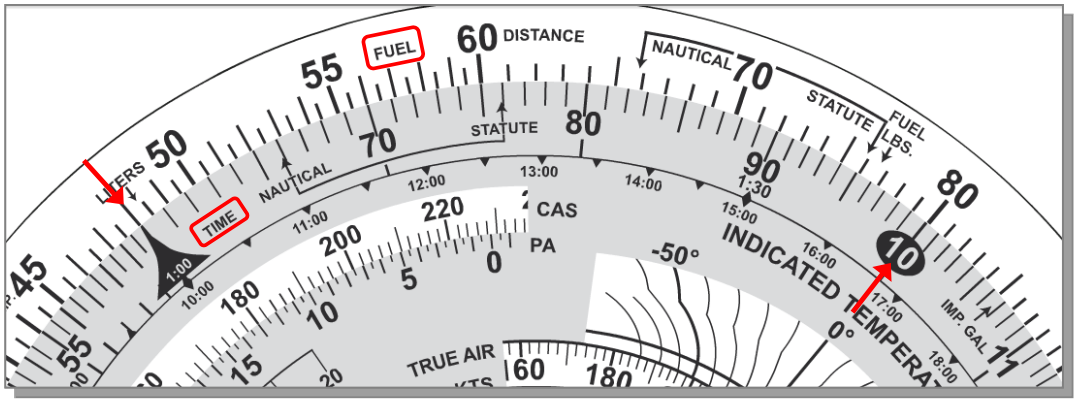
Answer: 129.73 kts

7.3.2 Fuel Quantity, Time and Fuel Flow

Similar to speed, distance and time calculations, a fuel flow of 480 kg/hr, corresponds to a fuel usage of 8 kg/minute. The fuel used for any given time interval at this fuel flow is displayed on the outer scale, opposite time (endurance) on the inner scale. Alternatively view the time corresponding to any given fuel quantity. Time is displayed on the inner scale and fuel is on the outer scale.

On the Jeppesen computer, the outer disc/scale is labelled 'Fuel Distance', thus indicating the dual purposes of these scales.

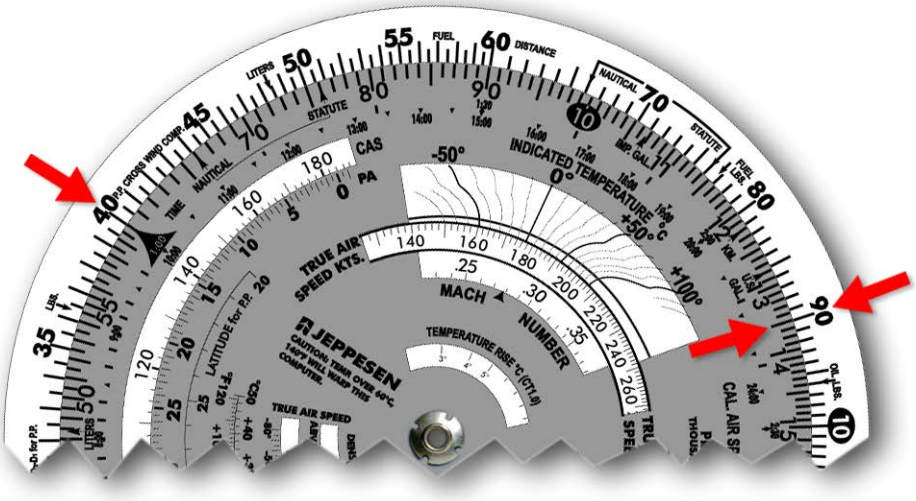
It is similar to Speed, Distance, Time calculations and any combination of Fuel, Fuel Flow, and Time can be calculated.



7.3.2.1 Fuel Quantity

Example: Find the fuel required to fly for 135 minutes at a fuel flow of 40 litres per hour.

- Set the fuel flow of 40 litres per hour on the outside scale opposite the rate index (black 1:00 triangle) on the inner scale.
- Read the fuel quantity required on the outer scale opposite 135 minutes on the inner scale.
- Each hour of flight consumes 40 litres at the given fuel flow rate. Since the time is greater than two hours, the fuel required will be more than twice the fuel flow rate. The answer will be greater than 80 litres.



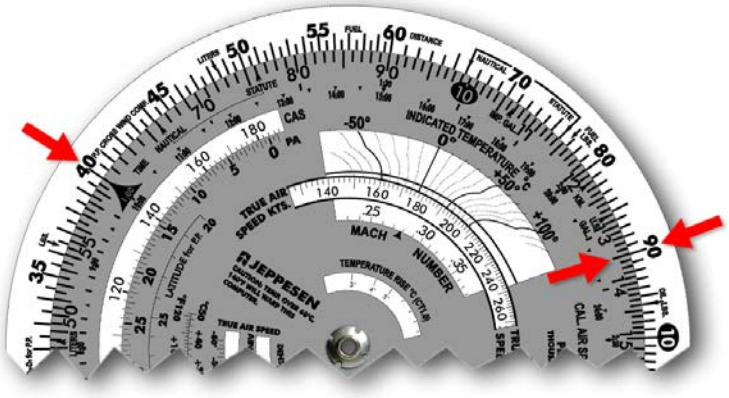
Answer: 90 litres

7.3.2.2 Endurance

Endurance is the time the aircraft can remain airborne with the fuel available at a given fuel flow. In light aircraft fuel planning, time is expressed in minutes.

Example: Determine the endurance (minutes) of the aircraft, fuel flow is 40 litres per hour with 90 litres of fuel.

- Set the fuel flow of 40 litres per hour on the outside scale opposite the rate index (black 1:00 triangle) on the inner scale.
- Read the endurance in minutes on the inner scale opposite 90 litres on the outer scale.
- For each hour of flight the aircraft requires 40 litres. Therefore, with 90 litres the aircraft will be able to fly for a period exceeding two hours. The magnitude of the answer will be greater than 120 min.



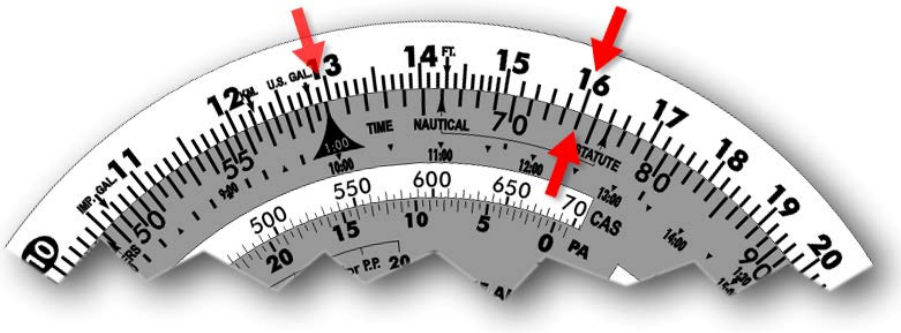
Answer: 135 minutes

7.3.2.3 Fuel Flow

The process of finding fuel flow is identical to the process to determine groundspeed.

Example: The aircraft has used 16 US Gallons in 74 minutes, calculate the fuel flow.

- Set the fuel quantity (16 US Gal) on the outer scale opposite the time (74 minutes) on the inner scale.
- Read the fuel flow on the outer scale opposite the black rate triangle on the inner scale.
- Since the time is greater than an hour, the fuel flow is less than 16 US Gallons per hour. The magnitude of the answer will be in the tens.



Answer: 12.97 US Gallons per hour

7.4 Unit Conversions

The following conversion types and units are discussed:

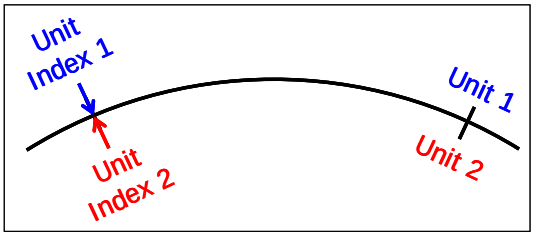
- Temperature
- Distance and speed
- Volume
- Mass
- Conversions between units of volume and units of mass.

Conversion between the various units can be done through various indexes located on the inner and outer scales.

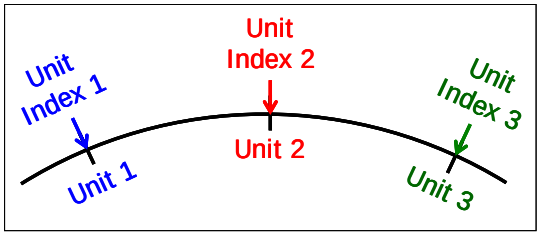
Two methods are used depending where on the scales the conversion arrows are located:

- Single unit method
- Multiple unit method.

The single unit method is used when converting from one type of unit into one other type and multiple conversions of the process is required, e.g. converting nautical miles into kilometres. The conversion arrows need to be on **opposite** scales.



The multiple unit method is used when converting from one unit type into two other types simultaneously, e.g. converting nautical miles into both kilometres and statute miles at the same time. The conversion arrows need to be on the **same** scale.

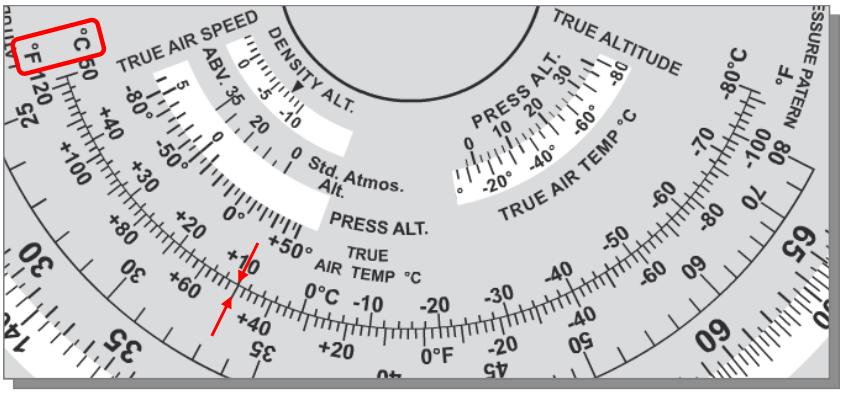


7.4.1 Temperature Unit Conversions

Converting between temperatures in degrees Celsius and degrees Fahrenheit is done on the solid line temperature conversion scale located close to the middle of the computer.

Example: Convert +10°C into degrees Fahrenheit.

- Read degrees Fahrenheit opposite +10°C on the Centigrade scale.



Answer: +50°F

7.4.2 Distance and Speed Unit Conversions

There is no difference between how distance or speed unit conversions are done and the same conversion arrows are used for either method.

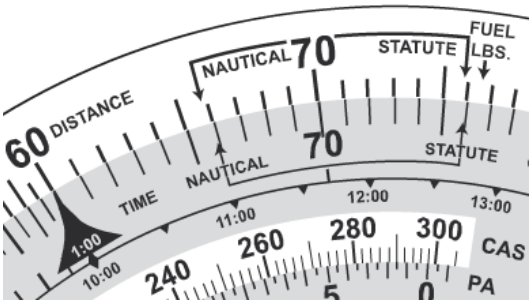
Conversion units:

- Nautical miles (nm)
- Statute miles (sm)
- Kilometres (km)
- Metres (m)
- Feet (ft).

Note: Direct conversions between major and minor units are not possible.

7.4.2.1 Major Distance and Speed Unit Conversions

Both the single unit and multiple unit methods can be used for major distance unit conversions. Conversion arrows are located on both the inner- and outer scales.



Exact Conversion Factors							
1	Nautical Mile	=	1.15	Statute Miles	=	1.852	Kilometres
			1	Statute Mile	=	1.609	Kilometres

Rough Conversion Factors for Estimations involving the Nav Computer							
1	Nautical Mile	≈	1.2	Statute Miles	≈	2	Kilometres
			1	Statute Mile	≈	1.5	Kilometres

Example: Convert 20nm to statute miles and kilometres (multiple unit conversion).

- Set 20 nm on the inner scale opposite the NAUTICAL arrow index on the outer scale.
- Read the statute mile value on the inner scale opposite the STATUTE arrow index on the outer scale.
- Without adjusting the computer, read the kilometre value on the inner scale opposite the KM arrow index on the outer scale.
- All the unit index arrows are on the same side (outer scale) and the conversion is done by using the conversion arrows on the inner scale and placing the values on the outer scale.
- Since each nautical mile is greater than one statute mile, the statute mile answer is in the twenties and since each nautical mile ±2 kilometres, the kilometre answer is less than double the nautical miles, i.e. ±40.

Answer: 23 statute miles and 37.04 kilometres

Knots are nautical miles per hour, miles/hour are statute miles per hour, use the same conversion arrows as used for distances for conversion between the various units of speed. The method to convert between units of speed is the same as converting distances.

7.4.2.2 Minor Distance and Speed Unit Conversions

The single unit method is used to convert metres into feet, as each conversion arrow is only available on one of the scales.

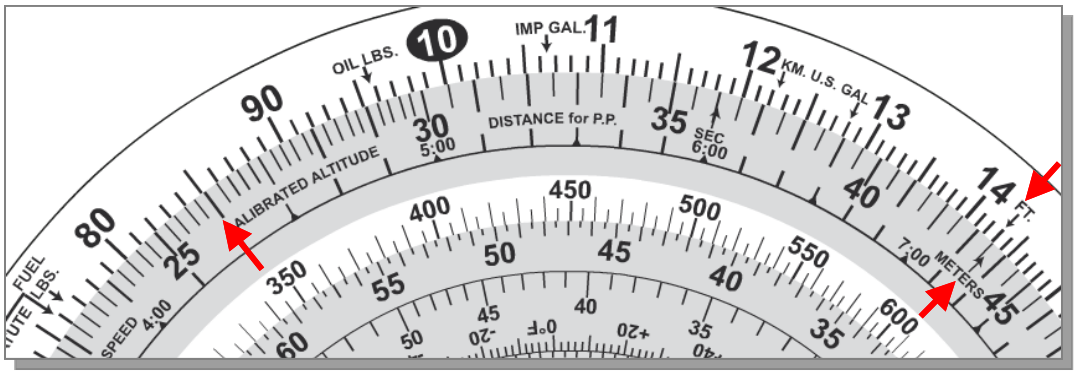
Exact Conversion Factors		
1 Metre	=	3.28 Feet

Rough Conversion Factors for Estimations involving the Nav Computer		
1 Metre	≈	3 Feet

Example: Convert 2,600 metres into feet.

Align the METERS conversion arrow on the inner scale with the FT conversion arrow on the outer scale.

- Set 2,600 m on the inner scale and read the corresponding value in feet on the outer scale.
- Since each metre is about three feet, the answer is three times the distance in metres (2,500 × 3 = 7,500). The answer is in the thousands i.e. greater than 7,500 feet.



Answer: 8,528 feet

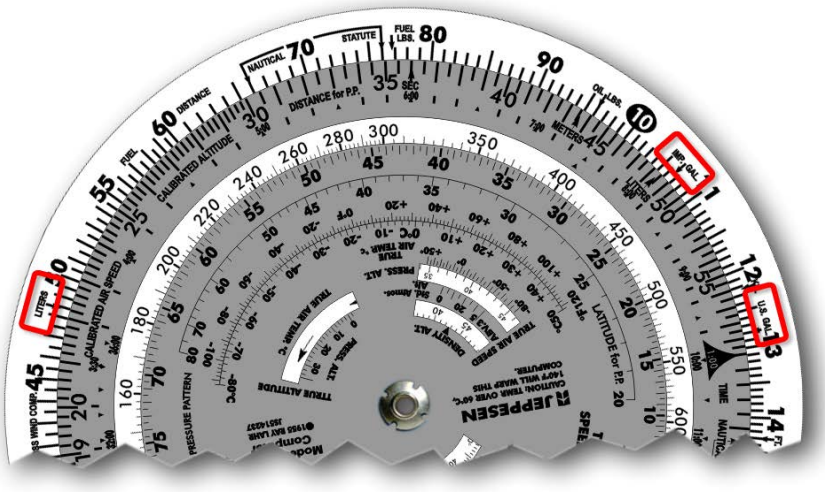
7.4.3 Volume Unit Conversions

The Jeppesen computer provides conversion scales between the common units of volumes of fuel. Labelled conversion arrows are placed around the circumference of both inner and outer discs as follows:

LITERS located near 48

US GAL located near 13

IMP GAL located near 11



Conversion arrows are available on both the inner and outer scales, therefore both the single and multiple unit conversion methods can be used.

Exact Conversion Factors

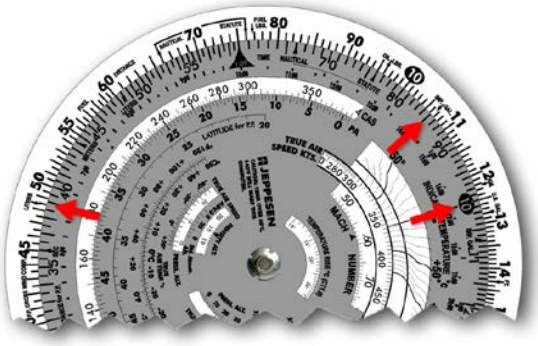
1	Imperial Gallon	=	1.2	US Gallons	=	4.546	Litres
			1	US Gallons	=	3.785	Litres

Rough Conversion Factors for Estimations involving the Nav Computer							
1	Imperial Gallon	≈	1.2	US Gallon	≈	5	Litres
			1	US Gallons	≈	4	Litres

Example Convert 100 US gallons into Imperial gallons, and litres.

The multiple unit method will be quicker to use for this example.

- Set 100 US gallons on the inner scale opposite the US GAL arrow on the outer scale.
- Locate the IMP GAL conversion arrow on the outer scale and read the converted value on the inner scale.
- Locate the LITERS conversion arrow on the outer scale and read the amount of litres on the inner scale.
- All the unit index arrows are on the same side (outer scale) and the conversion can also be done by using the conversion arrows on the inner scale and placing the values on the outer scale.
- One Imperial gallon is 1.2 US gallons, the answer for the Imperial gallons is less than 100.
- Each US gallon is approximately four litres. The answer in litres is less than 400.



Answer: 83.3 Imperial gallons and 378.5 litres

7.4.4 Mass Unit Conversions

The single unit method is used to convert kilograms into pounds as each conversion arrow is only available on one of the scales.

Use the LBS conversion arrow located on the outer scale close to 35 for all mass unit conversions (and not the FUEL LBS or OIL LBS indexes). The KG conversion arrow can be found on the inner scale between 16 and 17.

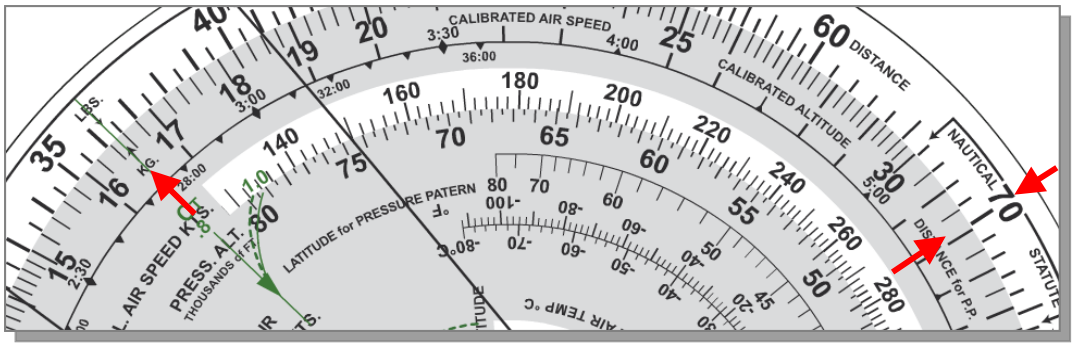
Exact Conversion Factors		
1 Kilogram	=	2.2046 Pounds

Rough Conversion Factors for Estimations involving the Nav Computer		
1 Kilogram	≈	2 Pounds

Example: Convert 700lbs into kilograms.

Align the LBS conversion arrow on the outer scale with the KG conversion arrow on the inner scale.

- Locate 700 lbs on the outer scale and read the value in kilograms on the inner scale.
- One kilogram is two pounds, therefore 700 lbs is less than 350 kg.



Answer: 317.52kg

7.4.5 Conversion between Units of Volume and Units of Mass

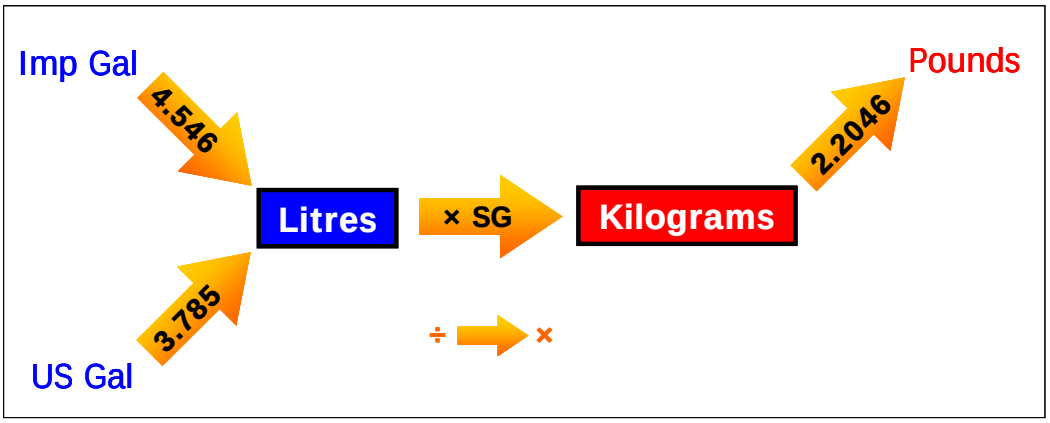
Multi-engine commercial aircraft tend to have fuel gauges calibrated in units of mass, rather than units of volume. When refuelling convert the required mass of fuel to an unit of volume, as the refuelling unit is calibrated in units of volume.

The term specific gravity (SG) is used to compare the density of a particular fluid to the density of water. The term “relative density” is an alternative term for SG and is used to compare the density of fluids.

Most aviation fuels weigh 70% to 82% of the mass of an equal volume of water, therefore the specific gravity is between 0.70 and 0.82. (Australian AVGAS has a SG of 0.71)

Water is the datum for SG calculations with a specific gravity of 1.0. Since 1 litre of water weighs 1 kg, it is possible to calculate the mass of a liquid provided its specific gravity is known.

The schematic below illustrates the process to follow:

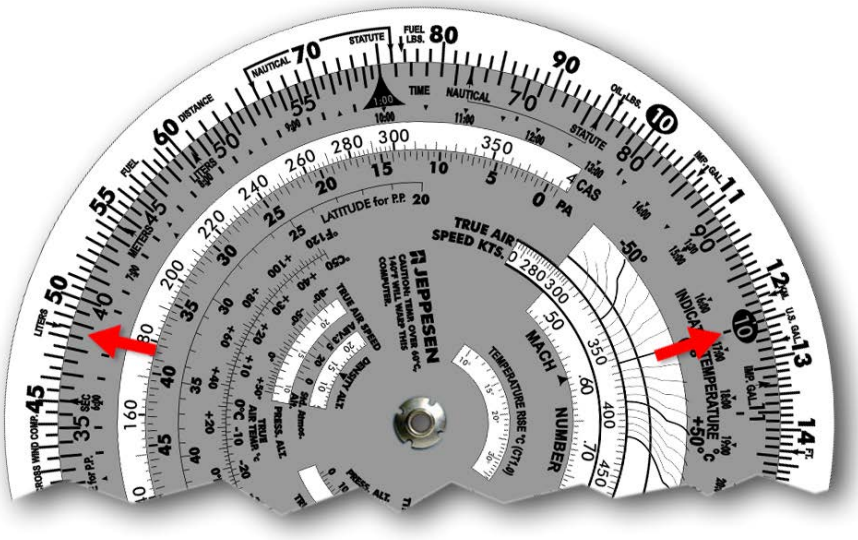


Convert the given volume into litres:

- Multiply the litres by the Specific Gravity (SG) of the particular fuel being used to calculate the mass of the fuel in kilograms.
- Convert to the required unit of mass.

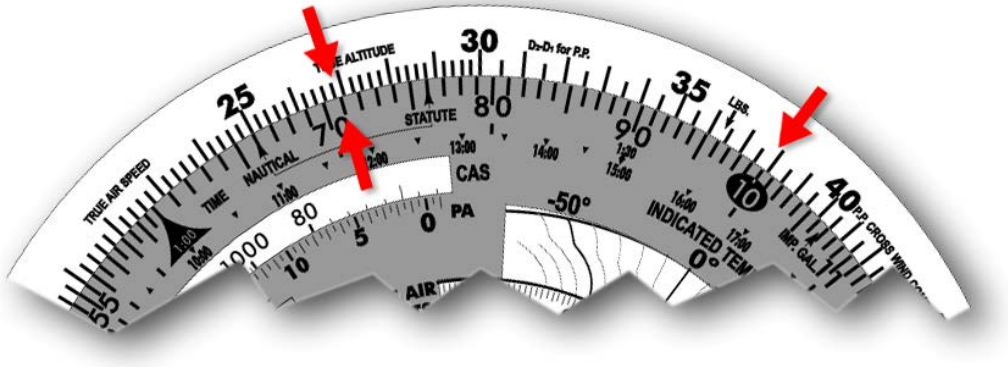
Example: Convert 100 US **gallons** of fuel, with SG 0.71, into **kilograms**.

- Convert 100 US gallons into litres by carrying out a volume to volume conversion as discussed.
- 100 US gallons are less than 400 litres, as 1 US gallon is ±4 litres.



Answer in litres: 378.5 litres

- Multiply value by the Specific Gravity of the fuel (0.71) to obtain the mass of the fuel in kilograms.

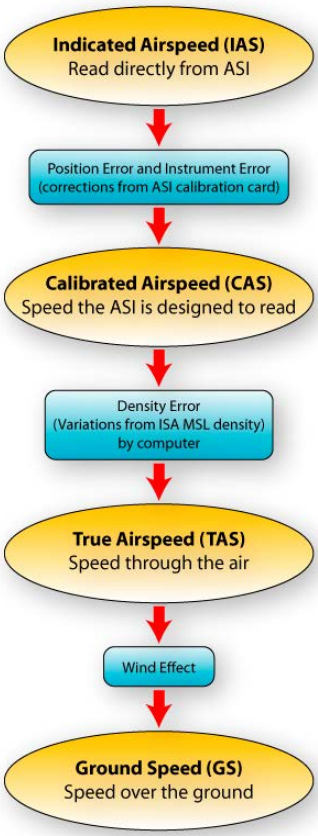


Final Answer: 268.74kg

- If the answer is required in pounds, apply the mass to mass conversion procedure.
- The process is reversed if the requirement is to convert from mass to volume.

7.5 Airspeed Corrections

The relationship between different types of speed:



The correction for density error between CAS and TAS is only correct at relatively slow speeds and low altitudes, i.e. CAS less than 200kts and altitudes below 10,000ft.

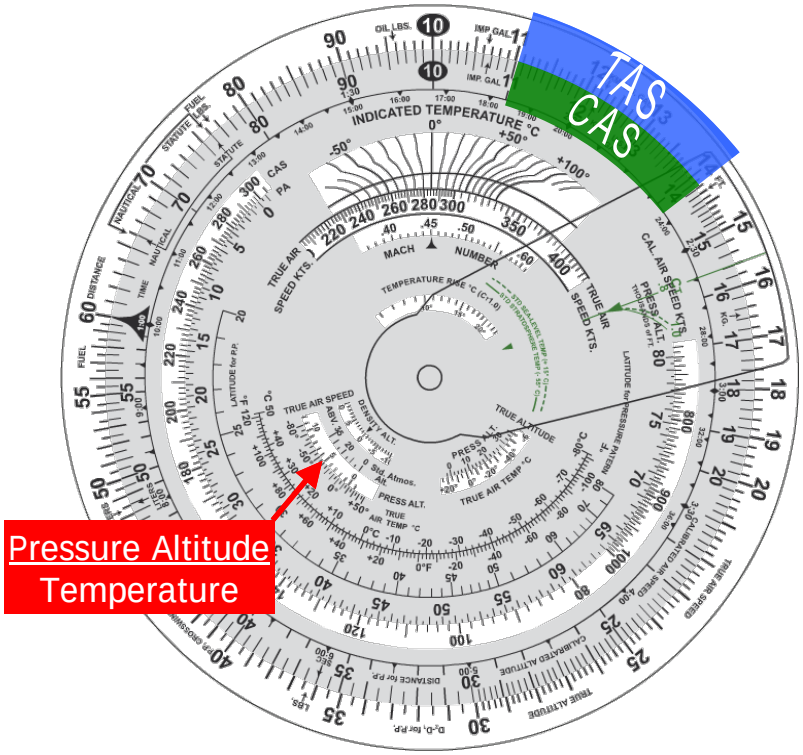
Additional corrections for compressibility are required outside these margins.

7.5.1 True Airspeed

To calculate true airspeed, three variables are set:

- Calibrated airspeed in knots, although other units of speed could be used.
- Pressure altitude in feet.
- Outside air temperature in degrees Celsius.

The pressure altitude is set opposite the outside air temperature in the TAS window near the centre of the computer. The CAS is set on the inner scale and TAS read on the outer scale.



Be careful setting your pressure altitude! Always find the zero pressure altitude and then from that set your pressure altitude. The pressure altitude scale is marked in thousands of feet. A value of 5 represents 5,000 ft and 50 represents 50,000ft.

The temperature scale has positive and negative temperatures values with divisions every 5°C. Interpolation to the nearest degree is required.

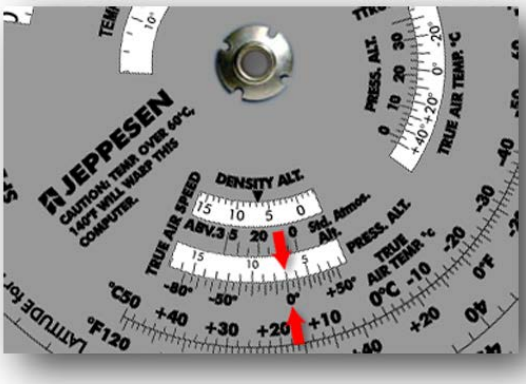
Opposite the IAS or CAS value on the inner scale, read the corresponding TAS value on the outer scale.

Set the CAS value on the inner scale and read TAS on the outer scale.

Example

Calibrated airspeed (CAS):	140 kts
Pressure altitude:	7000 ft
Outside air temperature (OAT):	0°C

- Set the TAS correction window to the pressure altitude 7000 ft opposite outside air temperature 0°C.



- Opposite the CAS of 140kts on the inner scale read TAS 155 kts on the outer scale.

Answer: 155 kts