a) We will use a compass with a needle embedded in a sphere. This sphere is submerged in kerosene where it keeps turning. The needle or – more precisely – the northern magnetic pole of the sphere, points downwards in a northerly direction in the Northern Hemisphere, but even at an inclination of 80° it is possible to determine the direction to the north (similarly, in the Southern Hemisphere it obviously points upward, to the north).

Disadvantages: We are "guessing" the direction to the north.

b) We will ballance off a standard compass on the other side by attaching a small weight to it so that the resultant force along the z-axis will be null.

Disadvantages: It is difficult to determine the mass of the weight in dependence on the inclination of the magnetic lines of force.

There is a shift in the centre of gravity.

c) We will wire up the compass with an electric conductor in the shape of a solenoid. The current flowing through the threads of the solenoid will create a magnetic field which will compensate the effect of Earth s magnetic field along the z-axis.

Disadvantages: It is necessary to carry a voltage supply with you.

d) We will use a little hand as a direction indicator which will be maintained by gravitation in the required horizontal position. (there will be free rotation on the vertical plain). To enable its movement on the horizontal plain, it will be connected to a magnetic needle whose vertical rotation will also unrestricted. The advantage of this method is that the little hand pointing to the north remains in the horizontal position even when the compass is inclined.

Disadvantages: The design of the mechanical parts poses a problem, for the pins have to be accurately designed and they are liable to mechanical damage.

Note: Solar storms are the cause of the needle vibrations which are quite intense around the Earth s magnetic poles (they also give a rise to the polar glow).

Conclusion:

We have identified the places on the globe with the highest changes in magnetic intensity. If all the metals are reasonably accurate, their application will depend on the equipment available to a particular expedition. It is obvious, however, that in the vicinity of the magnetic poles all the methods described above will fail.

Geographical north (or south) may be determined with the highest degree of accuracy by means of a gyroscope. The disadvantage of this method is the considerable weight of the equipment.

It is also possible to determine a geographical position quite accurately using the position of the stars.

finally, case *b* shows the discs from the nearest point from where they are still distinguishable. It is obvious that the lowest point between the two maxima in the intensity course must be sufficiently deep for the two maxima to be distinguishable. For visual observation its depth must be at least 20% of the maximum intensity (Rayleigh's criterion). When using modern equipment we can distinguish 10% or even 5% as well. We stayed at the level of 20% because the equipment in question is rather difficult to come by. This level reflects the distance of the middles of the discs equal to the perimeter of the discs. We will make it equal to the maximum distinguishability – in our case the smallest distinguishable anuglar distance equals 0,61 . r : l.

Experimental comparison of the results

In view of the fact that theoretical results are rarely identical to real ones (e.g. because of the fact that we assumed the lens was ideal), we decided to observe several binary stars. All the photographs come from the observatory at Petřín in Prague. We used telescopes made by The Carl Zeiss Jena company with objective diameters of 180 and 200 mm.

The following table shows all of the observed objects (photos taken on 28th and 29th March 1994):

No.	object	angular distance
1	pi Boo	5,6"
2	gamma CrB	0,7"
3	gamma Leo	4,4"

Summary

The photographical materials confirm our evaluations fairly well. Especially gamma Coronae Borealis with an angular distance 0,7" confirmed that the theoretical and practical results are in sufficient conformity. So we can see that the distinguishability of the telescope doesn t depend on overlighting (very considerable esp. in Prague) and by a calm atmosphere very good results can be reached.

At the same time we can see the binary stars with very small angular distance (close to the maximal distinguishability) are really very hard to distinguish (e. g. mentioned gamma CrB) and a good photo of such an object must come only from the hand of a skilled photographer.

Problem No. 2 - Compass

The problem, as formulated by our team, is based on a detailed analysis the one described by Cherry-Garrar. We decided to state it in the following way:

Describe the magnetic field of the Earth which affects the magnetic compass needle and explain how to eliminate the sudden changes in the direction of the needle, in order to the determine which direction north is?

If we want to obtain a precise picture of Earth's geomagnetic field, we would have to measure the intensity and direction of the magnetic field of the entire globe. Unfortunately, the Earth's magnetic field varies in time and it is also very inconsistent in some places. For example, if we travel around the Earth at the line of latitude 60° north, the direction of the magnetic needle will not always be the same. In Greenland the angle of the needle and to the tangent of the Earth's plane will be −85° and, whereas, in Scandinavia this angle will be a little over −75°. These deviations are caused not only by the displacement of the magnetic axis from the axis of rotation, but also by tectonic activity, which affects the thickness of the Earth s crust and changes its composition due to the magnetic properties of some minerals (eg The Chersky Mountains). If two people start off from two different places on the globe and continue north, i.e. to the southern magnetic pole, they won t necessarily arrive at the same destination, for there are at least two dominant magnetic poles in the Arctic at the moment (there are two southern poles there) and in the Russian federation (Chersky Mountains) there is a local pole (due to the high concentration of iron ores).

There are therefore two problems:

1) The needle of a conventional compass typically tends to turn down which causes it to get stuck.
2) There is more than one northern and one southern magnetic pole.

The needle of a compass is affected by the magnetic field both in vertical and horizontal direction:

The magnetic field of intensity **H** may be broken down into:

OH .... angle δ determines declination,
OF .... angle β determines inclination,

where

$\mathbf{OH} = \mathbf{OF} \cos\beta$	$\mathbf{OX} = \mathbf{OH} \cos\delta$
$\mathbf{OZ} = \mathbf{OF} \sin\beta$	$\mathbf{OY} = \mathbf{OH} \sin\delta$
i.e. $\tan\beta = \mathbf{OZ} / \mathbf{OH}$	i.e. $\tan\delta = \mathbf{OY} / \mathbf{OX}$

Note.: The actual solution of problems 1.), 2.) varies with time, for the magnitude of intensity of the Earth's magnetic field changes. This intensity is the highest in the following places:

3) Change in intensity of the Earth's magnetic field causing inclination of the needle:

• north of the Reindeer Lake	(60° n.l., 100° w.l.) - 60 μT
• around the town of Curitiba	(26° s.l., 52° w.l.) - 24 μT
• south of Australia	(60° s.l., 135° e.l.) - 68 μT
• the Katanga river basin	(60° n.l., 103° e.l.) - 62 μT

4) Change in intensity of the Earth's magnetic field causing declination of the needle:

• the Pacific Ocean	(55° s.l., 116° w.l.) - 120 μT
• the Sargasso Sea	(26° n.l., 59° w.l.) - −180 μT
• north of New Guinea	(0° n.l., 140° e.l.) - −80 μT

If we do not move around at higher geographic latitudes, but travel around the globe between 80° n.l. a 60° s.l., we need not take into account problem No. 2. We therefore have to eliminate problem No. 1.