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Pilot Navigation

Revision Notes and Questions

Cadet …….

HOW TO USE THIS BOOK

Only essential knowledge and key revision points have been included in this manual. You must have a thorough knowledge of its contents before the examination.

Read each page, then read the questions and underline or highlight the correct answer. Revise the questions and answers as they will constitute a high proportion of the actual examination questions (typically 23 out of the 25 questions!).

Ensure your answers are correct before using them in your final revision.

Contents

Dec 06 Final revision – no changes since May 05

TAFs and METARs

Weather information is passed to aircrew by Terminal Aerodrome Forecasts (TAFs) and Meteorological Actual Reports (METARs). Standard codes are used for brevity.

The code CAVOK (cloud and visibility OK) means the visibility is at least 10 km and there is no cloud below 5000ft.

TAF and METAR Decodes

BR	Mist	FZ	Freezing	SN	Snow
DZ	Drizzle	TS	Thunderstorm		
HZ	Haze	FG	Fog	RA	Rain
FU	Smoke	SH	Shower		

\- Slight + Heavy

In the northern hemisphere, if you stand with your back to the wind, where is the higher pressure air?

a) On your left. b) In front of you.
c) On your right. d) Above you.

Where on this pressure diagram will the wind speed be greatest?

a) A
b) B
c) C
d) D

If the wind indicated by the isobars on a weather chart is 200 degrees / 20 kts, what would you expect the surface wind to be?

a) 175/15
b) 175/25
c) 230/15
d) 200/20

How does the met office pass information about airfield weather to aircrew?

a) By using TAFs and METARs.
b) By television.
c) By radar.
d) By TEMPOs and BECMGs.

The main difference between a TAF and a METAR is:

a) One is a report, the other is a forecast.
b) One TAF is more reliable.
c) One never includes the wind velocity.
d) One is for a longer time period than the other.

If you saw the term CAVOK in a weather report, what would it mean to you?

a) Visibility 5 km, cloudbase 10,000 ft.
b) Combat all-terrain vehicles OK.
c) Visibility better than 5 km and no cloud below 10,000 ft.
d) Visibility better than 10 km and no cloud below 5,000 ft.

In a TAF what would -SHSN mean?

a) Heavy snow.
b) Snow all day.
c) Sleet.
d) Light snow showers.

CHAPTER 5 WEATHER

Pure air consists of 79% nitrogen, 20% oxygen and 1% other gases, however the major variable in the atmosphere that affects weather is water in all its forms.

The air pressure at sea level is caused by the weight of the air above us. With altitude, pressure reduces and so does the temperature.

Water Vapour

Air holds water vapour as an invisible gas, the warmer the air, the more water vapour it can hold. If the air is cooled below its dew point it can no longer hold water as a vapour and droplets start to form. Dew, mist, fog or clouds will start to form.

There are four 'trigger actions' which cause air to rise, turbulence, convection, orographic uplift and frontal uplift. In each case, pressure and temperature fall until the dew point is reached and at that altitude the base of the cloud is formed. At high levels clouds consist of ice crystals (cirrus) but most clouds are visible droplets of water.

Thunderstorms

Thunderstorms present a variety of hazards to an aircraft and are best avoided by a large margin. Some of these hazards are: icing, precipitation (usually hail), turbulence, lightning and severe downdrafts. Modern aircraft carry weather radar to assist in avoiding thunderstorms and turbulence.

Isobars

Isobars join points of equal pressure and help meteorologists and pilots to understand how the air is moving. In the northern hemisphere it circulates clockwise around anticyclones (high pressure areas) and anticlockwise around cyclones (low pressure areas). The easy way to remember this is that if you stand with your back to the wind, the area of **L**ow pressure is on your **L**eft.

Isobar patterns represent the wind at 2000 ft above the surface. The direction of the lines gives the direction of the wind and the closer the lines are together, the stronger the wind. At the surface the wind is approximately 25% less strong than at 2000 ft and will have backed by about 25°. For instance, if the 2000 ft wind is 270/20 the surface wind will be 245/15.

What is the major variable in the atmosphere that affects weather?

a) Water in all its forms. b) Cigarette smoke.
c) Pressure. d) Temperature.

What causes the air pressure at sea level?

a) Depression.
b) The weight of the air above it.
c) All the aircraft flying around.
d) The movement of highs and lows on the weather chart.

When the temperature drops to the dew point, but is still above freezing, what kind of weather can you expect?

a) Fog. b) Rain.
c) Sleet. d) Thunderstorms.

The 4 main reasons that air moves vertically are known as the trigger actions. What are these?

a) Conduction, precipitation, thunderstorms, convection.
b) Turbulence, convection, orographic and frontal uplift.
c) Turbulence, conduction, orographic, fiscal.
d) Market forces, radiation, x-rays, frontal uplift.

The base level of clouds is normally the pint at which rising air has cooled to what temperature?

a) 0 degrees C. b) Its dewpoint.
c) 0 degrees F. d) Its condensation.

What are clouds made of?

a) Visible droplets of water. b) Water vapour.
c) Scotch mist. d) Steam.

What is the best thing for an aviator to do about thunderstorms?

a) Avoid them by a wide margin.
b) Use the radar to go through the centre.
c) Pass downwind of them.
d) Stay on the ground.

Which of the following is not one of the hazards to a/c that is found in thunderstorms?

a) Icing. b) Lightning.
c) Isobars. d) Turbulence.

What form of precipitation is commonest in thunderstorms?

a) Drizzle b) Snow
c) Hail d) Showers

What do aircrew use to avoid thunderstorms?

a) Radio beacons. b) Seaweed.
c) Radar. d) Weather forecasts.

CHAPTER 1 UNITS

Vertical Distance and Speed

Despite metrification, most countries still use feet to measure aircraft height and altitude. Only in Russia and China are you expected to fly and report altitude in metres.

Despite still using feet to measure aircraft altitude, most countries have adopted metres to show elevations on maps - the British OS map is an example. Great care is needed because an aircraft being flown in thousands of feet can be in a very dangerous position if a navigator reads a mountain top as being 2000 feet instead of 2000 metres! (One metre equals approximately 3.3 feet.)

The calculation of safety altitude (above which we must fly if there is any doubt about terrain clearance) is the navigator's number one priority.

Vertical speed is measured in metres per minute in Russia and China, feet per minute elsewhere.

Most countries except the USA use metric units for meteorological reports.

Aircraft and Fuel

American built aircraft measure fuel in pounds or imperial tons, whereas most others use kilogrammes (kg) or metric tonnes. In theory, fuel should be measured by mass as the amount of thermal energy in one unit of fuel relates directly to its mass. Unfortunately, you cannot weigh fuel when an aircraft is airborne, so the alternative is to measure its volume.

In which two countries would you expect to be told by air traffic control to fly at a height of 300 metres instead of 1000 feet?

a) Russia and China.
b) UK and Ireland.
c) Australia and New Zealand.
d) USA and Mexico.

Why must you be very careful if using an OS map to work out safety altitudes?

a) The map does not cover a large enough area.
b) The map is out of date.
c) The elevations are in metres.
d) The grid is based on kilometre squares.

An aircraft is flying at 2000ft above sea level, towards a hill whose peak is 1000 metres above sea level. If the pilot takes no action, will the a/c:

a) Hit the hill more than half way up the slope.
b) Miss the hill by 1000 metres.
c) Miss the hill by 1000 ft.
d) Hit the hill near the peak.

The Navigator's No 1 priority is:

a) Calculation of safety altitude.
b) Keeping the a/c above safety speed.
c) Navigating with a sextant.
d) Calculating a/c altitude in metres.

The units used for vertical distance and speed in most countries are:

a) Metres and metres per minute.
b) Metres and knots.
c) Feet and knots.
d) Feet and feet per minute.

The country which is changing to metric units most slowly in aviation is:

a) Russia b) USA
c) UK d) France

What units of fuel would you expect to see on the gauges of a Eurofighter (Typhoon) aircraft?

a) Kilogrammes.
b) U.S. Gallons.
c) Imperial gallons.
d) Pounds.

Why do we use units of volume for a/c fuel, even though it would be more correct to measure its mass?

a) It is impossible to weigh the fuel in the air.
b) The Americans don't like doing it that way.
c) The mass of the fuel depends on its type.
d) The fuel is affected by outside air temperatures.

Fuel Conversion

Different types of fuel each have a Specific Gravity (SG). This is a measure of the ratio between the weight of the fuel and the weight of the same volume of water. Water has an SG of 1.0; typically jet fuel has an SG of 0.8 - this means that a litre of jet fuel will weigh only 80% of the weight of a litre of water.

Conversion of fuel weight to volume, or between various types of units (lbs, kgs, gallons, litres etc) can be done on a calculator, a DR computer or using a chart in the RAF Flight Information Handbook.

Pressure

Atmospheric pressure is caused by the weight of the air above us.

The higher we go, the less air there is above us. Atmospheric pressure is greatest at sea level and reduces as we climb up through the atmosphere.

Pressure can be measured in pounds per square inch (psi), inches of mercury (the method used in the USA), in mm of mercury, or in millibars (mb).

Millibars are used everywhere outside the USA.

The average sea level pressure is 1013 millibars. The table below shows how the atmosphere thins with altitude.

Altitude (feet)	Air Pressure (millibars)
Sea level	**1013**
10,000	700
18,000	500
24,000	400
30,000	300
34,000	**250**
39,000	200

Note that at a commercial airliner's typical cruising height of 34,000 ft, the air outside has only about one quarter of the air pressure at sea level. Consequently the amount of oxygen available is only one quarter of that at sea level. If it were not for the pressurisation system which maintains a higher air pressure inside the aircraft, those on board would lose consciousness.

If an a/c fuel tank was filled with water, it would contain 5000 pounds of water. If this water is now replaced with fuel at an SG of 0.80, how heavy would the fuel be?

a) 4000 pounds.
b) 400 gallons.
c) 8000 pounds.
d) 5000 pounds.

If the fuel tanker has its gauges calibrated in different units from the receiver aircraft fuel gauges, what method of conversion would the crew use?

a) A DR computer.
b) A fuel weight and volume conversion chart.
c) A calculator.
d) Any of the last three answers.

What causes the air pressure at sea level?

a) The movement of highs and lows on a weather chart.
b) All the aircraft flying around.
c) Depression.
d) The weight of the air above it.

Which units are used to measure pressure in the atmosphere throughout Europe?

a) Inches of mercury.
b) Millibars.
c) Atmospheres.
d) Hectonewtons.

Outside the USA, which units are used to measure atmospheric pressure?

a) Inches of mercury.
b) Pounds per square inch.
c) Millibars.
d) Millimetres of mercury.

What is the typical atmospheric pressure at sea level?

a) 200 millibars
b) 1013 millibars
c) 29.98 millibars
d) 1013 inches of mercury

Flying at a typical airliner cruising level of 34000 feet, what would you expect the atmospheric pressure outside the aircraft to be?

a) One half of sea level pressure.
b) One tenth of sea level pressure.
c) Three quarters of sea level pressure.
d) One quarter of sea level pressure.

Most large a/c have cabin pressurization to maintain air pressure inside the a/c fairly close to sea level pressure. Why is this?

a) It maintains the oxygen level.
b) It reduces the a/c fuel consumption.
c) It keeps the cabin warm.
d) It helps the stewardesses keep the passengers calm.

CHAPTER 4 MAP READING

Limitations

You can make the same mistakes map reading in the air as you can on the ground, but with the extra mental pressure that there is no time when you are flying to have a discussion about your location.

Aircraft Altitude

The best features for map reading depend on whether the aircraft is at high or low altitude. At low level it is important to choose features which have vertical extent, chimneys, hills etc. At high level vertical features cannot be seen and larger features are needed (lakes, woods, islands).

The most important characteristic of a map reading feature is that it is unique.

Contrast and Colour

Of the natural features used in map reading, rivers and coastlines are generally the most useful because they show the greatest contrast and colour change between themselves and the land.

Map Scales

Special maps are produced for map reading from the air. Emphasis is placed on features more easily identified from the air and the maps are made to a much smaller scale, typically 1:500,000.

Timing Marks

Before embarking on a flight in an aircraft without sophisticated navigation aids, a student will put timing or distance marks along each of the legs of his route. If he loses his place along his track he need only consult his ***watch***, work out the time in minutes since the last waypoint, and that will tell him where to look on the map.

What is the main difference between map reading on the ground and in the air?

a) There is no time in the air to discuss where we are.
b) You don't have to wear an oxygen mask on the ground
c) You do not need waterproof maps in the air.
d) The scale of maps is so different.

What is the essential requirement of a feature for use in low level map reading?

a) It must be a different colour from the background.
b) It must be a water feature.
c) It must be large enough to be seen at high speed.
d) It must have vertical extent.

What is the major difficulty with map reading from an a/c at high level?

a) The weather.
b) The maps are not accurate enough.
c) Vertical features cannot be seen.
d) Everything looks so small.

What is the most important characteristic of a map reading feature?

a) It must be small enough.
b) It must be tall enough.
c) It should be unique.
d) It must be large enough.

When choosing natural (rather than man-made) features for map reading, what characteristic is most important?

a) How they are shown on the map.
b) Their contrast and colour.
c) Their size.
d) Whether they are frozen or not.

In a simple a/c, what piece of equipment do we rely on to assist with map reading?

a) The radar.
b) The watch.
c) The gyro magnetic compass.
d) The magnifying glass.

Why do we put timing (or distance) marks on a map to assist with map reading?

a) To calculate ETA.
b) To monitor the groundspeed.
c) In case we lose our place.
d) To check fuel consumption.

Radar Navigation

Airborne radar has been refined to such a stage that ground returns received by an aircraft are matched to a 'computerised map' enabling an accurate fix to be obtained simply at the press of a button.

One disadvantage of this system is that the radar transmissions can be detected by the enemy.

Long Range Fixing

During the 1950's and 1960's a number of long range 'area' navigation systems were developed (Gee, Decca, Loran and Omega). All worked on a similar principle, measuring the time it takes two synchronized signals to arrive from two different transmitting stations to give a fix.

Global Positioning System (GPS)

With airborne microcomputers and the network of Global Positioning satellites, it is now possible for even an unskilled operator to obtain fixes with accuracies of a few metres.

Active / Passive Systems

The development of radar-homing missiles has necessitated the development of even more sophisticated electronic warfare (EW) countermeasures. EW is a growth science and is the subject of a constant development race between nations.

EW measures are used to protect 'active' navigation systems, but another approach is to use only 'passive' systems. Passive systems do not transmit, merely receiving signals such as those transmitted by GPS satellites and combining that information with up to three inertial navigation systems (GPS + triple INS).

Conclusion

Despite the availability of very accurate navigation systems, a great deal of aviation training time is devoted to old fashioned methods such as map reading, particularly in a student's early stages of training.

In the Tornado GR variants, a computer generated low level map can be superimposed over the radar picture. What does this enable the navigator to do?

a) Avoid carrying paper maps.
b) Take quick, accurate fixes.
c) Spot the golf courses he/she would like to play.
d) Use look down, shoot down missiles.

What is the major disadvantage of radar in combat a/c?

a) It only works at night.
b) You need a weapon systems operator to use it.
c) It gives away your location.
d) It only works at low level.

All long range nav aids work on a similar basis. What does the equipment use to calculate position?

a) Old Moore's Almanac.
b) Time interval between synchronised signals.
c) Time interval between successive fixes.
d) Phase difference on various radials.

Only one long range Navigation System gives accuracies of about 100 metres. Which is it?

a) GEE.
b) DECCA.
c) GPS.
d) LORAN.

What is the best defence against enemy detection of active navigation systems in fast jet a/c?

a) Use only astro navigation.
b) Climb to service ceiling.
c) Scramble/unscramble the signals.
d) Use only passive systems.

The best passive navigation system is:

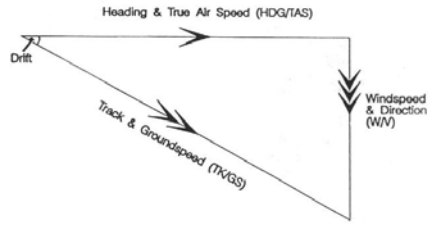
a) Astro alone?
b) Loran with astro?
c) Triple inertial with GPS?
d) Twin inertial with Omega?

In the early stages of training, students are made to concentrate on which method of navigation?

a) Astro navigation.
b) Air plot.
c) Map reading.
d) Mechanical track plot.

CHAPTER 2 FLIGHT PLANNING

The Triangle of Velocities



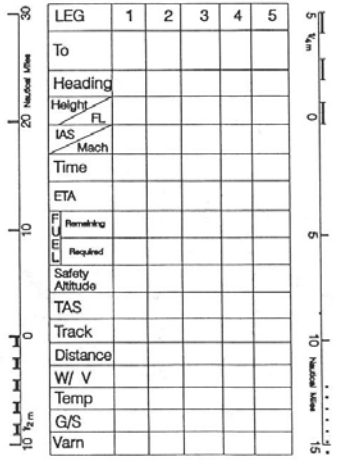
In this diagram of the triangle of velocities, the vector with one arrow represents heading and true airspeed. The vector with two arrows represents track and groundspeed. Windspeed and direction is shown by the vector with three arrowheads.

Drift is the angle between the track and heading vectors.

Each vector constitutes two pieces of information, a direction, and a value indicated by the length of each arrow. As long as we have four of the elements of the vector triangle, we can find the other two. The solution can be found by a variety of methods, but the quickest is to use the Dalton DR Computer.

Flight Planning

In the world of the private pilot and light military trainers, flight planning is carried out using the Pilot Navigation Log Card.



In the triangle of velocities, which vector represents the wind velocity?

a) The angle between track and heading.
b) The vector with one arrowhead.
c) The vector with two arrowheads.
d) The vector with three arrowheads.

In the triangle of velocities, which vector represents the track and groundspeed?

a) The longest one.
b) The vector withy two arrowheads.
c) The vector with one arrowhead.
d) The shortest one.

In the triangle of velocities, which vector represents the heading and airspeed?

a) The angle between track and heading.
b) The vector with one arrowhead.
c) The vector with two arrowheads.
d) The vector with three arrowheads.

How is drift shown in the triangle of velocities?

a) The angle between heading and wind direction.
b) The angle between track and heading.
c) The angle between track and wind direction.
d) It is not shown at all.

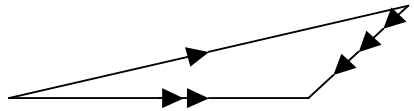
How many elements of the vector triangle are needed in order that the triangle may be solved?

a) 3 b) 4
c) half d) 6

What is the quickest and most accurate way of solving the vector triangle?

a) Mentally.
b) Using a sheet of graph paper.
c) Using a word processor.
d) Using the Dalton DR Computer.

The diagram shows a vector triangle for a flight along an easterly track. With an N.E. wind, which of the following is true?



a) The TAS is less than the groundspeed.
b) The a/c experiences port drift.
c) Without doppler radar, nothing is certain.
d) The heading is approximately 080 degrees.

What is the purpose of the Pilot Navigation log card?

a) It records the instrument readings every 6 minutes.
b) It enables the pilot to plan the flight.
c) It tells the pilot where the a/c is.
d) It is an accurate record of the flight for squadron statistics.

The pilot must enter important details on the log card for each leg. He must measure the tracks with a protractor and the distances using dividers.

Temperature is required in order to calculate the true airspeed (TAS) from the calibrated airspeed (CAS).

Fuel Planning

The time for each leg and the fuel required is also calculated and logged on the card. Running out of fuel in a car is inconvenient, in an aircraft it is disastrous.

The timings on the log cards also help pilots pass accurate estimates of time of arrival (ETA's) at waypoints or destinations.

Safety Altitudes

The safety altitude is calculated by adding 1000 ft to the highest elevations (mountains, TV masts etc) on or near the track, and rounding up to the nearest 100 ft. If meteorological conditions deteriorate, the pilot must always be prepared to climb above the safety altitude.

Air Traffic Control Flight Plan

Before a pilot commences his flight he must submit an ATC Flight Plan so that ATC units along his route and at his destination have details of his intended flight.

The ATC Flight Plan will include the aircraft callsign, type of aircraft, time and place of departure, speed and altitude, intended route and ETA at destination. It will also include safety information, such as, the number of people on board and the types and quantities of emergency equipment carried.

What must a pilot do in order to complete the Pilot Navigation log card?

a) Extract the tower frequencies from the navigation handbook.
b) Measure the tracks with a protractor and the distances with dividers.
c) Measure the tracks with dividers and the distances with a protractor.
d) Ensure that the a/c has the correct equipment fitted.

Why do you need to know the outside air temperature at operating altitude in order to complete your flight planning?

a) To ensure that the passengers meals stay frozen.
b) To calculate the TAS from the CAS.
c) To calculate IAS from Mach No.
d) To ensure that the engines will work.

As well as solving the triangle of velocities, what other information is logged on the Pilot Navigation log card?

a) Amount of fuel received from tanker.
b) Time for each leg and a/c registration.
c) Met forecast of icing and thunderstorms.
d) Time for each leg and fuel required.

For what reasons do we need to calculate leg times and ETA's on our pilot navigation card?

a) Fuel and de-icing fluid.
b) To calculate safety altitude and variation.
c) Fuel and Air Traffic.
d) Air Traffic and for astro calculations.

If the highest obstacle near your track is 1750', what is your safety altitude?

a) 2700 ft
b) 1800 ft
c) 3800 ft
d) 2800 ft

If you are flying an a/c at 2000' and you fly into cloud, to what altitude must you climb?

a) 3000 ft
b) To safety altitude or higher.
c) Flight level 40
d) Maintain altitude.

Which of the following would you not expect to find on an Air Traffic Control flight plan?

a) Destination.
b) Callsign.
c) Persons on board.
d) Wind forecast.

CHAPTER 3 POSITION FIXING

In the pioneering days of aviation aircraft could not fly unless the crew could see the ground, as map reading was the only means of navigating.

Although big strides forward were made during and after the Second World War, it was not until the 1970's that world-wide coverage was achieved with a fixing aid known as Omega. More recently this has been superseded by Satellite Navigation (SATNAV) and the Global Positioning System (GPS).

Visual Fixing

By using a map to positively identify a feature on the ground below, you are making a visual fix known as a pinpoint. The pinpoint is still a very reliable method of fixing one's position, particularly in the early days of training.

Radio Aids

The next time you listen to a small portable radio, try turning the radio through 360° in the horizontal plane. You will find that there are two points in the circle where reception is poor, and two points where reception is best. The Radio Direction Finder (DF or radio compass) works on the same principle to find the direction of the aircraft from a beacon. By using lines from two further beacons (preferably at about 60° from each other), a 'three position line fix' can be plotted to accurately locate the position of the aircraft.

VOR/DME and TACAN

A more modern method of position finding utilises VOR/DME (civilian) or TACAN (military) beacons. Both give the same information, namely the magnetic bearing from the beacon to the aircraft, and the range.

Astro Navigation

Astro navigation works on the principle of using a sextant to measure the angle of the sun or stars to determine position. Perhaps its only advantage nowadays is that it cannot be jammed. It has been superseded by GPS.

In the early days of aviation, what did pilots have to rely on for navigation?

a) Map reading. b) The navigator.
c) The observer. d) The stars.

What is the name of the first long range navigation system to give world-wide fixes?

a) Sputnik. b) Omega.
c) Loran. d) GPS

The system in the last question is now being replaced by what modern system?

a) ILS b) TCAS
c) LORAN d) GPS

The name of a fix that you get from reading a map is known as:

a) Pinpoint.
b) Pinprick.
c) DR position.
d) Air position.

The radio compass works on the same principle as which of these equipments:

a) A Radio 1 transmitter?
b) A gyro magnetic compass?
c) A small portable radio?
d) A radio sonar buoy?

The radio compass enables you to take what kind of fix?

a) VOR/DME fix. b) 3 position line fix.
c) Tacan fix. d) Astro heading fix.

In a 3-position line fix what is the ideal angle between position lines?

a) 30° b) 45° c) 60° d) 90°

The civilian equivalent of TACAN is known as:

a) LORAN b) OMEGA
c) ADF d) VOR/DME

Both VOR/DME and TACAN give the same information. Is it:

a) Magnetic track and groundspeed?
b) True heading and range to the beacon?
c) Airway centreline and distance?
d) Magnetic bearing and range to the beacon?

What is the major advantage of Astro Navigation over more modern systems?

a) It is more accurate.
b) It can only be used by naval aviators.
c) It cannot be jammed.
d) It is easier to use.