



*air cadet publication*  
*instructors guide*

*basic navigation*



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## **Basic Navigation**

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# CHAPTER 1

## BASIC NAVIGATION

### ***What is navigation all about?***

1. Good navigation is all about knowing where you are on a map, where you want to go and choosing the best route to follow in order to get there. It combines good map reading skills and good compass work.
2. Navigating is a skill that if done well can bring a great deal of personal satisfaction- so practice as much as you can. On expeditions, never leave the navigation totally to others. It is always good practice to involve yourself in checking your position and route, even if you are not leading or navigating for the group. Your aim should be to know exactly where you are on the map at any time.

### True North or Grid North?

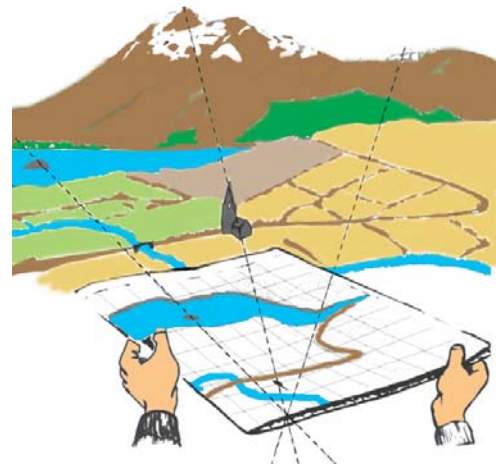
### ***The difference between true north and grid north***

3. You will already have read about the National Grid being a network of lines placed over a map of the British Isles as a sort of indexing system. On any OS map the grid lines enable you to identify a small area of ground by its Grid Reference.
4. These grid lines differ from lines of latitude and longitude in that they cover a flat surface (the map) and so are regular. Lines of latitude and longitude cover the curved surface of the Earth with lines of longitude getting closer and closer together as they approach the north and south poles.
5. Because of this difference between these 2 sets of lines, grid lines do not actually point to the north pole of the Earth (True North) - instead they are said to point to an imaginary point called Grid North. The actual difference between the two norths varies depending on where in the UK you are but is normally no more than 2°.
6. In navigation you must always use Grid North as your reference, True North has no real significance as far as your map is concerned.

### Setting or Orientating your map

### ***Orientating your map by eye***

7. One of the first things you must try doing when using a map is to relate the features on the map to the ground that you can see in front of you. To help you do this you must turn the map in such a way that identifiable features on the ground are in their correct position relative to the map.



**Fig 1-1** Setting the map to match features on the ground.

8. If you are following a path or a river simply turn the map until the path or river lines up with the direction you are walking in. It should now be relatively easy for you to see changes in direction, junctions and the appearance of features which will confirm your actual position. Walking with the map set takes a little getting use to but it should help to pin point your position at any time.

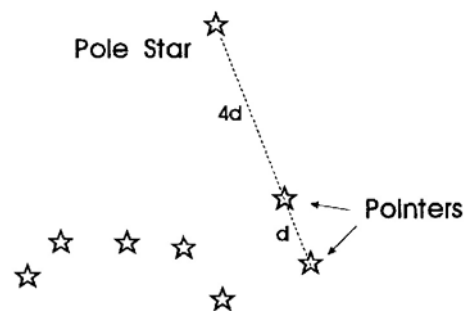
Finding North without a compass

**3 methods of finding north without a compass**

9. If you find it difficult to set the map using features on the ground, it may help to know where North is. If you have a compass then the task is easy but without a compass determining North is a little more difficult. You can however, get a rough idea of where North is by using one of the following simple techniques.

The Pole star

10. In the northern hemisphere the direction of the north pole is indicated by the position of the Pole star. This can be found by following the pointers in the group of stars known as the Great Bear or Plough.

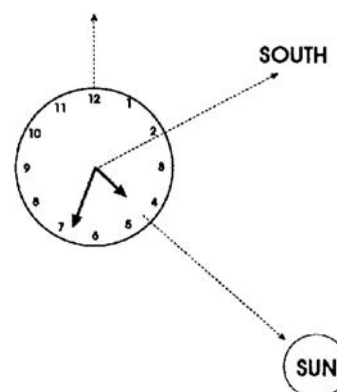


**Fig 1-2** Finding true north by using the star constellation of the Plough.

### Using a watch

11. If you can see the sun, hold your watch horizontally with the hour hand pointing at the sun. Now bisect (halve) the angle between the hour hand and the 12 o'clock position. This line points due south. In British Summer Time (Apr - Oct) bisect the angle between the hour hand and the 1 o'clock position.

**Fig 1-3** Orienting yourself using a watch

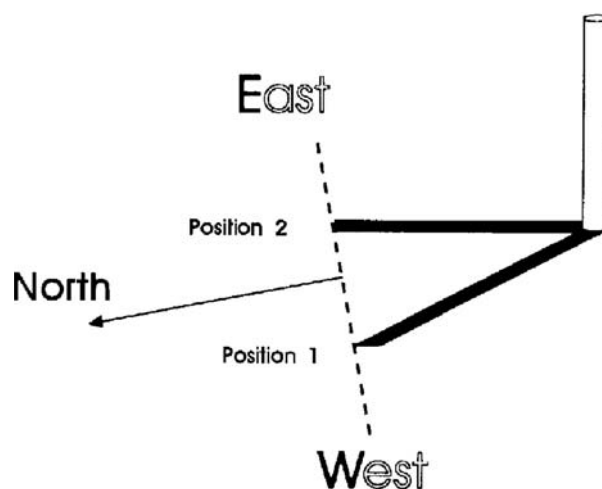


If you only have a digital watch, draw a little diagram of a watch with hands showing the correct time and use that instead.

### The shadow method

12. Before you can use this method the sun must be shining sufficiently to cast shadows. Place a stick upright in the ground and mark the end of its shadow using a small stone. Wait for 10 -15 minutes and use a second stone to mark the new position of the stick's shadow. A straight line between the two markers runs roughly west to east.

**Fig 1-4** Using the movement of a shadow to find north

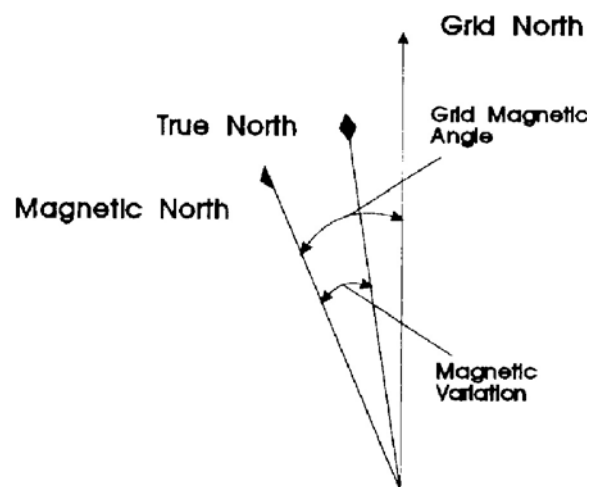


## Magnetic North

### **Magnetic Variation**

13. The earth behaves like a giant magnet with its own magnetic field. A free moving magnetic needle will align itself with the earth's magnetic field and point in a north/south direction. Unfortunately the magnetic north pole does not coincide with the geographical north pole of the earth (true north)- in fact it is to be found in Canada, somewhere north of Hudson Bay. In the British Isles the magnetic north pole is presently between 3° and 5° west of true north.

*Fig 1-5 The 3 North Poles as shown on an OS map (The angles have been exaggerated for clarity)*



This magnetic variation as it is called is different in different parts of the world. In the Alps for example, it is 1 or 2 degrees west. In some areas of the world magnetic north is east of true north. The magnetic variation must be allowed for when using a map and compass for navigating. To help you, the magnetic variation is always displayed on the bottom of an OS map.

14. One further complication is that the magnetic north is not fixed. It moves very slowly and changes its position a little every year. This movement can be predicted and adjustments made to compensate. This information is also to be found at the bottom of your map.


## Grid Magnetic Angle

### **Grid Magnetic Angle**

15. Because all your compass references will be made to either grid north or magnetic north, the angular difference between these 2 norths must be known. This difference is called the Grid Magnetic Angle (GMA) and is displayed on every OS map in the centre of the top margin.

## Sample Questions

***Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.***

1. The difference between true north and grid north arises because:
  - a. Lines of latitude and longitude match grid lines exactly.
  - b. Lines of latitude and longitude do not match grid lines exactly.
  - c. Grid lines get closer together near the poles of the Earth.
  - d. Lines of latitude are not parallel.
  
2. The symbol represents.
  - a. True north.
  - b. Grid north.
  - c. Magnetic north.
  - d. Actual north.
  
3. The angular difference between magnetic north and true north is called.
  - a. Variation.
  - b. Deviation.
  - c. Resection.
  - d. Orientation.
  
4. Positioning your map to relate to features on the ground is called:
  - a. Ranging the map.
  - b. Setting the map.
  - c. Sighting the map.
  - d. Organising the map.
  
5. Which north changes its position slightly over the years?
  - a. True north.
  - b. Grid north.
  - c. Magnetic north.
  - d. Actual north.



## CHAPTER 2

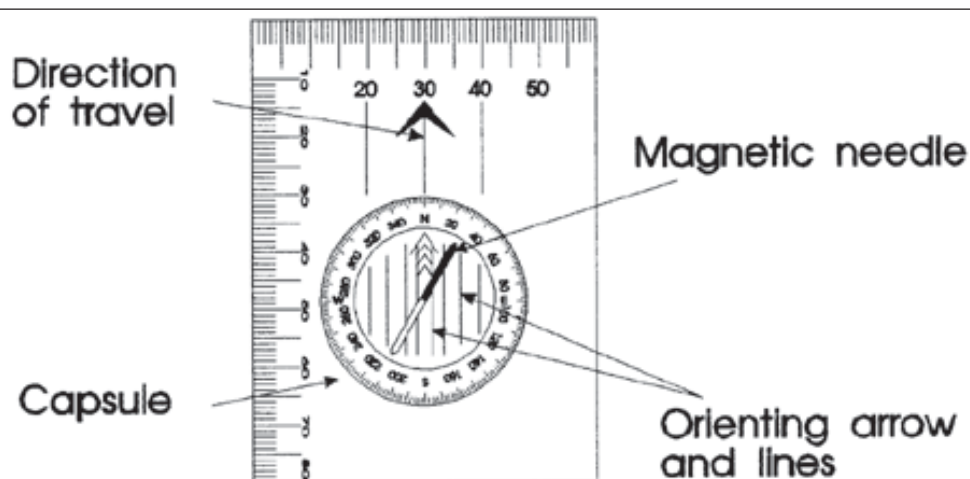
### THE COMPASS

#### **Silva Compass**

1. There are many different varieties of compass available to the walker. The Silva range seems to be the most popular and so this is used as a model for this publication. At first sight there seems a bewildering array of numbers and scales - do not worry, it will all become clear later. Initially we will look at the basic direction finding features.

2. The diagram shows the basic compass with a free moving magnetic needle - half red (points north) and half white (points south). The needle is housed in a transparent capsule which has 360 degrees marked around the rim and orienting lines marked on its base. It also has a large north-south arrow marked on the base. The capsule should be relatively easy to turn and may be filled with a liquid which "damps" the compass needle so that it settles down quickly.

3. A compass is a precision instrument and as such requires careful handling if it is to work properly. Try not to drop it and always store it away from electrical items containing strong magnets such as TV sets, telephones, doorbells, etc. After a period of time you may find that your compass develops a small air bubble in the capsule. This should not prevent you from using it as long as the bubble does not get too big.



**Fig 2-1** The basic compass

## Deviation

### **Magnetic deviation**

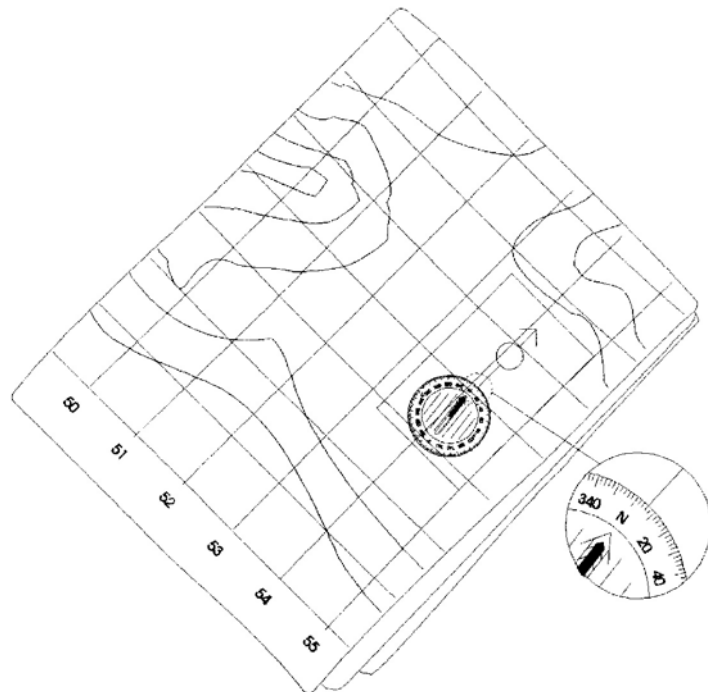
4. Since the compass needle is a small magnet it will be affected by ferrous metals placed close by. Your compass needle will be deviated from its true position if objects such as metal badges, watches, cameras, wire fences are too close to it - so take care when using your compass.

### **Setting the map**

#### Setting the map with a compass

5. In the previous chapter we mentioned the value of setting the map, to make it easier for you to identify features and follow a planned route. If you cannot readily set the map using observable features you can set it with your compass.

**Fig 2-2** Setting your map with a compass



- a. Turn the compass capsule until the grid magnetic angle (GMA) is set against the direction arrow ( say  $6^\circ$ ).
- b. Place the compass onto the map so that the long edge of the compass matches the N-S grid lines and the direction of travel arrow points to the top of the map.
- c. Turn the map and compass TOGETHER until the compass needle falls inside the orienting arrow - red end pointing North.

6. Your map should now be correctly set and you can use it to identify features on the map with the real features on the ground.

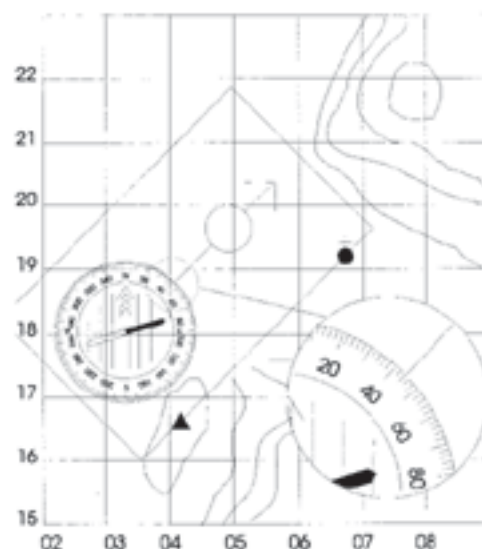
### Setting a compass heading

#### **Compass bearings**

7. Picture yourself at the trig point at GR 042 166 on the map, planning to walk to the church at GR 067 192, but unable to see the church from your position. You will need to work out a compass heading.

8. Place the compass on the map with its long edge running through both points and the direction of travel arrow pointing in the direction you wish to travel. You do not need to set the map for this operation.

**Fig 2-3** Turn the capsule so that the orienting lines are parallel to grid lines



9. Hold the compass plate firmly in this position and turn the compass capsule until the orienting lines on its base are parallel to the north-south grid lines and the orienting arrow points to the top of the map.

10. The compass now registers the number of degrees between grid north and your intended direction of travel. In this case  $44^\circ$ . To find out what your actual direction of travel should be, you will need to add the GMA (say  $6^\circ$ ) - so turn the compass capsule to add another  $6^\circ$  to make the reading  $50^\circ$ .

11. Remove the compass from the map. Hold it in front of you so that it is level and the direction of travel arrow points away from you. Rotate your body until the magnetic needle falls within the orienting arrow on the base of the capsule - red end pointing north.

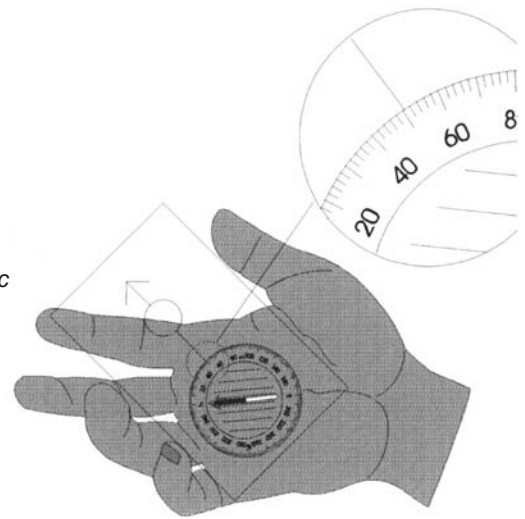
The direction of travel arrow should now be pointing directly at the church that you want to walk to.

12. To help you remember to add on the GMA when taking a bearing from a map with a westerly magnetic variation, remember the phrase

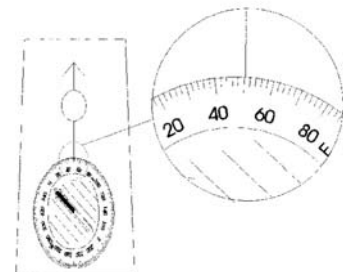
GRID to MAG - ADD

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**Fig 2-4** Turn your body so that the magnetic needle falls inside the orienting arrow.



**Fig 2-5** Turn the capsule so the magnetic needle falls inside the orienting arrow.



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Walking on a bearing

**Walking on a bearing**

13. You should always try to avoid walking while staring at your compass. Instead, you should look along the direction of travel and pick out some feature in the far distance - possibly on the horizon, and walk to that.

14. If the visibility is poor you may find it difficult to pick out a distant feature to line up on. In this case, sight on an object at the limit of your visibility, a rock, a tussock of grass, a bunch of reeds and walk towards that. As you approach your chosen object, others will appear behind it and in line with it. Use these continually appearing objects to do your straight line compass march.

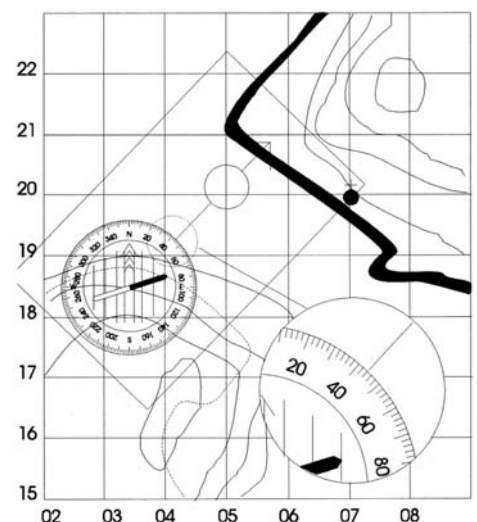
### Compass to map

#### ***Transferring from compass to map***

15. You will often find it useful to take a compass bearing and convert it to a map bearing, for example to identify a feature or to help pinpoint your position. Imagine that you are on the path at GR 051 179 on the map below and you see a church in the distance that you want to identify on the map. This is what you must do:

- a. Point the direction of travel arrow at the distant church.
- b. Hold the compass in this position and turn the capsule until the orienting arrow lies directly beneath the north end of the compass needle. This gives the magnetic bearing.
- c. Now turn the capsule to deduct the GMA ( $6^\circ$ ). This now gives the grid bearing.
- d. Place the compass on the map (you do not have to set the map) with its long edge passing through your present position, on the path at GR 051 179. DO NOT TURN the capsule.

**Fig 2-6** Rotate the compass (not the capsule), to get the orienting lines parallel to the grid lines.



e. Pivot the whole compass around your position until the orienting lines are parallel to the north-south grid lines and the orienting arrow points to north on the map.

f. The edge of the compass that runs through your position should now run through, or point at, the symbol for a church. This should be the church you can see in the distance.

16. To help you remember to deduct the grid magnetic angle (GMA) when taking bearings on features and finding them on the map, remember the phrase:

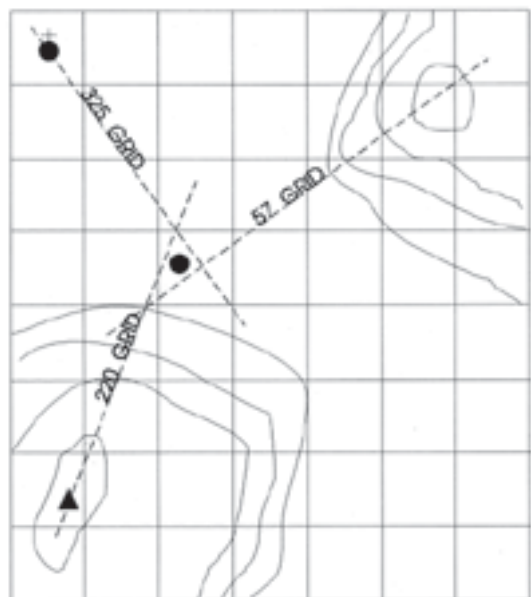
MAG to GRID - get RID

Resection

**Finding where you are**

17. If you have only a vague idea of where you are on the map and you wish to determine your position more accurately, then you could try resection. Before using this technique however, you should be able to identify at least 3 features on the ground around you, the edge of a wood, a church, a hill, etc.

18. Taking each feature in turn, take its compass bearing, convert it to a grid bearing and plot its position on the map, as explained above. Draw a faint pencil line along the long edge of your compass so that it passes through the known feature. Repeat this for the other 2 features and the point where all 3 lines cross marks your position.



**Fig 2-7** Your position is the centre of the triangle.

It is unlikely that the 3 lines will meet at a point, in which case you take your position as being near the centre of the triangle so formed.

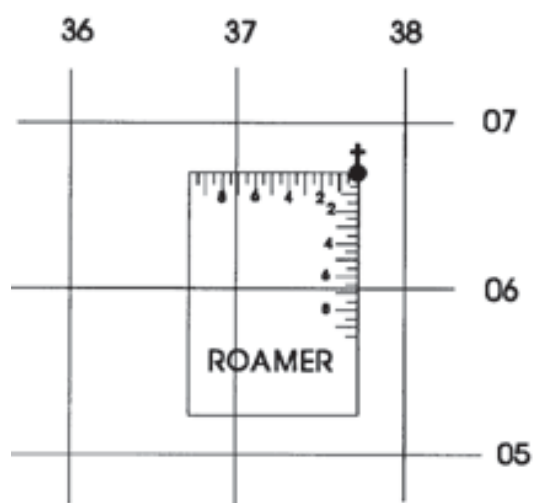
19. If you are standing on a path marked on a map or next to a river, but you are not sure exactly where, taking a bearing on only one feature may be enough to determine your position accurately, as long as the bearing on the feature does not cut the path or river at a shallow angle.

### Scales and Roamers

#### **Using a Roamer**

20. Around the edge of your compass you should find a variety of different ruler markings to help you measure distances on a variety of maps. You may also see 2 or more roamers for use with different scaled maps. A roamer can be used to find a 6 figure grid reference more accurately than by estimation. Place the corner of the correct roamer on the map feature whose reference you want, then read from where the scales intersect the grid lines - eastings first. Always read the nearest low figure (SW corner).

**Fig 2-8** Read to the lowest number



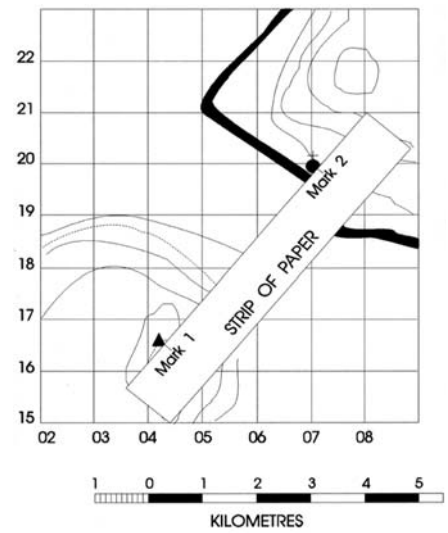
21. It is important that you check that the roamer you are using is of the correct scale for the map.

### Measuring distances on a map

#### **How to measure distances**

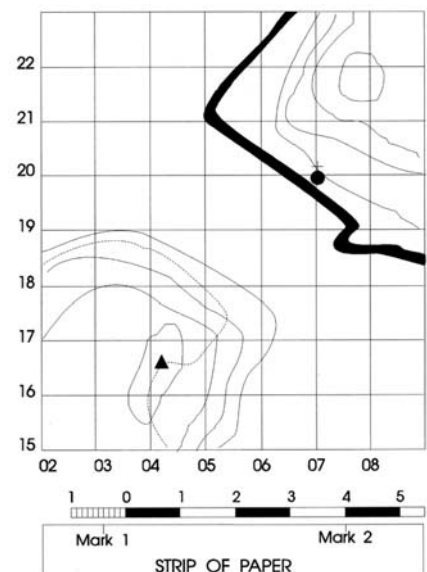
22. The best way to measure distance on a map is to use a pair of dividers. Measure the distance between 2 features on the map by opening the dividers to touch each feature and then transfer this measurement onto the scale at the bottom of the map. Care must be taken not to puncture the map with the divider points.

23. Alternatively, you can use a straight edge of paper as a temporary ruler. Place the piece of paper between the 2 features on your map and mark their position on the paper.



**Fig 2-9** Mark the position of the 2 features

24. Now place the straight edge of paper with the 2 marks onto the scale at the bottom of the map and read the actual distance. The scale lines on your map all have the unit to the left of the zero sub-divided into tenths. By placing your paper on the scale so that the right hand mark is on a whole number of units, the second mark should fall on the tenths to the left of the zero.



**Fig 2-10** Place the right hand mark on a whole number

## Sample Questions

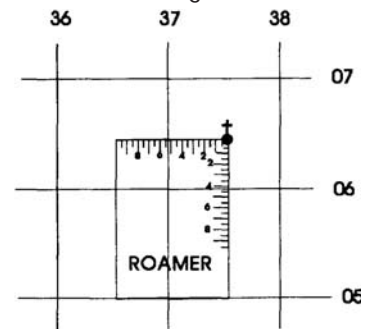
***Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.***

1. A grid bearing from a M726 series map can be converted to a magnetic bearing by:

- Adding the angular difference between grid north and true north.
- Subtracting the angular difference between grid north and true north.
- Adding the angular difference between magnetic north and grid north.
- Subtracting the angular difference between magnetic north and grid north.

2. The 6 figure GR shown would be:

- 375064
- 064375
- 376065
- 065376



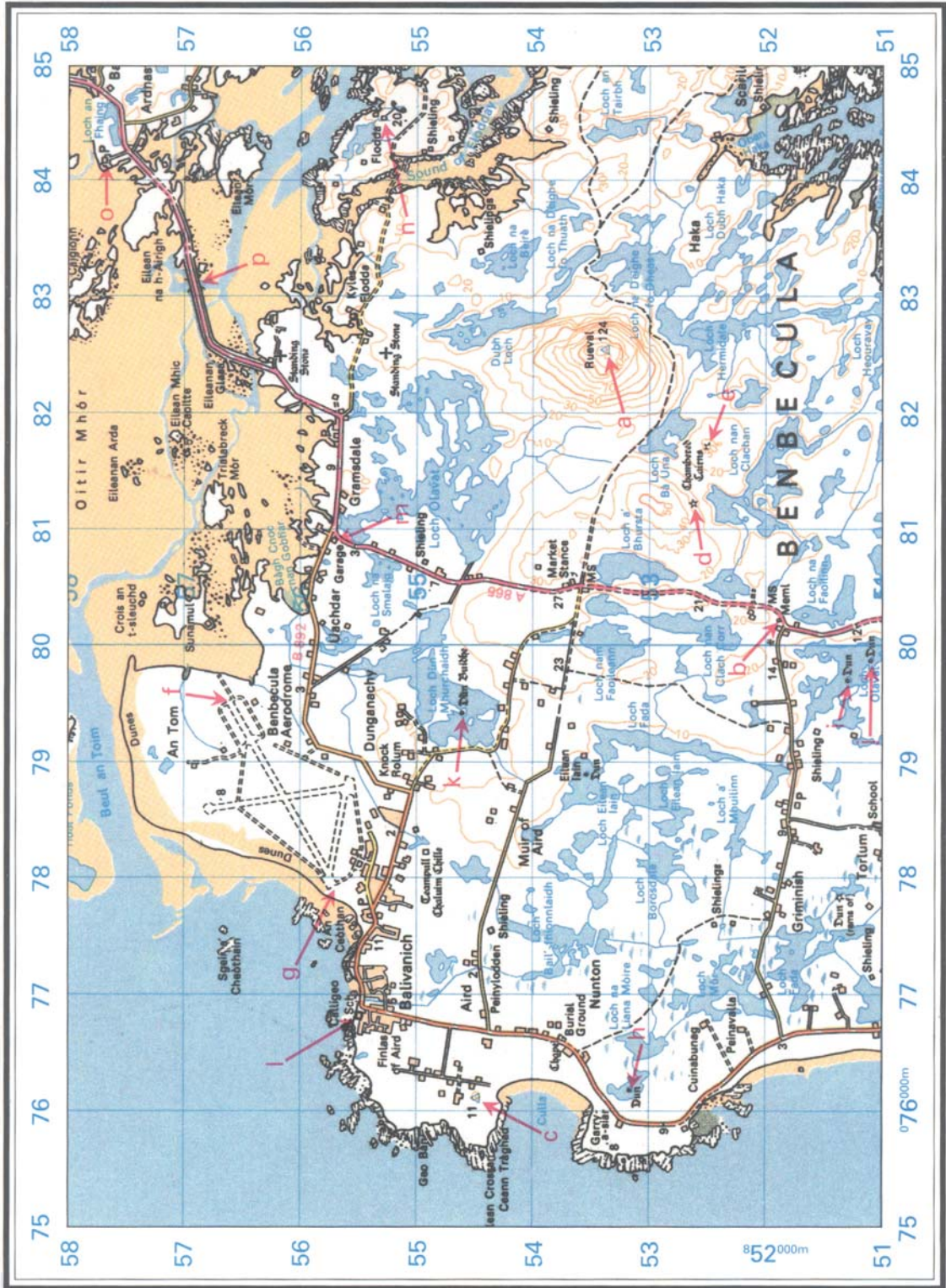
3. The capsule of a Silva compass is often filled with a liquid to:

- Prevent the needle from moving.
- Increase the needle's sensitivity.
- Allow the needle to settle down quickly.
- Allow the needle to be seen more clearly.

4. When using a compass to take a bearing on a distant object, you would first of all:

- Point the direction of travel arrow at the object.
- Align the red compass needle to point at the object.
- Turn the capsule so that the orienting arrow points at the object.
- Turn the capsule to subtract the GMA.

Cover this map with tracing paper before drawing any lines - and use pencil only



## Bearings

For this exercise the Grid Magnetic Angle (GMA) is  $6^\circ$ .

1. What are the grid bearings between the following points?

a to b

d to e

h to i

l to m

a to p

2. What are the magnetic bearings between the following points?

c to a

f to g

j to k

n to o

3. What is the magnetic bearing from west to east of the road in GR7854?

Cover this map with tracing paper before drawing any lines - and use pencil only



## Resection

### Observation Post (OP) data

OP1 GR 382826	OP2 GR 343873
OP3 GR 394878	OP4 GR 355859
GMA = 6°	

**Note: This exercise has been produced from the map, therefore the lines of sight may not actually be intervisible.**

- From OP1 you can see stationary vehicles along the track between GR 3783 and GR 3884. The magnetic bearing to the lead vehicle is 353°. Give the 6 fig GR of this vehicle.
- You are at OP3 and you see a party moving south in open country. You take a magnetic bearing of 264°, OP2 and OP4 also report the party on magnetic bearings of 180° and 18° respectively. Plot these bearings and give the 6 fig GR of the party's position.
- You are on the track between GR 4086 and GR 4085 and you need to locate your exact position. You take a magnetic bearing of 210° to the radio mast at GR 3982. Plot the bearing and give the 6 fig GR of your position.
- You are establishing an OP and need to confirm your position. Using the following information give the 6 fig GR of your position.

TARGET POSITION	MAGNETIC BEARING
Radio mast GR 3988	130°
Trig point GR 3488	243°
Peak GR 3791	33°

- Overnight you move position. Confirm your new position by plotting the resection from the following data and give a 6 fig GR.

TARGET POSITION	MAGNETIC BEARING
Trig point GR 3488	353°
Radio mast GR 3982	125°
Hill 544 GR 3886	72°



## CHAPTER 3

### PRACTICAL NAVIGATION

#### Measuring Distances

##### ***Measuring distances on the ground***

1. If you know where you started from and you know where you wish to go to, it should be an easy matter to measure the distance you need to travel on the map and, using the correct scale, calculate the actual distance over the ground. If, however your objective is hidden from you by the lie of the land or poor visibility, finding it may not be as straight forward as you imagine. Your compass will tell you that you are going in the right direction, but unless you are lucky enough to walk straight to your target, how do you know when to stop? You must rely on an estimation of the distance covered since your last check point. There are two ways of estimating distance:

- a. Timing.
- b. Pacing.

#### Timing

##### ***How long does it take you to walk 1km?***

2. If you know how fast you can walk, then you should be able to work out how long it will take you to cover a known distance. For example if the distance to your next objective is measured on the map to be 2km and you know that you walk at 4 km per hour - it should take you half an hour to reach it. So, by walking on the correct compass bearing for half an hour or so, you should be close to your objective.

##### ***Things to consider***

3. This is not as easy as it sounds. Factors to consider before you can estimate your walking speed accurately include:

- a. Going Uphill. You are likely to go a lot slower when slogging up a steep mountain side than walking along a flat footpath. You will therefore need to make some allowance for variations in terrain. A Scottish climber called Naismith in 1892 devised a rule to calculate walking speeds, which is still valid today.

##### ***Naismith's rule***

For a reasonably fit walker aged 13 to 16, you can work out an average time for a day's expedition by using this adaptation to Naismith's Rule:

4 km per hour as measured on the map, plus  $\frac{1}{2}$  hour for every 200m of climbing.

b. Going Downhill. Although most people will be able to walk faster than normal when descending gentle downhill sections, there comes a point when a steep downhill section must be treated with such care that it slows the walker down. Over a day's walking you would normally ignore the descents because the time gained on gentle descents is often cancelled by the time taken on steeper ones. For short distances however, it is advisable to add 10 minutes for every 200m of steep descent.

c. Fitness. The group can only move at the speed of the slowest member. You should always try to ensure that all members of a walking party are at a reasonable level of fitness - if not then you will need to make further allowances.

d. Terrain. It is not always possible to tell from the map just how rough the ground will be. Marshes, boulder fields and forests can all slow the walker down by different amounts. If you are unsure of the terrain - allow for slow progress.

e. Load. Carrying a heavy pack can slow a walker down by as much as 50% of normal speed, taking into account extra rest periods required and the speed over the ground. If your expedition involves carrying heavy packs, then make allowances by reducing your overall speed to 3 km/hr or even 2 km/hr in some instances.

### Pacing

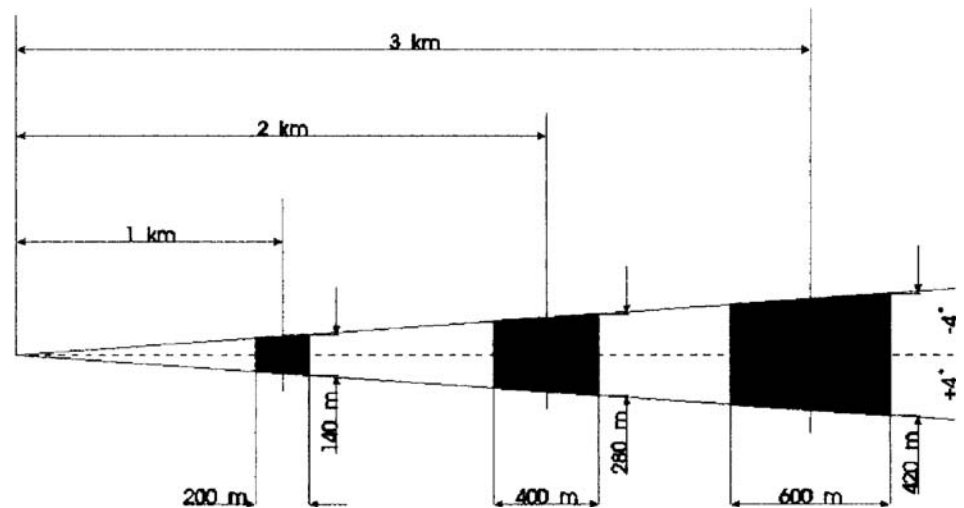
#### **Counting paces**

4. Where very accurate distance measurement is required you could try counting the number of paces you take. This practice is well used by orienteers and with lots of practice can be very accurate indeed - over short distances only. As a general rule you count the number of double paces, or each time the same foot hits the ground. You will have to practice this technique over different types of terrain so that you can make the necessary adjustments as you go along.

## Errors

***Try to be as accurate as possible***

5. No matter which method of estimating distance you choose, there will be an error attached to it. This is particularly true when you are inexperienced. If you add to this the possible error in measuring direction, you will begin to see the difficulties that lie ahead for the young navigator.
6. Assuming a possible error of  $\pm 10\%$  in measuring distance travelled and one of  $\pm 4^\circ$  when measuring direction, you can see how quickly your area of uncertainty can grow as you walk along.



**Fig 3-1** The area of uncertainty becomes large after only a short distance.

7. After only 1 km the area of uncertainty is about the size of 4 football pitches. This increases to a staggering 36 football pitches after 3 km. The lessons you must learn from this are:
  - a. Keep the legs of your route as short as possible.
  - b. Practice your compass work until you can take bearings as accurately as possible.
  - c. Practice pacing and timing distances to reduce the error as much as possible.

Aids to navigation

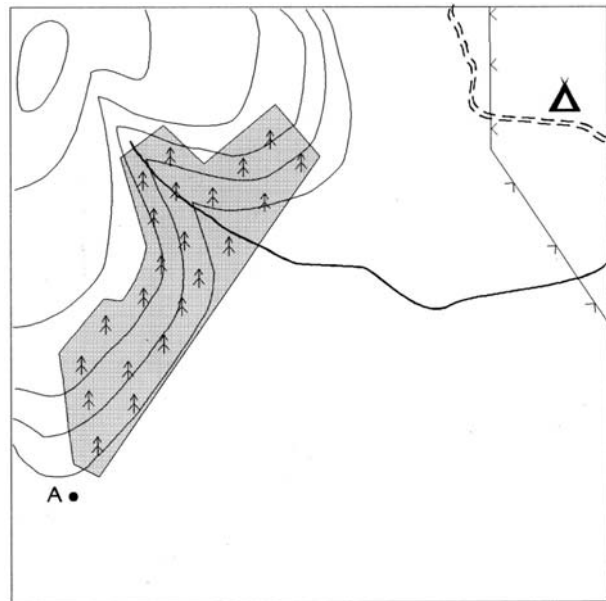
**Techniques to help you navigate**

8. Good navigators will not rely solely on accurate compass work and good distance measurement to find their way around. They will use a number of techniques to improve their navigation.

Handrailing

9. If a track or path leads directly where you want to go, then you would probably follow it. You could just as easily follow a wall, river, a ridge, electricity pylons or any other linear feature that leads the right way. You are using the linear feature as a "handrail". To get to the camp site from position A you could follow the edge of the wood to the stream, follow the stream to the power line, follow the power line to the path - then along the path to the camp site. (see fig 3-2)

**Fig 3-2** Following linear features is called Handrailing.



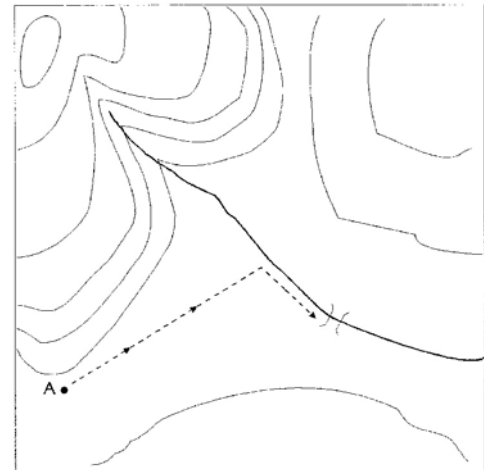
10. When handrailing along a stream make sure you are not side tracked by a tributary - check the general direction of the stream with your compass.

Aiming Off

11. Imagine that you are at point A and you want to cross the river at the bridge. If you aim directly for the footbridge, the chances are that you would miss it, and you would have no way of knowing whether to turn upstream or downstream to look for the bridge. (see fig 3-3)

12. Instead of aiming straight for the bridge, you should deliberately aim off slightly to one side. You would then know which way to turn when you hit the stream.

**Fig 3-3** Aim to one side of the bridge so that you know which way to turn on reaching the river.

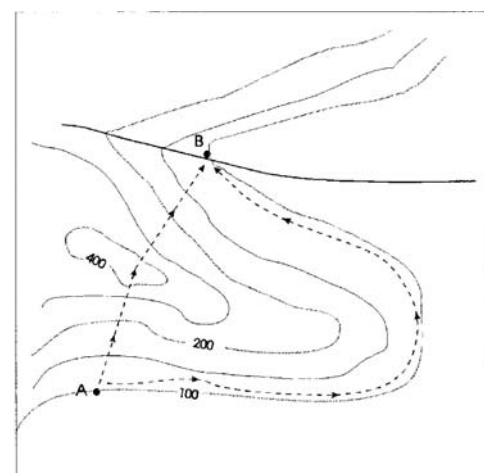


### Contouring

13. Is it better to go round a hill or up and over the top? The two routes may take the same time, but "contouring" round takes less effort. Before you decide you must be aware of the fact that your navigation when contouring has to be very good, particularly in poor visibility - there is a natural tendency to lose height and to travel too far around the curve. It helps if you can head for a collecting feature, such as a stream, that will prevent you from going too far.

14. In the example below the route around the spur is 4km and will take you about one hour to walk. The alternative route over the hill is only 2km long but you have 200m to climb. Using Naisith's rule, how long would this route take to walk?

**Fig 3-4** Take care when deciding the best route to follow.

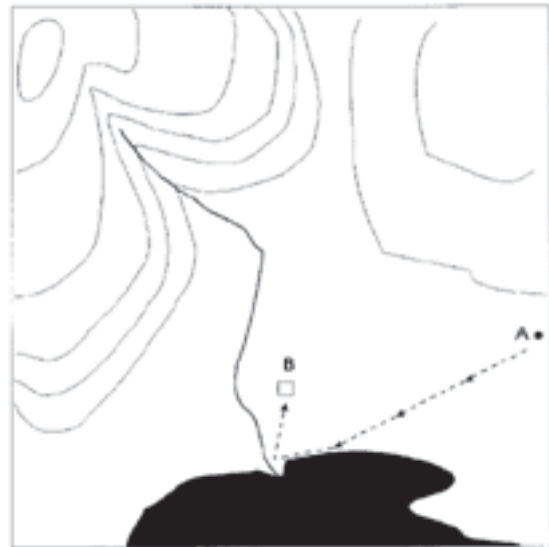


### Attack Points

An attack point is an easily identifiable feature which is close enough to your objective to enable you to home in on it with some degree of accuracy. In other words it pays to go slightly out of your way to hit a definite target, in order to increase your chances of reaching your final objective successfully.

---

**Fig 3-5** Aim for an easily identifiable feature close to your target.



## Sample Questions

***Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.***

1. While walking on the hills, the most accurate way of measuring short distances would be:
  - a. Frequent checks on your position by resection.
  - b. Counting the number of paces.
  - c. Always choosing the flattest route.
  - d. Aiming off.
  
2. The term Handrailing means:
  - a. Never straying from well defined paths.
  - b. Walking on a compass bearing.
  - c. Walking with your map set.
  - d. Following a linear feature to your destination.
  
3. An attack point would be:
  - a. Any trig point.
  - b. Any prominent feature close to your objective.
  - c. Any prominent feature that can easily be identified.
  - d. The summit of any hill.
  
4. Measuring distances accurately while out walking is important because it helps to:
  - a. Pinpoint your position accurately.
  - b. Choose the shortest route.
  - c. Calculate your speed of travel.
  - d. Keep on schedule.
  
5. Contouring means:
  - a. Gaining as much height as possible.
  - b. Losing as much height as possible.
  - c. Walking around a hill.
  - d. Walking over a hill.



## CHAPTER 4

### WEATHER

#### ***About the weather***

1. When you are out on expedition you are very much at the mercy of the elements. It is possible with good equipment to plod on regardless of what nature can throw at you. It is much more satisfying, however, if you can exploit the weather and work with it rather than against it.
2. Choosing a route where the wind is at your back or altering your route to take in summits that are not shrouded in cloud, or setting up camp before the heavens open, can all create a delicious feeling of smugness as well as comfort. Before you can do this, however, a little knowledge of the weather is required.
3. During the planning phase of your expedition develop a routine of listening to the daily weather forecast - start up to a week before you go. This should give a general view of the weather pattern for the period of your expedition, but it will not necessarily be accurate for the area you are in. For this you need to ring the local meteorological office and ask for a forecast for the specific area that you are interested in. The number can often be found in the front of the telephone directory for the area. This method has the advantage that you can leave it until the very last minute when you are actually in the area - and so you get the very latest, updated version.
4. Unfortunately, weather has a habit of changing rapidly and not always in accordance with the weather forecast - so experienced hill walkers must try to predict the weather as they go along. In order to do this they must have a basic understanding of wind and cloud movements and of the underlying weather patterns which cause them.

#### Air Masses on the Move

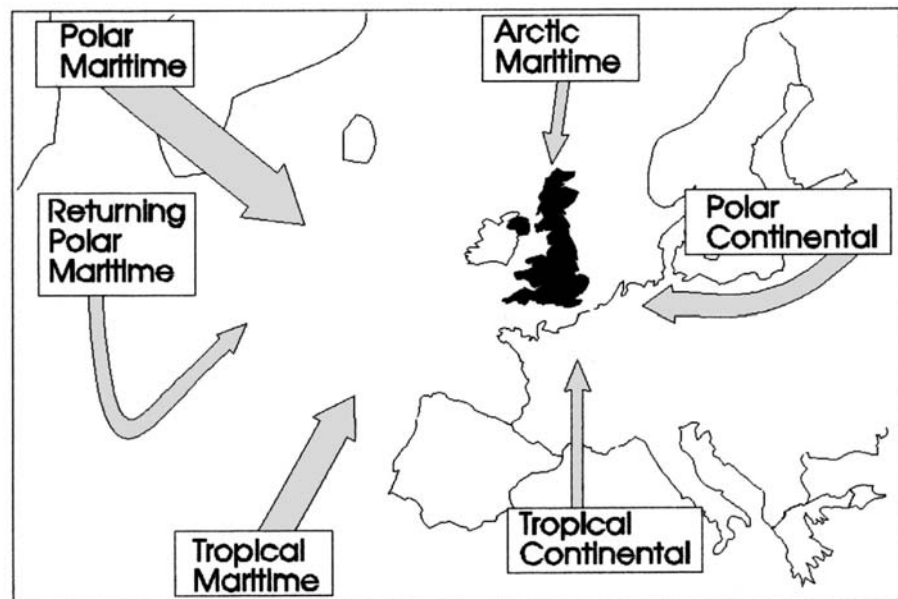
#### ***About the atmosphere***

5. Everybody knows that the earth's atmosphere is constantly moving. At first sight this movement seems to be chaotic and unpredictable, but patterns are seen to emerge if it is studied carefully. The sun warms the earth's surface unevenly, with the result that warm air rises over the equator and flows at high level towards the poles. On the other hand, cold air sinks at the poles and flows towards the equator across the surface. This simple model is complicated by the fact that as the warm air

risers and then moves north (or south in the southern hemisphere) it becomes crowded as it approaches the poles because there is less space. This squeezes some of the air down, forcing it to mix at lower levels. Further complications are added to this air movement when the effect of a spinning earth is taken into account. The overall result is that there are basically six main air masses that affect the weather in the British Isles.

### Main Air Masses

6. When air moves along the surface of the earth for an appreciable time it acquires the temperature of the land (or sea). In addition, air crossing the sea will collect water vapour - and the warmer the air the more water vapour it will hold. It is clear, therefore, that the 6 main air masses will each have fairly distinctive characteristics.



**Fig 4-1** The main air masses affecting the British Isles. The width of the arrows is an indication of the frequency of occurrence.

### Polar Maritime

7. Originating in north Canada and Greenland, crosses the Atlantic Ocean picking up water vapour before reaching the British Isles. Typical weather conditions are:

Summer - Cool winds, heavy showers, thunder storms in mountains

Winter - Heavy showers in west with snow in mountains. Clear skies at night in the east giving frost.

#### Returning Polar Maritime

8. Originating in north Canada as very cold, dry air. Initially it moves south, and so it begins to warm and pick up water vapour. By the time it reaches the British Isles it is much warmer and wetter than Polar Maritime air. Typical weather conditions are:

Summer - Warm with squally showers and storms inland.

Winter - Stratus cloud. Showers in the western mountains.

#### Tropical Maritime

9. Originating in warm tropical oceans around the equator. Brings warm and wet air. Typical weather conditions are:

Summer - Warm south-west winds. Low stratus cloud over west coast.

Winter - Stratus cloud, hill fog and drizzle, clearing in the north-west. Warm with prolonged rainfall in westerly mountains.

#### Tropical Continental

10. Originating in North Africa, this warm air moves north over Europe and has little opportunity to pick up water vapour. Typical weather conditions are:

Summer only - Very hot and dry, hazy with occasional thunder storms.

#### Arctic Maritime

11. Originating in the very cold Arctic seas, picks up a little moisture as it travels south. Typical weather conditions are:

Summer - Very cold with frequent heavy showers.

Winter - Very cold strong north, north-easterly winds. Heavy snow showers in north.

Polar Continental

12. Originating in Siberia it is very cold in winter but warm in summer. The short sea track to the South of England means that it remains quite dry whereas in Scotland, having to cross much more water, weather conditions can be quite different.

Summer - Warm and dry, cloud free. East coast tends to be cool and showery with coastal fog in the north.

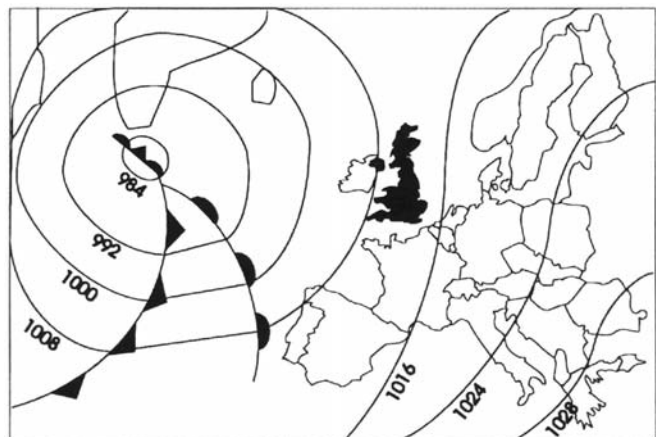
Winter - Sleet and snow showers in the north. Cold strong east winds.

Fronts and Frontal Depressions

**Isobars**

13. Fronts and depressions are the cause of much of the poor weather that we experience. Weather changes occur when air moves as a result of variations in air pressure. To try to understand what is happening to the air pressure, meteorologists draw lines through all points that have the same air pressure - isobars. Rather as contour lines on a map help you to picture the shape of a particular feature on the ground, isobars help you to visualise areas of high or low pressure, so that air movement can be more easily understood.

**Fig 4-2** Typical weather map.  
The numbers refer to pressure in millibars.



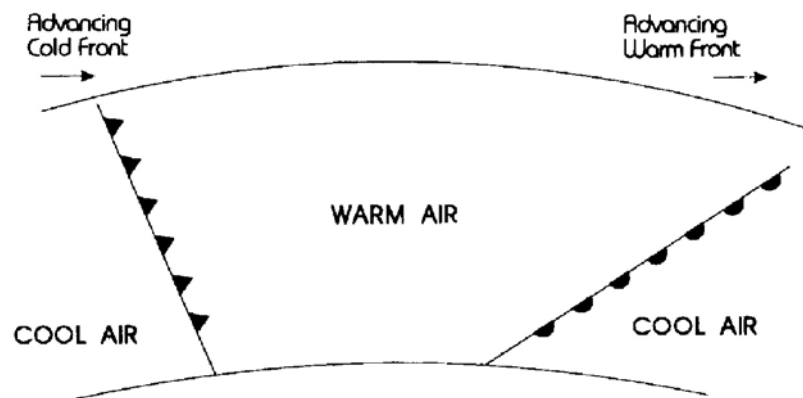
**Depressions and anticyclones**

14. The distance between the isobars indicate a change in pressure or pressure gradient - a steep gradient with the isobars close together will result in high winds, whereas widely spaced isobars result in light breezes. The areas of low pressure are called depressions or lows and those of high pressure are anticyclones or highs.

**Warm and cold fronts**

15. Along with depressions there are phenomena known as fronts where a cold air mass meets a warm one. When the two air masses meet, instead of mixing

together, the warm air tends to rise over the cold air causing a drop in pressure. The cold air rushes in to fill the gap, producing a circular or spiralling motion in towards the centre of the depression. In the northern hemisphere, the circular motion of the air is always in an anticlockwise direction round the centre of the low; hence the rule - stand with your back to the wind, the low pressure (and the worst of the weather) is on your left.



**Fig 4-3** Section through a frontal system. Note that the cold front is steeper than the warm front.

#### **Occluded front**

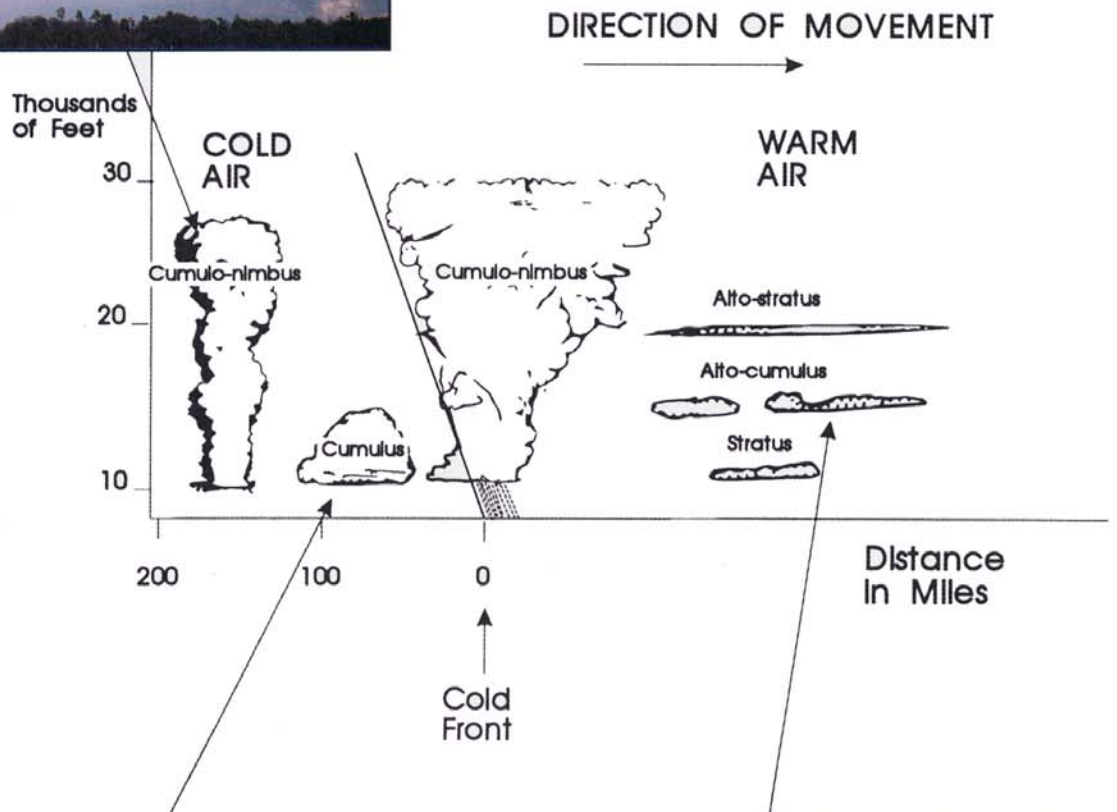
16. As the depression moves along, the wedge of warm air moves with it. Because the cold front moves slightly faster than the warm front, eventually the cold air will slide right under the warm air to form a continuous layer of cold air at ground level with the warm air on top. This is called an occluded front and is usually a sign that the depression is filling up. An occluded front is shown as a line carrying alternate semi-circles and triangles.

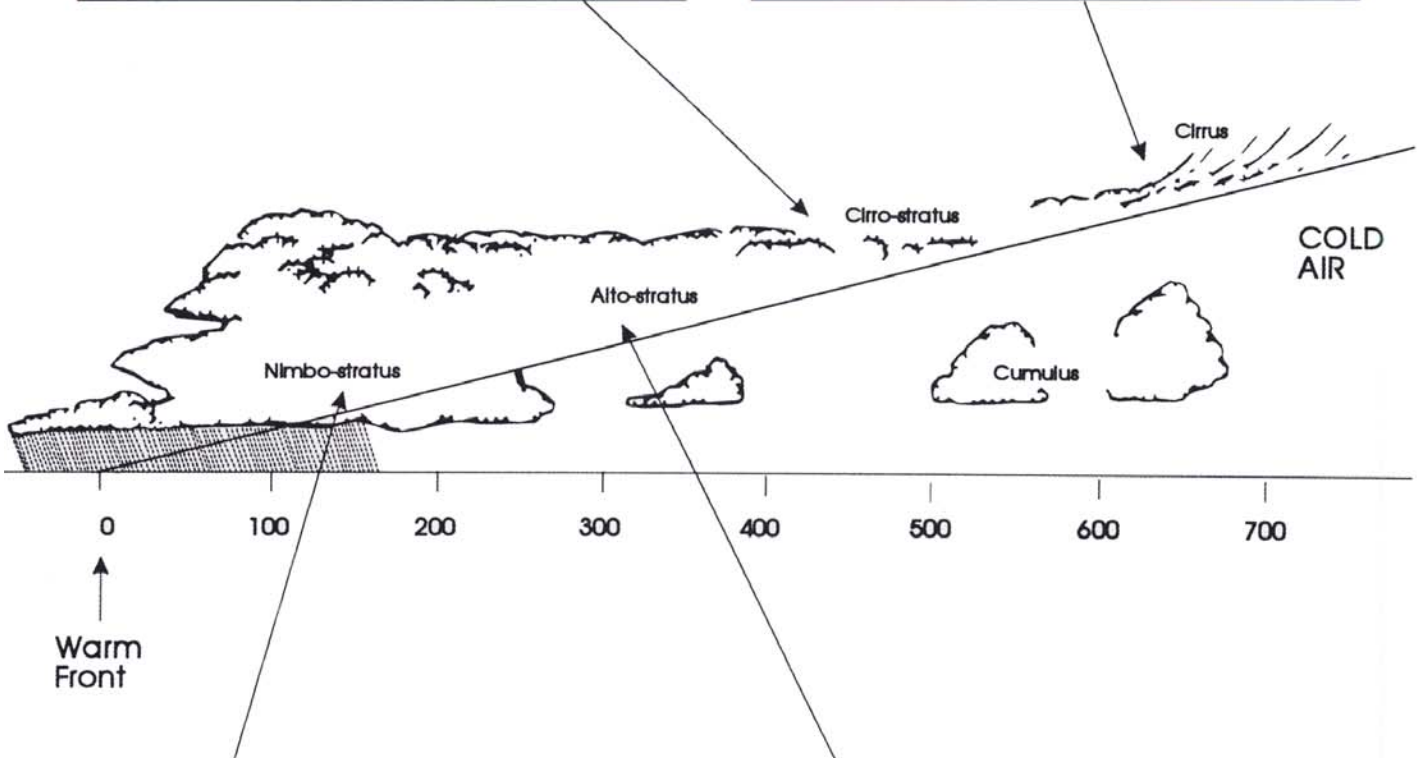
17. Typical weather patterns associated with the various phases of a depression are shown over the page. It must be remembered, however, that no two depressions are ever exactly alike.

#### Upper winds

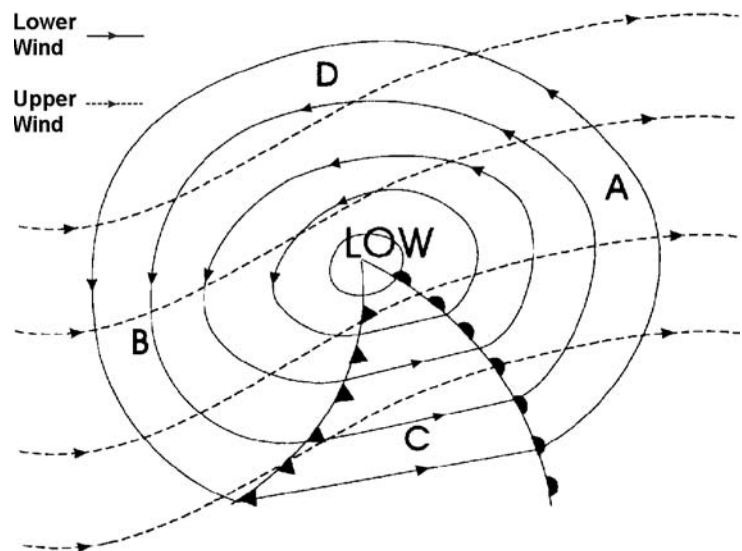
#### **Upper winds**

18. Upper wind is responsible for the general movement of the depression, and its direction can be determined by the movement of the highest clouds. The diagram shows isobars for both upper and lower winds. Their relationship to each other can be used to indicate the weather shortly to reach you. (see fig 4-4)





19. If you are standing at position A with your back to the lower wind, and the upper wind is moving from left to right - the depression has not yet reached you and the weather is likely to deteriorate.
20. If you are standing at position B with your back to the lower wind and the upper wind is moving from right to left, then the depression has passed and the weather is likely to improve.
21. If you are standing at position C or position D with your back to the lower wind and the upper wind is either moving towards you (at D) or moving away (at C), then there is likely to be little immediate change in the weather.



**Anticyclone**

**Fig 4-4** Weather map showing isobars for both upper and lower winds.

Anticyclone

22. An anticyclone is a region of high pressure, with light winds circulating in a clockwise direction (in the northern hemisphere) round the centre of high pressure. In general they are stable slow moving systems, consisting of warm dry air, bringing long periods of fine clear weather.

**Basic cloud formations**

Clouds

23. Clouds are named according to both their shape and height. There are three main types of cloud:

- a. Cirrus - Found only at high levels and are composed of ice crystals. The word cirrus means a 'thread' or 'hair'.
- b. Cumulus - A lumpy or heaped cloud.
- c. Stratus - Featureless layer of cloud.

24. The basic names of clouds may be combined, and the prefixes cirro- or alto- added to identify the height at which the cloud is occurring. The words cumulus and stratus on their own identify clouds whose base is below 2000m. Cumulus may be combined with nimbus (Latin for rain), to give cumulonimbus - a heaped rain cloud. A layer cloud from which rain is falling is nimbostratus.

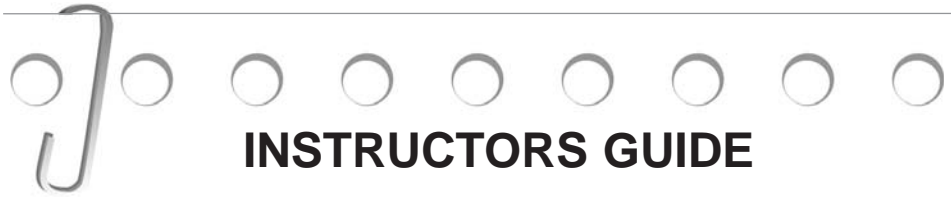
High Clouds	<b>CIRRUS</b>	11000m 35000ft
	Cirrocumulus Cirrostratus	
Medium Clouds	<b>ALTO</b>	5500m 18000ft
	Altostratus Altostratus	
Low Clouds	<b>CUMULUS</b>	2000m 6500ft
	Cumulonimbus  <b>STRATUS</b> Stratocumulus	

## Sample Questions

***Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.***

1. Which major air mass brings the UK very hot, dry summers?
  - a. Polar Continental.
  - b. Tropical Continental.
  - c. Tropical Maritime.
  - d. Returning Polar Maritime.
  
2. Isobars are lines drawn on a weather map joining points of equal:
  - a. Temperature.
  - b. Humidity.
  - c. Windspeed.
  - d. Pressure.
  
3. An area of low pressure is also known as:
  - a. An anticyclone.
  - b. A depression.
  - c. A warm front.
  - d. An occluded front.
  
4. Generally, an area of high pressure will tend to bring:
  - a. Long periods of fine weather.
  - b. Long periods of poor weather.
  - c. Fast moving wet weather systems.
  - d. Fast moving fine weather systems.
  
5. High level clouds names could begin with the prefix:
  - a. Strato.
  - b. Alto.
  - c. Cirro.
  - d. Nimbo.

## CHAPTER 1



## INSTRUCTORS GUIDE

BASIC NAVIGATION**Page 32.2.1-1 Para 3**

The diagram shows how the country is divided into squares measuring 100km by 100km - the National Grid. Each square is further divided into 1km squares producing the grid referencing system we are familiar with. The horizontal lines of the national grid system (northings) originate from the 49°N line of latitude and the vertical national grid lines (eastings) originate from the 2°W line of longitude. It must be stressed that the grid system, being rectilinear, differs from the lines of latitude and longitude, with the difference increasing the further one gets from the lines of origin. This means that, the only grid line to point to True North is the one that coincides with the 2°W line, the rest miss it by differing amounts. Every sheet has this difference recorded in the map margin, for each corner of the map - it is never more than 2° in the UK.

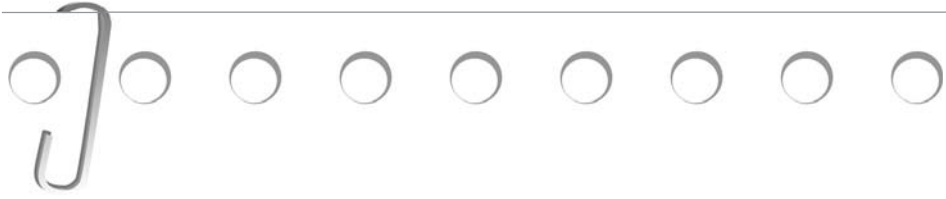
Walking with the map set

Walking with the map set is never an easy thing to do as symbols and place names are often upside down. It will be useful to practice the technique as frequently as possible. Exercises using street maps are often a good starting point.

Using a street map of the local area ask the cadet to:

- a. Plan the shortest route between two points.
- b. Pass details of the route to a second person, who is not in possession of a map, by word of mouth.
- c. Walk the route following the verbally given instructions.
- d. Compare results.

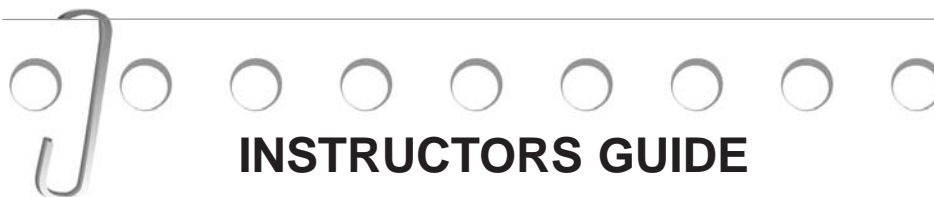
# CHAPTER 1



**Page 32.2.1-4 Para 13**

1. The movement of magnetic north can be predicted and the appropriate adjustment made to the magnetic variation. At the present time magnetic north is moving in a direction which reduces the westerly variation from locations within the British Isles by approximately  $\frac{1}{2}^{\circ}$  in 5 years.
  2. Cadets must be aware of the difference between:
    - a. Magnetic Variation.
    - b. Grid Magnetic Angle (GMA).
-

## CHAPTER 2

THE COMPASS**Page 32.2.2-5 Para 15**

One drawback of the conventional compass is the constant adjustments required to take into account magnetic variation. On some compasses the dial can be adjusted to allow for this so that the figure shown against the direction of travel arrow is always the magnetic bearing.

Cadets should be discouraged from using this type of compass until they are fully conversant with the manipulation of magnetic and grid bearings.

Store compasses in their cases and away from strong magnets. If the magnetic compass needle is kept in a strong external magnetic field for a period of time, its own magnetic poles could be reversed.

To witness the effect of ferrous metals on the compass needle, allow the cadets to experiment with their compass. Note how the reading changes when the compass is placed close to a:

Radiator

Penknife

Zip fastener

Bunch of keys...etc

---

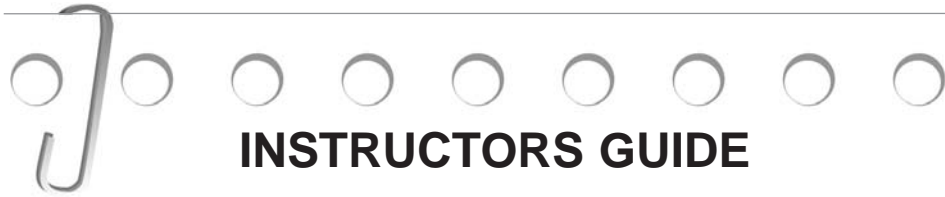
Back Bearings**Page 32.2.2-7 Para 17**

There may be times when it is useful to know the back bearing to a particular feature - that is the compass bearing from the feature to your present position. To do this:

- a. Point your direction of travel arrow at the feature, as if you were taking a normal compass bearing.
- b. Turn the compass capsule until the orienting arrow lies directly beneath the SOUTH end of the compass needle.
- c. Subtract the Grid Magnetic Angle (GMA) for a grid bearing.

This now gives the bearing of your position from the feature.

---



## INSTRUCTORS GUIDE

### PRACTICAL NAVIGATION

**Page 32.2.3-2 Para 4**

#### Pace Counting

This really needs a lot of practice to perfect but can be very effective for SHORT distances only ( 1-2 km). Cadets should practice counting the number of double paces over a 100m flat piece of ground - repeat 10 times and take the average.

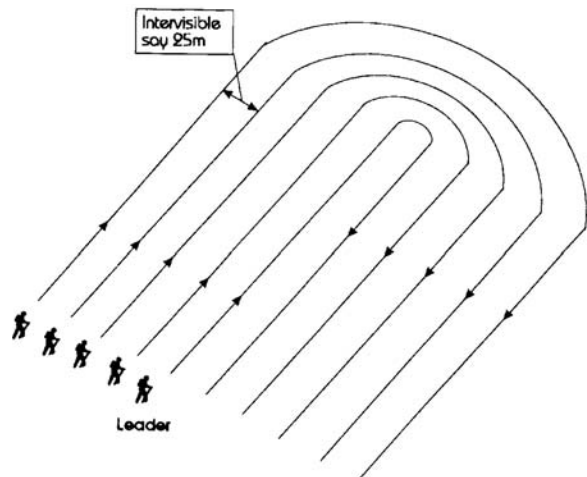
They should be allowed to work out for themselves their pace count across different types of terrain.

#### Search Patterns

It is unlikely that inexperienced navigators will find their objective every single time - particularly in poor visibility. They may need to search the area. If this is the case it should be stressed that cadets should not dash about randomly in the hope of stumbling across an objective - they can become totally lost and disorientated. Instead a systematic search of the area is needed. There are two basic approaches:

##### a. Sweep Search

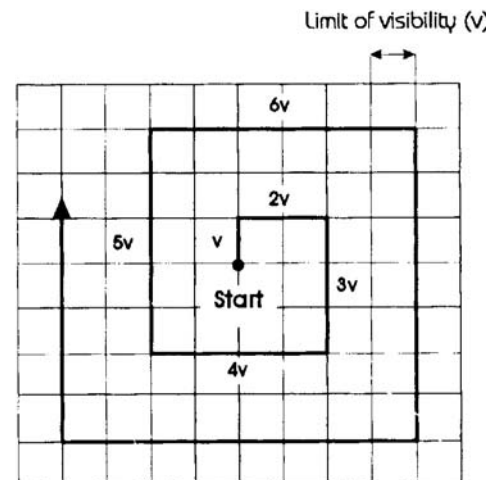
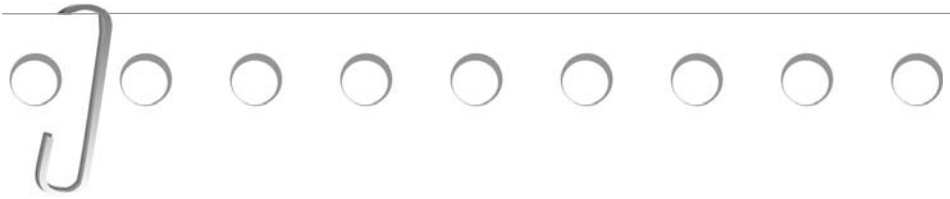
Space out the party to the limit of their visibility and sweep backwards and forwards across the area until the objective has been found.



##### b. Spiral Search

Has the advantage of being executed by only one person. Start by walking in a chosen direction, say north, a distance of one visibility (as far as you can see). Turn east and walk 2 visibilities; then south for 3 visibilities and so on. On the diagram it can be seen that there is no point on the grid that can not be seen from some point on the marked search route.

## CHAPTER 3

Teaching Navigation

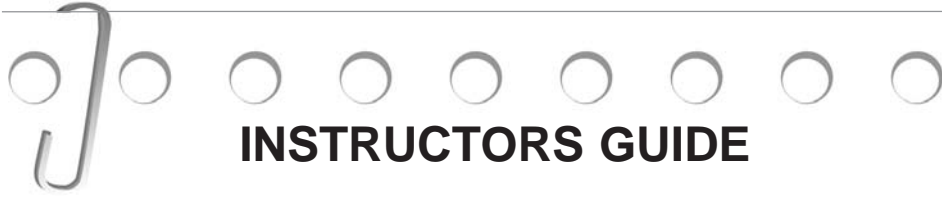
Cadets should be given every opportunity to practice their skills in map reading and navigation out in the field. Simple instruction in navigation can be fun and lessons must not be allowed to turn into extra geography lessons.

Encourage all cadets to take a part in the navigation exercise - never leave it to one or two individuals.

Orienteering is an ideal sport to try. It will keep you fit as well as develop your skills of navigation. It has all the excitement of a treasure hunt and gives you a great deal of satisfaction when you actually find the control buried deep inside a forest. Courses can be set for all types - from beginner to expert.

Making navigation more fun

1. On a large open field, aim for a set point and walk blindfold to estimate your tendency to drift to one side.
2. Draw a map of your local area from memory - check what features are missed.
3. Map reading crosswords.
4. Small scale orienteering. In the Sqn grounds, set markers (coins) on the ground and give bearings on which to walk to recover markers.
5. Treasure hunts involving pace counting, recognition of features and compass bearings.
6. Measure pace counts over different terrains, uphill and downhill.



**INSTRUCTORS GUIDE**

WEATHER

**Page 32.2.4-4 Para 13**

Weather on the mountains

Cadets must be encouraged to follow weather forecasts for the area in which they intend to go. Local conditions however, can differ significantly from these generalised forecasts.

Temperature

As air is forced to rise over mountains, it expands as the pressure reduces. This expansion causes the air to cool at a rate (the lapse rate) of approximately  $-1^{\circ}\text{C}$  for every 150m. The water vapour held in this cooling air will condense to produce cloud and ultimately rain.

Going down the lee side the air is dry and warms as it descends.

Wind

A range of mountains acts as a barrier to the flow of air. The air must either go round the obstacle or over it. Both have the same effect - an increase in wind speed. This funnelling effect of mountains is well known - The Mistral blowing down the Rhone valley in France.

Battling against a strong wind uses a lot of extra energy. A light breeze of 5mph (8km per hr) exerts a force of 0.1 lb per sq ft (0.5kg per sq metre). This changes rapidly to:

<u>Wind speed</u>	<u>Force</u>
20 mph(32kmph)	1.5 lb per sq ft ( 7 kg per sq m)
60 mph(96kmph)	13 lb per sq ft ( 61 kg per sq m)

A wind blowing against an object exerts a force roughly proportional to the square of its velocity. If the wind speed increases by a factor of 3 then the force exerted increases by a factor of 9.

**Page 32.2.4-7 Para 15**

Local heating and cooling effects

Air quickly acquires the temperature of the ground with which it is in contact. During the day warm rocky mountain tops will heat up the air relatively quickly, causing it to rise. Cooler air from the valleys will move up the mountain to replace this rising air, producing a gently uphill breeze known as anabatic wind. It rarely reaches excessive speeds.

At night however the mountain tops lose their heat very quickly and the cold air in contact with the ground begins to flow down hill producing katabatic winds - these can sometimes be quite strong. Even very gentle slopes are sufficient to cause cold air to accumulate in valley bottoms and hollows often producing frosts and fog belts.

## Self Assessment Questions - Answer Sheet

Chapter 1      Page 32.2.1-7

1.      b
2.      c
3.      a
4.      b
5.      c

Chapter 2      Page 32.2.2-11

1.      c
2.      a
3.      c
4.      a

Chapter 3      Page 32.2.3-7

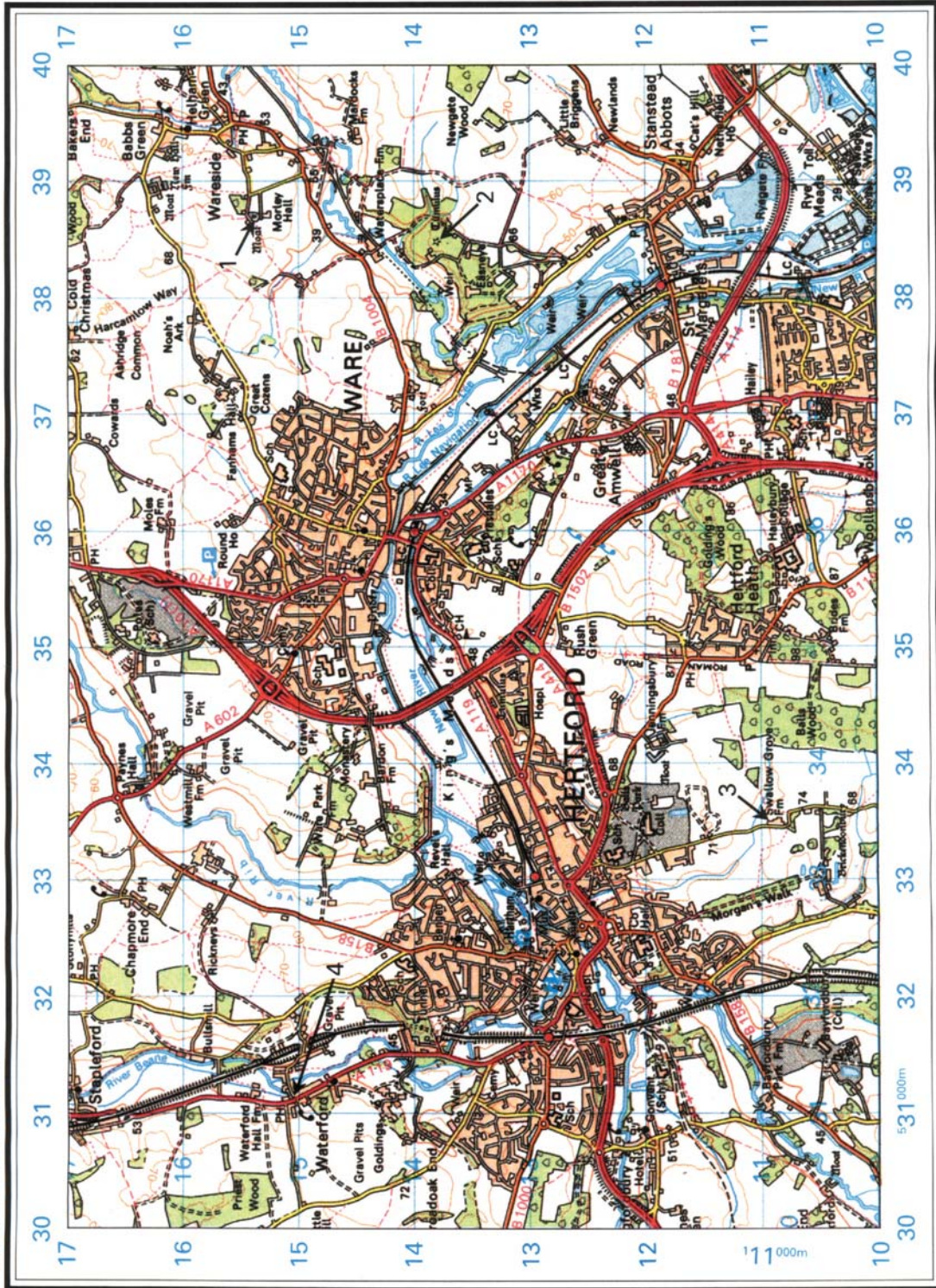
1.      b
2.      d
3.      a
4.      c
5.      c

Chapter 4      Page 32.2.4-11

1.      b
2.      d
3.      b
4.      a
5.      c

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

### TEST YOUR SKILLS

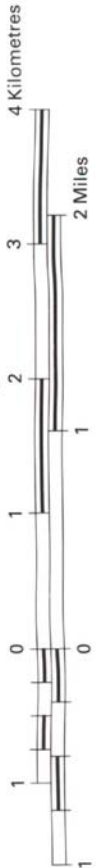


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Extract from Series M726  
Sheet 166, Edition 10-GSGS

Map Reading Exercise GSGS 5676  
Supersedes GSGS 5426 and SMS MAPRIC

CONTOUR INTERVAL 10 METRES  
SCALE 1:50,000



Produced under the direction of the  
Director General of Military Survey,  
Ministry of Defence, United Kingdom, 1992.

Based upon Ordnance Survey Mapping

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1. Identify the features indicated by the arrows numbered 1 and 2.
  - 1.
  - 2.
2. Give the six figure grid references of the features indicated by the arrows numbered 3 and 4.
  - 3.
  - 4.
3. Measure the road distance between the Roundabout in GR 3710 to Moles farm in GR 3616.

Answer.
4. Measure the straight line distance between the Church in GR 3415 and the Church at GR 387 122.

Answer.
5. What is the grid bearing from the Convent in GR 3111 to the Church with tower in GR3212?

Answer
6. What is the magnetic bearing from the trig point in GR 3410 to the Church in GR 3712?

Answer.

(For this exercise only-GMA is 100 Mils West)

