ABF Pilot Training Manual

Part 8

Navigation (NAV)

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Reading

Meteorology and Navigation by Trevor Thom (Aviation Theory Centre, current edition) gives more thorough explanations than these study notes. See 'Basic Principles' in chapter 10, all of chapter 11, and 'Aeronautical Charts for Visual Navigation' in Chapter 12.

Also useful are:
Ballooning Handbook by Don Cameron (Pelham Books, London 1980) - chapter 5.
The Ballooning Manual by Bob and Carol Howes (Airlife, UK 1991) - chapters 15 and 29.
The last two are written for the UK, where the maps and charts are slightly different, but the general principles apply to balloon navigation anywhere.

You will need
A Topographic Survey Map (scale 1:50,000 or 1:100,000) – eg, the map for your flying area
A Visual Terminal Chart (VTC)
VFR Flight Guide (VFG) or AIP Book.

You should also look at
A Visual Navigation Chart (VNC)
A Terminal Area Chart (TAC)
An En Route Chart – Low (ERC Low)
A World Aeronautical Chart (WAC)
Planning Chart Australia (PCA)

The Navigation exam

- Twenty question multiple choice exam.
- Time allowed 70 minutes.
- Minimum pass mark is 70%.
- You will need a metric ruler, a protractor and a calculator.
- You may refer to AIP book during this exam.

The exam includes an imaginary flight with changes of wind speed and direction. For the purpose of the exam it is assumed there is no difference between true north, grid north and magnetic north. Additional information such as Danger Areas and ABF Sensitive Zones must be taken into account. Your measurements and calculations must be accurate; a standard similar to fixed-wing aviation is required. The calculations are fairly simple, and examples are given later in these notes.

The exam uses sections of a VTC and a 1:50,000 topographical map. You need to be very familiar with the use of these maps and their symbols as the map legends are not supplied.

Navigation in practice

In flight most balloon pilots navigate accurately enough using approximate 'rule of thumb' measurements and calculations. For example, you fix your position on the map at take-off and again after ten minutes, hold your thumb and forefinger against the two fixes on the map, and then hold them against the scale at the edge of the map, or against the grid, to check the distance. Multiply this by 6 to get the distance you are likely to cover in an hour, or simply count off multiples of the same distance ahead with thumb and forefinger to plot your estimated position after 20 or 30 minutes.

In flight navigation checklist:
- **Topographic map, compass** and **clock** are mandatory
- **Aviation chart** need not be carried provided the essential information from the chart has been marked on your topographic map
- **Pencil and eraser** are useful to fix your position on the map
- **Binoculars, GPS and spare GPS batteries** also useful.

Units of measurement

<u>Horizontal distance for navigation purposes is in nautical miles</u> (NM). 1 NM = 6080ft or 1852m, about 12% longer than a statute mile. 'Miles' in aviation always means nautical miles, unless stated otherwise.

<u>Horizontal speed is in knots</u> (KT). 1 knot = 1 nautical mile per hour. There is no such thing as a knot per hour! Watch out - wind speed is usually given in knots, but sometimes in km per hour.

<u>Horizontal distance for other purposes</u> (eg, for visibility or clearance from cloud) is in <u>kilometres</u> (km) <u>or metres</u> (m).

<u>Direction</u> is shown in <u>degrees, always as a 3 figure group</u>. East is 090°, North is 360°. Direction is usually measured *towards* the object or direction of flight. However, wind direction is always expressed as where the wind is coming *from*. 12 knots of wind from the south (180°) is abbreviated in forecasts as 180/12 or 18012.

<u>Height or altitude (vertical distances) in aviation are always in feet</u>. **Altitude** is the vertical distance of a level, a point, or an object considered as a point, measured from mean sea level, eg 2,000ft **AMSL** (above mean sea level). **Height** is the vertical distance of a level, a point, or an object considered as a point measured from a specified datum such as ground level, eg 1200ft **AGL** (above ground level)

It is a common mistake to omit the datum. Note: a maximum allowed (or practical) altitude is called a **ceiling**.

Vertical speed is in feet per minute (fpm), often abbreviated as **ROC** (rate of climb) or **ROD** (rate of descent), and is measured by a variometer. Some variometers are graduated in knots rather than fpm – one knot is equal to 100fpm.

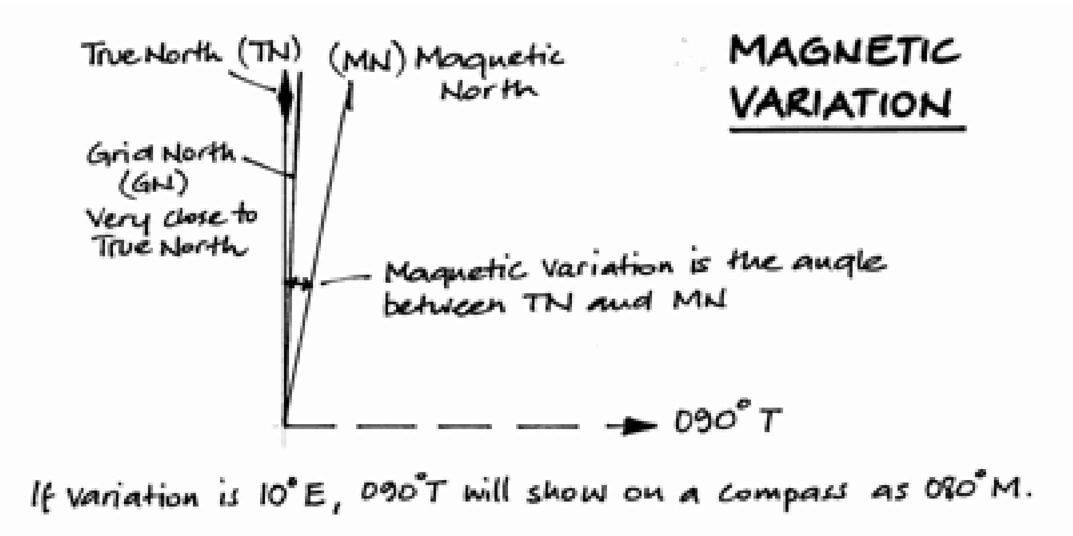
Direction and position

The compass rose indicates directions and is divided into 360 degrees. Degrees are subdivided into minutes (60 to a degree) and seconds (60 to a minute). A direction of 220 degrees, 40 minutes, 30 seconds is abbreviated 220° 40' 30". Alternatively minutes may be shown to one decimal point, so the same direction would be given as 220° 40.5'. Using a hand-held magnetic compass you are unlikely to be accurate to within even one degree.

True bearings (°T) are directions relative to the true North Pole, which is on the axis of rotation of the earth. An arrow pointing to true north is normally shown on maps.

A topographic map uses a **grid** of east-west and north-south lines to help in measuring and locating positions on the map. There is a quite small difference between **grid north** and true north which is usually ignored.

Magnetic bearings (°M) are directions as they appear on the compass, relative to the magnetic north pole. The magnetic pole is offset from true north, and so a magnetic bearing is usually different from the true bearing. A typical relationship between true north, grid north and magnetic north is shown below:



Magnetic variation is the amount by which a magnetic bearing varies from the true bearing. The amount of magnetic variation depends on your location; it also varies over time. A magnetic variation of 10° east means that magnetic north is 10° to the east of true north. The magnetic bearing will therefore be 10° less than the true bearing (eg

090°M would be equivalent to 100°T). When the variation is west the magnetic amount be the greater than the true amount. This is easily remembered by:

"Variation east, magnetic least."

Example: Information in the margin of a topographic map of Adelaide dated 1980 shows the magnetic variation is 6° 15' eastwards, plus 02' annual change easterly. Magnetic variation in the year 2005 will therefore be 6° 15' *plus* 25 x 2 minutes = 50 minutes, which gives a total of 7° 05' east, which is close to 7°. In 2005 a magnetic bearing of 030°M would therefore give a true bearing of 037°T (remember – variation is *east*, so the magnetic figure is *least*). In practice, magnetic variation is often ignored unless very precise flying is required as in a competition task.

On topographic maps and VTC charts, the magnetic variation is written in the margin. On VNC, ERC and WAC charts, which cover much more terrain, the magnetic variation can vary significantly across a single chart, and so is indicated by **isogonals** which are lines across the chart joining points of equal magnetic variation. (The isogonal which joins points of zero magnetic variation is called an agonic line.)

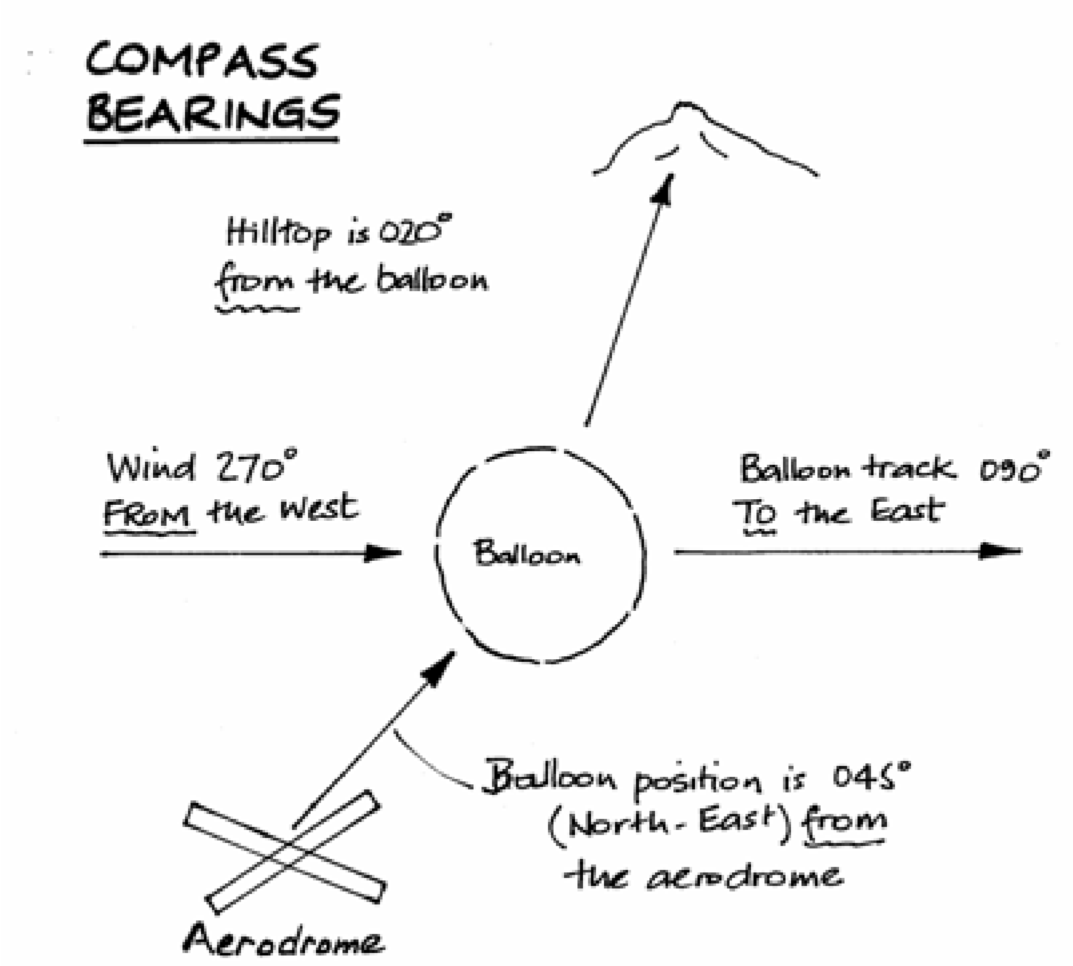
Magnetic deviation means any local error caused by something affecting the compass reading, such as nearby metal objects or metallic ore deposits in the ground. Fixed compasses in ships and planes are corrected for this. To minimise magnetic deviation, hand held compasses should be used a few metres away from cars or other large metal objects.

Some navigation terms are intended for powered aircraft, which from inside the cockpit can appear to be *heading* in a particular direction but are typically blown a bit off *course* by a crosswind factor, so that the resulting *track* is a slightly different direction on the map. Balloons by comparison have zero airspeed as they fly with the wind rather than through it. They also do not have a nose or front end to aim or 'head' towards something. So in a balloon the *direction the balloon is actually moving towards* is both its **heading** and its **track**.

Your **bearing** (eg, from an aerodrome), is the *magnetic direction from that point towards your position*.

> Example: '5 miles northeast Mildura' means your position is 5 miles *from* Mildura aerodrome *towards* the northeast.

ARE YOU UP TO DATE?
New regulations and procedures may apply from time to time.
Check on the ABF website that you have the latest version of these study notes.



Whenever you determine your present position on the map this is known as a **fix**. It is a good practice in ballooning to fix your position every ten minutes or so, and to pencil it on the map if you are in an unfamiliar area. If you are momentarily lost (it happens to the best of pilots at times), you can estimate your current position from your last fix. The process of calculating where you expect to be after a specified time, starting from your present position and considering the wind speed and direction, is called **dead reckoning** (from 'deductive reckoning'– does not mean it will be 'dead accurate'!).

YOUR FEEDBACK PLEASE!
If you have any corrections or suggested improvements to these study notes please advise the ABF Operations Manager.

Charts

Aviation charts are available from Airservices Australia, and are updated every six months. You must have access to a current chart of your flying area; the best chart to use is the most detailed one available. The different types of charts are listed below in order of suitability for ballooning:

VTC (Visual Terminal Charts - scale 1:250,000) **VNC** (Visual Navigation Charts - scale 1:500,000)	*both of these are good for balloons*
TAC (Terminal Area Charts - various scales) **ERC Low** (En Route Low charts - various scales)	*only use if VTC or VNC are not available*
WAC (World Aeronautical Charts)	*if no other chart exists*

Together, these charts cover major aerodromes and the routes between them. The 'visual' charts **VTC** and **VNC** are designed for visual rather than instrument flying, and show key airspace details and radio frequencies with some easily recognised topographical features. **TAC** and **ERC Low** have little topographical detail.

You must be familiar with symbols used on VTC and VNC charts. You must be able to interpret the boundaries and dimensions of various kinds of airspace, particularly on VTC and VNC charts, and be able to transfer these details fairly accurately onto the topographic map you use in flight. Note that 'CTAF' aerodromes no longer have defined airspace boundaries as CTAF now refers to procedures only.

WAC charts cover all of Australia at a scale of 1:1 million, and due to their scale are really only useful for remote areas not covered by other charts or for very long distance balloon flights. Airspace boundaries are not shown on them, but aerodromes are shown by name and further details of these can be found in ERSA.

Planning Chart Australia (PCA) is a guide to all the WAC charts. It also shows boundaries of aviation forecast areas (also shown in ERSA), and indicates the likely range of VHF radio reception.

Maps

Topographic Survey Maps produced by government mapping authorities are far more practical for balloon flying and retrieving, and are available from good map shops. The most suitable scales are 1:50,000 (2cm on the map equals 1km) and 1:100,000 (1cm equals 1km), as they show sufficient detail to clearly identify your position in relation to roads and physical features. If the ground crew have exactly the same map as the pilot it is much easier when giving directions to each other.

You must mark ABF declared **sensitive zones (SZs)** on your flight maps. For details of SZs consult local balloon pilots, and check the ABF website.

You must be familiar with typical topographic map symbols, and be able to give a position by grid reference or latitude and longitude promptly and confidently (see below).

It is quite acceptable to transfer essential information from the aviation chart to your topographic map. This is easier than trying to follow both the chart and the map while flying. Your map must show aerodromes, controlled airspace, prohibited, restricted and danger areas (as required in CAO 95.54).

The best way to learn navigation is by using maps and charts every time you go ballooning – before, during and after the flight. It does not matter whether or not you are on board the balloon, as map skills are just as important for the retrieve crew.
If you are not confident with topographic maps, don't be alarmed at the detail. It is largely a matter of practice. Ask your instructor to help you get oriented. Check the scale and the grid size (the distance between grid lines). Learn the symbols for key features, and practice identifying on the map some of the features you will most easily see from the air, such as hills and valleys, towns, roads, rivers, towers, silos, railway lines and major powerlines.

Some people prefer to turn the map so it is lying in the same direction as the countryside it represents. This can make it easier to recognise and plot directions, but harder to read the words. Just do what works best for you.

Grid references

The **grid** is the matrix of horizontal and vertical lines on topographic maps, used to help locate a point on the map. The distance between grid lines usually represents 1km on 1:50,000 maps (1km or 2km on 1:100,000 maps), but you should always check it. Grid lines are numbered from 00 to 99 at the edge of the map – they eventually repeat, but not on any single map sheet. The **grid reference (GR)** for a point on the map is found by measuring *across, then up* (remembered as '*Easting then Northing*'). If you get this the wrong way round, you will locate a completely different place!

> Example:
> Choose a point on the map (say a road intersection).
>
> *Easting* – read off the nearest vertical grid lines to the chosen point by counting across (say the point lies between lines 35 and 36), then estimate how many tenths the point is beyond the 35 line (say 2 tenths). The easting for that point is 352.

Then Northing – do the same for the horizontal lines. Say the point is 7 tenths past the 22 line, which gives a northing of 227. The full **six-figure grid reference** is then 352 227. On a 1km grid this should be accurate to within 100 metres.

A more accurate **eight figure grid reference** can also be calculated, using a map aid called a graticule. This divides the grid squares into accurate tenths, within which you can estimate into quarters again (shown as 2, 5, 7 or 0). The above 6 figure GR 352 227 might then be more precisely estimated as 3522 2270.

Grid north is slightly different from true north, as it is difficult on a flat map to accurately represent the curved surface of the earth. The difference is usually disregarded as it is quite small.

Latitude and longitude

Latitude and longitude are divisions of the earth's surface, taking the full circle of the earth as 360°. Latitude lines are horizontal and parallel on the map, and latitude is measured north or south from the equator, which is taken as 0°. Longitude lines converge at the north and south poles like slices of an orange, however on most topographic maps the amount of convergence is very small. Longitude is measured moving east or west away from Greenwich (near London), which is assumed to be 0°. So the direction must always be shown with latitude (ie, N or S) and longitude (E or W). In Australia, you measure *down first* (away from the equator), *then across from left to right* (away from Greenwich). Eg, Mildura aerodrome is at Latitude S 34° 14', Longitude E 142° 05'. Note this is different from grid references, which are measured across, then up.

On aviation charts, latitude and longitude lines are printed as the main positional reference. However on topographic maps the latitude and longitude are simply indicated at the corners of the map, and at intervals along the edges (and sometimes with small crosses in the body of the map). Note that they are NOT parallel with the map grid. So to estimate latitude on your flying map, you must look at *both* the left and right edges of the map, and allow for any slight difference between them. Then do the same for longitude using the top and bottom edges of the map. You must be able to calculate the latitude and longitude of a location on a topographic map to the nearest minute (1/60 of a degree).

Vertical measurement

Vertical distances are expressed in different terms according to the context (in practice these terms are often used rather loosely):

- **Altitude** is the vertical distance above mean sea level **(AMSL)**. Watch out – aviation charts and your altimeter are calibrated in feet, but topographical maps usually show contours and spot heights in metres!

- **Elevation** is the vertical distance of a particular reference point on or fixed to the earth's surface, measured from mean sea level.

- **Height** refers to the vertical extent of an object above ground level (**AGL**).

Example:
The height of a tower is 350ft AGL. Ground level is 500ft above mean sea level. The *elevation* of the top of the tower is therefore 350 + 500 = 850ft AMSL.
A balloon flying 700ft above the ground at the same point would therefore be at a height of 700ft AGL. Its *altitude* would be 700 + 500 = 1200ft AMSL.

Altimetry

An **altimeter** is simply a very sensitive barometer, as it measures changes in air pressure. As altitude increases, air pressure decreases, due to the fact that there is less weight of air above. The main scale of an altimeter is graduated in feet (or metres) to enable you to read the height of the altimeter above a given point, for example above sea level. A secondary scale (subscale) shows air pressure.

Air pressure is measured in hectopascals (HPa), previously called millibars (mb). As a guide:

1HPa less = 30ft higher (approx.)

At any given location and height the air pressure is not constant, but is gradually changing as the weather systems move through. So an altimeter may read zero feet at sea level one day, while on the next day (if the atmospheric pressure has dropped) it will indicate a height *above* sea level even though the instrument has not been moved.

In order to override this local daily variation, the subscale **pressure setting** is adjusted before each flight so that the altimeter again reads the correct height for the current air pressure.

The pressure setting which causes the altimeter to display the **altitude in feet AMSL** (above mean sea level) is called **QNH**. A balloon altimeter is normally set to **local QNH** or if this is not available the **area QNH** (these are obtained from aviation forecasts). An alternative is to set the altimeter to read the elevation of your launch field just before you take off, which is effectively the same as setting local QNH.

An alternative pressure setting, called **QFE**, causes the altimeter to display the height above a given location, such as an aerodrome or launch field. This setting is not generally used by balloons. ('QNH' and 'QFE' are just convenient 3 letter codes.)

Standard pressure setting (1013.2 hPa) is used by all aircraft above a specified altitude (10,000ft in Australia), to allow long-distance flights to be made without resetting the altimeter frequently. The procedures for using this are given in VFG pages 70-71 (and see Altimeter Settings in the FRP notes in this manual).

Time and date

Time is written using the 24 hour clock, the first two figures being the hour and the last two the minutes, starting at 0000 (midnight) and onwards through 0001 and 0002 etc, ending at one minute to midnight (2359) and then back to 0000 again. 1315 is therefore 1.15pm.

Time and date can be combined as a 6, 8 or 10 figure group. 10.35am on the 13th of April 2002 is shown as 0204131035,

ie, from greatest to least	02	04	13	10	15
	year	month	day	hours	minutes

An 8-figure group simply omits the year (the current year is assumed). A 6-figure group omits the year and month (the current year and month are assumed).

Co-ordinated Universal Time (**UTC**) is calculated from zero longitude at Greenwich, and was previously called Greenwich Mean Time. UTC can also be abbreviated as **Z** in meteorological messages. Aviation information and forecasts are given in UTC unless shown otherwise, so you must be able to convert UTC to local time and vice versa.

Local standard time sectors in Australia are Western, Central and Eastern Standard Time (UTC plus 8, 9.5, and 10 hours respectively). So 0200Z plus 9.5 hours equals 1130CST (often spoken as 'eleven-thirty local').

Daylight

Daylight is defined as the period from **first light** (the beginning of morning civil twilight) until **last light (**the end of evening civil twilight). **Night** is the rest of the time. Balloons may fly between first light and last light provided there is sufficient visibility (see below).

First light and last light for any location can be calculated from the tables printed in AIP or VFG, given the date and the latitude and longitude of the location. You calculate the time for the precise location, then adjust this to UTC, then to local standard time. See explanation and examples in AIP, VFG or the Trevor Thom book –you must be able to do this calculation.

Notes:

1) **Visibility** may be reduced by factors such as cloud cover, high terrain to the east (affecting first light) or the west (last light), dust, haze, fog, etc. Do not assume it is automatically OK to take off at first light, or keep flying till last light – you must also have the minimum legal visibility (see VMC in the FRP section of this manual).
2) Sunrise, sunset and civil twilight times for any date and any location are calculated for you on www.ga.gov.au/geodesy/astro, but you cannot use this in the exam!

Conversions

You must know these conversions which are useful for ballooning:

1kg = 2.2 lbs
1NM = 1.85km
Metres multiplied by 10 and divided by 3 gives feet.

Also useful:

5 statute miles = 8km
Temperature in °F minus 32, then divided by 9 and multiplied by 5, gives °C
See AIP or VFG for other conversions.

Calculations

The calculations required in the NAV exam are fairly straightforward, however if you are one of the many people who do not find calculations easy, it may help to use the following 'square' system.

1. Put each step of the question into simple terms, to be clear what you are trying to find out. Eg, 'the balloon descends at 700 feet in 3 minutes, so how many feet will it descend in 11 minutes?'
2. Write the figures into four corners of a square, putting an 'A' in place of the answer you want to find, as shown below. Make sure the units (eg feet and minutes) are the same in each line – don't put minutes in one and hours in the other!

(feet)	(minutes)
700	3
A	11

3. Starting at A, move around the square (in either direction, it makes no difference). **Take the first figure** you come to, **divide it by the next figure** and **multiply it by the third** (you can use a calculator). So in this example,

A = 700 divided by 3 multiplied by 11
= 2567 feet

A more complex calculation is usually just a few steps; the system above can often be used for each step. The 'square' system is shown for the following calculations.

Ground speed and fuel use

<u>To calculate wind speed in knots (ie how many nautical miles in one hour)</u>

Question: You launch at 0830, and at 0840 you fix your position 2NM away. What is the wind speed?

Set up the square:

(NM)	(minutes)
2	10
A	60

10 minutes is the time from 0830 to 0840.

A = 2 divided by 10 multiplied by 60
= 12 NM (in one hour)
ie 12 knots.

To convert this to km/hour, you can set up another square for the next step, using the conversion 1NM = 1.85km.

(NM)	(km)
1	1.85
12	A

A = 12 divided by 1 multiplied by 1.85
= 22.2 km

So a speed of 12 knots will be the same as 22.2 km/hr.

<u>To calculate fuel use (eg, how many litres in one hour, or how many minutes a certain number of litres will last)</u>.

Question: You launch with a total of 90 litres of fuel. After 20 minutes you estimate there are 75 litres remaining. How many litres will you use in one hour? How much longer can you fly if you are to land with 30 minutes of fuel still remaining?

Step 1:

(litres)	(minutes)
15 (90 – 75)	20
A	60

A = 15 divided by 20 multiplied by 60
= 45 litres per hour

Step 2:
The total flight time if all 90 litres of fuel is used is found from the following square. Use the same basic information as above that 15 litres lasted 20 minutes.

(litres)	(minutes)
15	20
90	A

A = 20 divided by 15 multiplied by 90
= 120 minutes

Total time to zero fuel is therefore 120 minutes. You have already been flying 20 minutes, and you must land 30 minutes before getting to zero fuel, so your remaining flight time is

120 minus 20 minus 30 = 70 minutes.

Rate of climb or descent

<u>To calculate rate of climb (or descent) using time</u>

Question: What rate of climb is required to ascend 2,000ft in 5 minutes?

(distance in ft) (time in mins)

2000	5
A	1

A = 2000 divided by 5 multiplied by 1
= 400 feet (in one minute)
ie 400 ft/min

<u>To calculate rate of descent using distance left to fly and wind speed</u>, more steps are required. You still need to end up with an answer in feet per minute, and to find this you need to know how many feet you need to descend in how many minutes.

Question: You are flying at 3,200ft AMSL, and you want to land at a point 2 miles ahead where the ground level is 200ft AMSL. What rate of descent will be required to achieve this if the wind speed is 12 knots?

Step 1: How many feet? You must descend from 3,200AMSL to 200AMSL. The distance to descend is therefore 3,200 minus 200 = 3,000 feet.

Step 2: How many minutes? You are travelling at 12 knots (12 miles in one hour), and you can travel 2 miles. Set up the square to calculate the time.

(miles)	(minutes)
12	60
2	A

A = 2 divided by 12 multiplied by 60
= 10 minutes

Step 3: Set up the square again to calculate the descent rate required to drop 3000 feet in 10 minutes. (You may not need the square for this one.)

(feet)	(minutes)
3000	10
A	1

A = 3000 divided by 10 multiplied by 1
= 300 feet (per minute).

GPS

Many pilots now carry a GPS (Global Positioning System), an instrument which uses satellite signals to locate its position anywhere on the earth's surface to within a few metres. A GPS can be a useful navigational aid, but *it is not a substitute* for a thorough knowledge of navigation theory and practice, and may not be used in the private pilot flight test.

It takes only a few minutes to learn how to read your position, track and speed with a GPS. With a little more practice it may also be used to show bearing, distance and estimated time to a competition goal, to warn if you are close to an SZ, or to give a grid reference for where you have landed (in case you are unsure of your map-reading).
A GPS is best left switched on during flight as it takes several minutes to warm up.

