GROUND SCHOOL

NAVIGATION I

1

GROUND SCHOOL

LECTURE ONE: MAPPING A SPHERE – NAVIGATIONAL THEORY

1. Form of the Earth – axis, latitude, longitude, hemispheres
2. Chart Projections – Mercator, Peters, Lambert
3. Scale
4. Measurement of Direction
5. Plotting Position – latitude and longitude
6. UK CAA VFR Chart analysis
7. Time and Navigation

2

GROUND SCHOOL

FORM OF THE EARTH: BASICS

In order to begin navigating, the earth needs to be segmented so we can express our position upon it

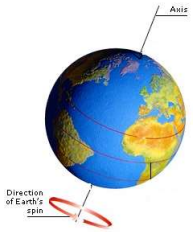
Many of these terms have been used since pre-Greek times by those exploring and mapping the earth

As pilots, you need to know the basics...

3

FORM OF THE EARTH: BASICS

GROUND SCHOOL



The earth spins about its AXIS which is slanted at an angle of approximately 23.5°

This slant is what leads to the earth having seasons

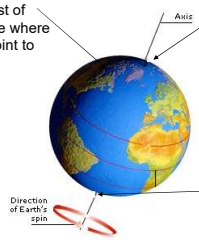
4

FORM OF THE EARTH: BASICS

GROUND SCHOOL

The magnetic NORTH POLE (north east of Canada) is the place where a compass will point to

The NORTH POLE



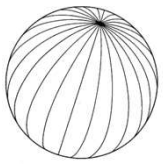
The SOUTH POLE lies at the opposite axis of the earth

Different types of north pole will be discussed later...

5

FORM OF THE EARTH: BASICS

GROUND SCHOOL



Cartographers (map-makers) then draw lines of equal length running from the north to south pole - LINES OF LONGITUDE

There are 360 lines of longitude – known as MERIDIANS

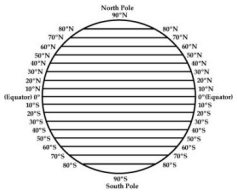
These are split into two – 180 lines (degrees) of east longitude and 180 lines (degrees) of west longitude …

… all based east or west of the PRIME MERIDIAN at Greenwich, London (or Paris if you're French!)

6

FORM OF THE EARTH: BASICS

GROUND SCHOOL



Lines running east-west are then drawn on the globe – LINES OF LATITUDE

There are 180 lines (degrees) of latitude – known as PARALLELS

These are split into two – 90 lines (degrees) north and 90 lines (degrees south) …

… all based north or south of the EQUATOR (0° line)

Not me!

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FORM OF THE EARTH: BASICS

GROUND SCHOOL

Lines of longitude and latitude are expressed in terms of :

DEGREES and MINUTES
e.g. N51˚34' W143˚17'

DEGREES and DECIMAL DEGREES
e.g. N62.05 E074.23

DEGREES and DECIMAL MINUTES

e.g. N73˚43.5' W123˚23.6'

There are 60 minutes in a degree …

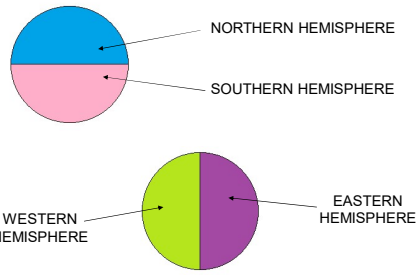
… and 60 seconds in a minute

8

FORM OF THE EARTH: BASICS

GROUND SCHOOL

We can then split the earth into big sections, or HEMISPHERES



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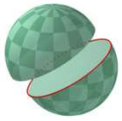
FORM OF THE EARTH: BASICS

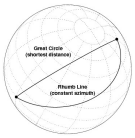
GROUND SCHOOL



A GREAT CIRCLE is any line that cuts the earth into two equal parts (this will become important in ATPL exams)

An example of a great circle is the equator or any line of longitude

A SMALL CIRCLE is any line that cuts the earth but does not cut through the centre



A RHUMB LINE is a line which crosses all meridians of longitude at the same angle

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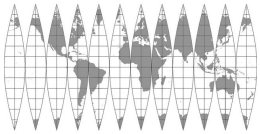
MAPPING THE EARTH: PROBLEMS OF A SPHERE

GROUND SCHOOL

Unless we're going to carry a globe around in the cockpit with us, we need to convert information onto a flat piece of paper

If we "cut" the earth into orange segments and lay each flat we will get a perfect representation but it will be difficult to use at the junctions of areas



Cartographers use different PROJECTIONS to get a best-worst result

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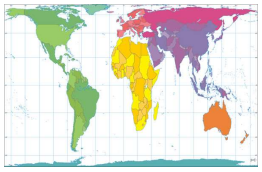
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL

Any projection trying to map a sphere onto a flat piece of paper will distort the result in some way or another

The MERCATOR projection is familiar to most but distorts the relative sizes of continents – Europe is much larger than it should be



The PETERS projection shows the continents in their correct relative sizes but with the wrong actual shapes

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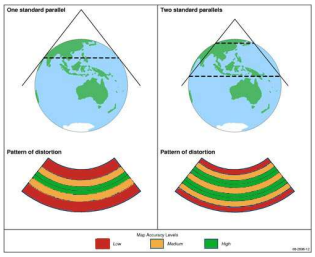
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL



On any projection there will be points on the map that are completely accurate. These are known as STANDARD PARALLELS

The more standard parallels that a map-maker can use, the more accurate the map will be

There are 3 main types of projection used:

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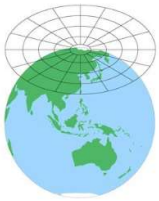
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL

AZIMUTHAL PROJECTION

Flat piece of paper at one point on earth (usually a pole)

Directions can only be measured from the central point and not between other points



Not used often but used in the United Nations map (left) due to its lack of importance to any one geographical area

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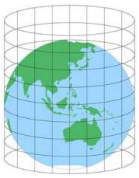
MAPPING THE EARTH: PROJECTIONS

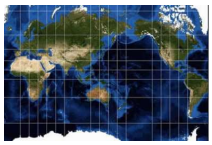
GROUND SCHOOL



CYLINDRICAL PROJECTION

Paper rolled around earth so that it has a constant contact around one parallel (usually the equator)

Good for mapping equatorial regions and lines of longitude and latitude are shown at right angles. Shapes are correct but size is distorted



The Mercator chart is a cylindrical projection

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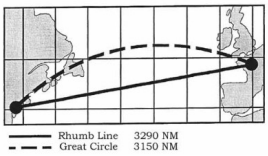
MAPPING THE EARTH: PROJECTIONS (CYLINDRICAL)

GROUND SCHOOL



On such a chart the shortest distance between two points (great circle) will be a curved line

This makes it a difficult chart to use for navigation

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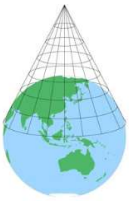
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL

CONICAL PROJECTION

Paper is rolled into a cone and placed over the globe. The paper touches in two sections

"Fan" shaped map if used for large areas, correct at two points but distortions occur away from these

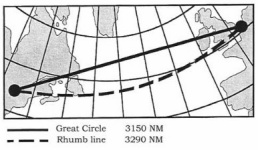


Generally used in mid-latitude areas and for national or regional maps only

17

MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL



On a conical projection a great circle is represented by a straight line

This makes it much easier to measure angles and distances

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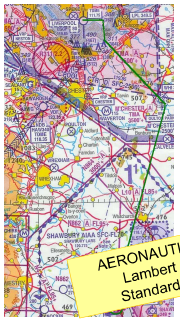
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL



So... Every map or chart you will see will tell you the type of projection it used and the standard parallels.

Have a look at the legend for your current CAA VFR chart...

AERONAUTICAL CHART ICAO 1: 500 000
Lambert Conformal Conic Projection
Standard Parallels 49° 20' and 54° 40'

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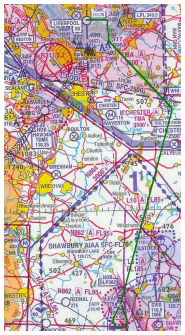
MAPPING THE EARTH: PROJECTIONS

GROUND SCHOOL



Advantages:

1. Accurate along 2 standard parallels
2. Angles are generally accurate (conformity)
3. Shapes are correct
4. Can be used to approximate the great circle (shortest distance) between two points)

Disadvantages:

1. Becomes more inaccurate away from the standard parallels
2. Angles become less accurate when measuring a long line

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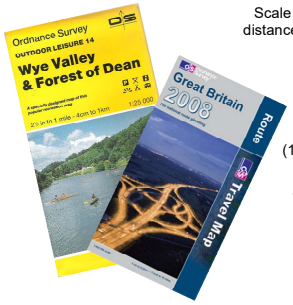
MAPPING THE EARTH: SCALE

GROUND SCHOOL



Scale indicates the relationship between a distance on a map and the actual distance on the ground

Usually expressed as a ratio

e.g. 1:100 000
(1 cm represents 100 000 cm (1 km))

The smaller the scale, the smaller the piece of paper will be to represent a given area

A scale of 1:250 000 is a larger scale than 1:500 000

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MAPPING THE EARTH: SCALE

GROUND SCHOOL

Somewhere on the chart will also be a graphical scale

NEVER photocopy a map and then try to measure distances – they will have been distorted by the copying process

You can also use the latitude scale on the chart – one degree of latitude is equal to 60 nm

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MAPPING THE EARTH: DISTANCE

GROUND SCHOOL

When measuring distance ALWAYS ensure that you use the correct scale ruler

Most aviation rulers have two scales – 1:250 000 and 1: 500 000

We will be using nautical miles (nm) but you could also use the legend scales for measurements in statute miles or in kilometres

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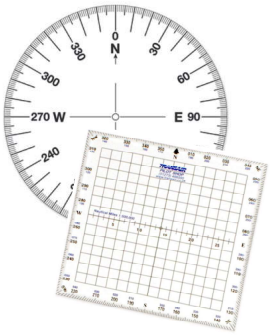
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL



Direction is expressed in degrees (°)

The circle is split into 360°

We can measure direction on a chart using a protractor (more of which later)

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MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

Being able to ascertain directions from a map or chart is very important

Not as simple as it sounds!

Maps are generally aligned to "true north" – the north pole

Compasses point to the magnetic north pole

The difference is VARIATION and it may be significant!

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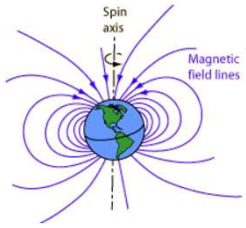
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL



The earth has magnetism caused by the internal iron core spinning

A compass will always point to the magnetic north pole

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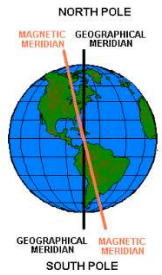
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL



The problem is that the magnetic north pole is always moving…

The magnetic north pole is currently north of Canada

One day the poles will suddenly reverse – we are about 300,000 years overdue for this occurring

Another good reason to always have an up-to-date chart!

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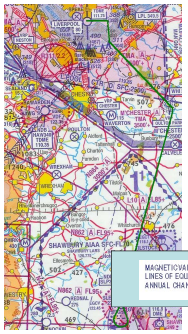
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL



Have a look at the legend to your CAA VFR chart and find the variation information...

The dashed lines on the chart show lines of equal magnetic variation and are known as ISOGONALS

The AGONIC LINE marks the position of zero magnetic variation

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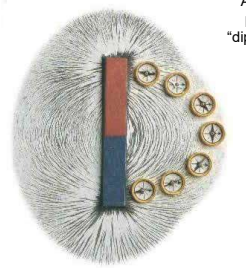
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL



As a compass gets physically nearer to any point where the magnetic field of the earth "dips" into the ground, it will become less useful

This is because the compass needle will also try to "dip" into the ground

The compass will indicate poorly and is generally useless in latitudes above 60° north or south

We have already discussed compass errors due to dip in the Aircraft General Knowledge lectures

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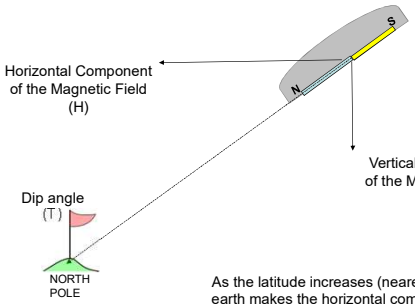
MAPPING THE EARTH: DIRECTION - DIP

GROUND SCHOOL



As the latitude increases (nearer to the pole) the earth makes the horizontal component decrease and the dip angle therefore increases

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MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

N	30°	60°	E	120°	150°
001°	029°	060°	089°	120°	152°
S	210°	240°	W	300°	330°
181°	212°	240°	268°	301°	330°

Compass Correction Card

It is very important to know how much interference the compass is subject to in an aircraft

The compass will be "swung" to calculate errors due to it being inside a metal box with lots of electrical equipment nearby

In this way known errors can be accounted for by the pilot

These errors are known as DEVIATION

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MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

So many errors... How do we know which direction to go in!?

CHART
Measure direction using a protractor (always measure in the middle of the track for long distances) to give true track

LEGEND Apply the correct amount of variation to get the magnetic track

N	30°	60°	E	120°	150°
001°	029°	060°	089°	120°	152°
S	210°	240°	W	300°	330°
181°	212°	240°	268°	301°	330°

Compass Correction Card

AIRCRAFT
Apply the correct amount of deviation to get the compass track

FLY
As accurately as possible – don't make all that hard work worthless!

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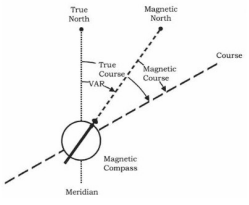
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

Variation can be "east" or "west"



EAST VARIATION

Magnetic North lies to the east of true north

The magnetic track will be less than the true heading

For example, true track is 045° but the magnetic heading is 040°

"VARIATION EAST, MAGNETIC LEAST"

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MAPPING THE EARTH: DIRECTION

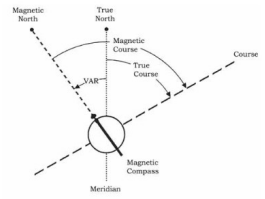
GROUND SCHOOL

WEST VARIATION

Magnetic North lies to the west of true north

The magnetic track will be more than the true heading

For example, true track is 045° but the magnetic heading is 055°



"VARIATION WEST, MAGNETIC BEST (MORE)"

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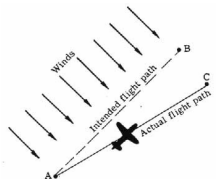
MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

Of course, we can't just fly that direction because the wind will blow us off course, but more of that in another lecture!



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MAPPING THE EARTH: DIRECTION

GROUND SCHOOL

Compass Heading +/- Deviation = Magnetic Heading +/- Variation = True Heading

C +/- D = M +/- V = T

or
"Cadbury's Dairy Milk is Very Tasty"
or
"True Virgins Make Dull Companions"

Once you have your true heading, you then need to apply drift to obtain the actual track you will fly

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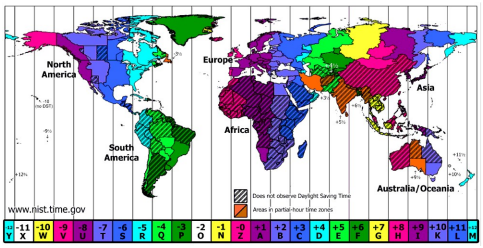
GROUND SCHOOL

TIME: THE NEED FOR STANDARDISATION

If all countries used their local time the result would be very confusing for international flights



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GROUND SCHOOL

TIME: THE NEED FOR STANDARDISATION

For aviation Greenwich Mean Time is used

Known as Coordinated Universal Time (UTC) or as Zulu time

"Zulu" time is less used now than previously (politically correct?)

Meridians to the west of Greenwich are behind UTC by 1 hour per 15° of longitude)

Meridians to the east of Greenwich are ahead of UTC by 1 hour per 15° of longitude)

There are some exceptions

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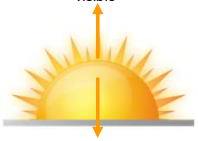
GROUND SCHOOL

TIME: SUNRISE AND SUNSET

Sunrise
The time at which the sun is first visible from the surface – the "upper limb" becomes visible



Sunset
The time at which the sun is first not visible from the surface – the "upper limb" goes below the horizon

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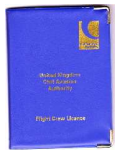
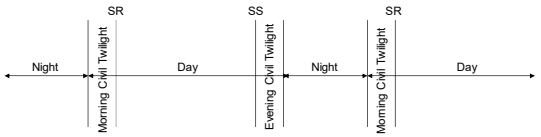
GROUND SCHOOL

TIME: SUNRISE AND SUNSET



A pilot with a PPL with no night rating must NOT fly later than 30 minutes after sunset and NOT earlier than 30 minutes before sunrise

This roughly equates to "CIVIL TWILIGHT" which is when the centre of the sun's disc is 6° below the horizon (either travelling upwards or downwards)



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GROUND SCHOOL

Lecture complete

Any questions?

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