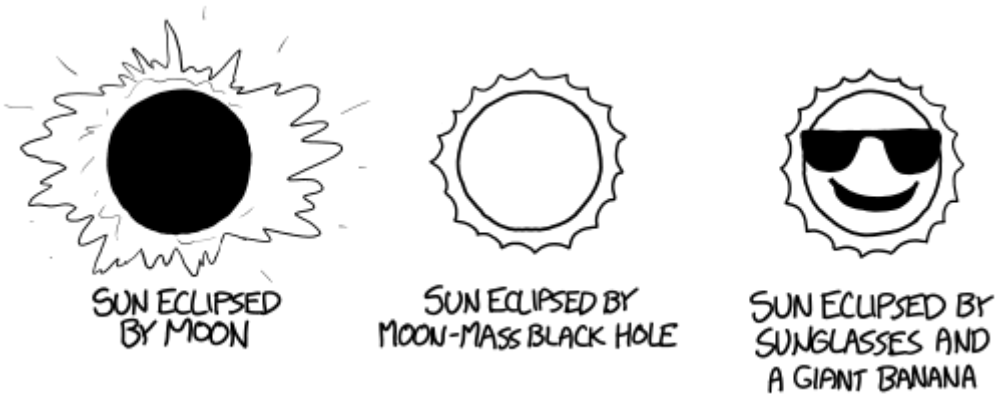
Advanced Higher Physics

Past Paper Questions

2.6 Polarisation



11. A student, wearing polarising sunglasses, is using a tablet computer outdoors. The orientation of the tablet seems to affect the image observed by the student.

Two orientations are shown in Figure 11A.

Landscape mode Portrait mode

Figure 11A

(*a*) In landscape mode the image appears bright and in portrait mode it appears dark.

(i) What may be concluded about the light emitted from the tablet screen? **1**

(ii) The student slowly rotates the tablet. Describe the change in brightness observed by the student as it is rotated through 180°. **2**

(*b*) Unpolarised sunlight is incident on a water surface a shown in Figure 11B.

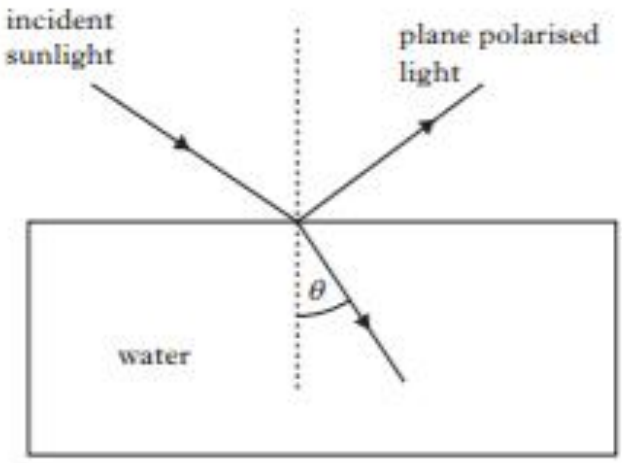


Figure 11B

The light is 100% plane polarised on reflection.

Calculate the angle of refraction θ. **2**

(5)

9. As part of a physics project a student carried out experiments to obtain values for the permeability of free space and the permittivity of free space.

The results obtained by the student were

permeability of free space, $\mu_0 = (1{\cdot}32 \pm 0{\cdot}05) \times 10^{-6}\,\text{H m}^{-1}$

permittivity of free space, $\varepsilon_0 = (8{\cdot}93 \pm 0{\cdot}07) \times 10^{-12}\,\text{F m}^{-1}$

(a) State the number of significant figures in the value of each result. **1**

(b) Use these results to determine a value for the speed of light.

Your answer must be consistent with (a). **3**

(c) (i) Determine which of the uncertainties obtained by the student is more significant for the calculation of the speed of light.

You must justify your answer by calculation. **3**

(ii) Calculate the absolute uncertainty in the value obtained for the speed of light. **2**

Revised 2013

16. A student is investigating polarisation of waves.

(*a*) State what is meant by *plane polarised light*. **1**

(*b*) While doing some background reading the student discovers that the Brewster angle i_p for the liquid solvent triethylamine is given as 54·5°. Explain, using a diagram, what is meant by the Brewster angle. **2**

(3)

Traditional 2013

13. A student is investigating polarisation of waves.

(*a*) State what is meant by *plane polarised light*. **1**

(*b*) The student wishes to investigate polarisation of sound waves and asks a teacher for suitable apparatus. The teacher says that sound waves cannot be polarised.

Why can sound waves not be polarised? **1**

(*c*) (i) While doing some background reading the student discovers that the Brewster angle i_p for the liquid solvent triethylamine is given as 54·5 °. Explain using a diagram what is meant by the Brewster angle. **2**

(ii) Calculate the refractive index of triethylamine. **1**

(5)

Traditional 2010

Marks

11. A light source produces a beam of unpolarised light. The beam of light passes through a polarising filter called a polariser. The transmission axis of the polariser is shown in Figure 11A.

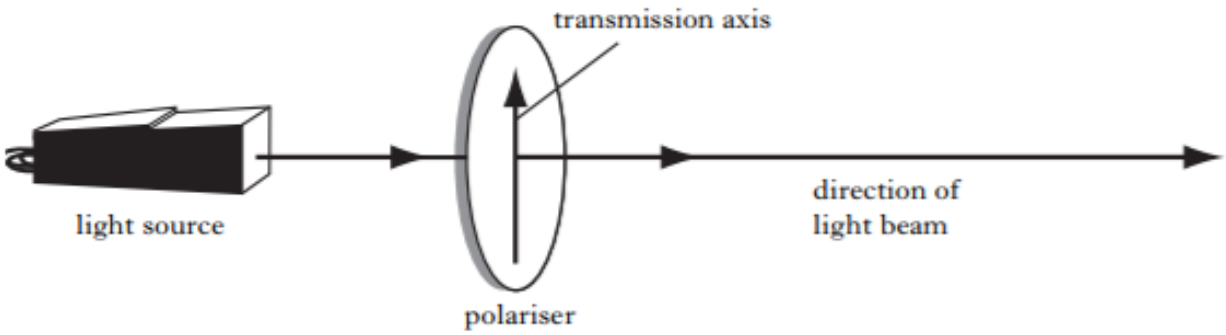


Figure 11A

(*a*) Explain the difference between the unpolarised light entering the polariser and the plane polarised light leaving the polariser. **1**

(*b*) The plane polarised light passes through a second polarising filter called an analyser.

The irradiance of the light passing through the analyser is measured by a light meter.

The transmission axis of the analyser can be rotated and its angle of rotation measured using a scale as shown in Figure 11B.

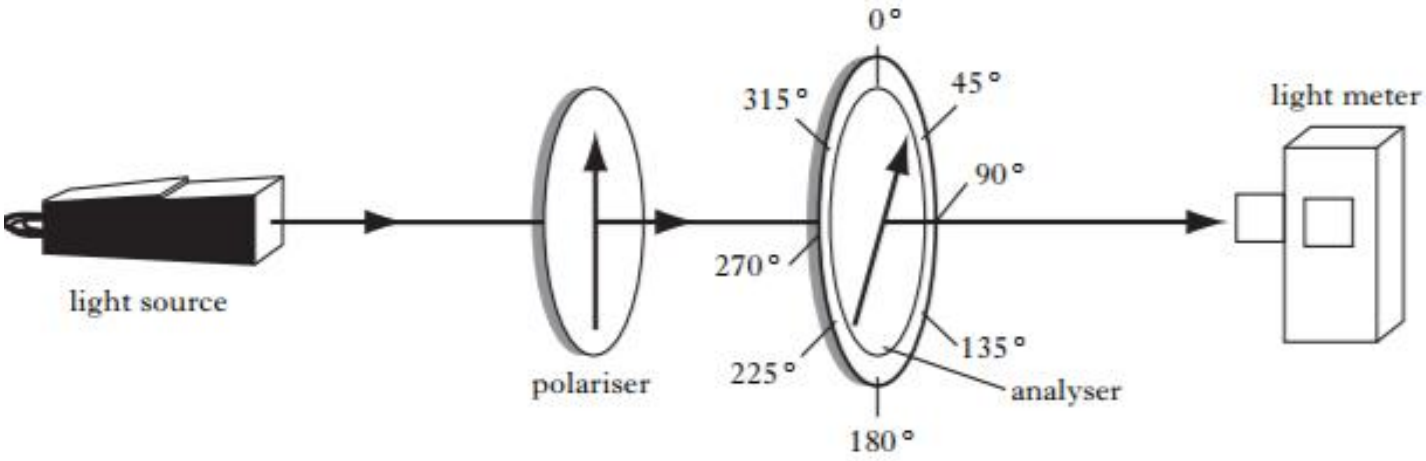


Figure 11B

(i) The analyser is rotated.

State the **two** positions on the analyser scale that will produce a maximum reading of irradiance, I_0, on the light meter. **2**

(ii) The relationship between the irradiance I detected by the light meter and the angle of rotation θ is given by

$$I = I_0 \cos^2\theta.$$

Explain how the equipment shown in Figure 11B could be used to establish this relationship.

Your answer should include:

- the measurements required;
- a description of how the relationship would be verified. **3**

(6)

Marks

10. (*a*) (i) State what is meant by the term *plane polarised light*. **1**

(ii) Figure 16 shows the refraction of red light at a water-air interface.

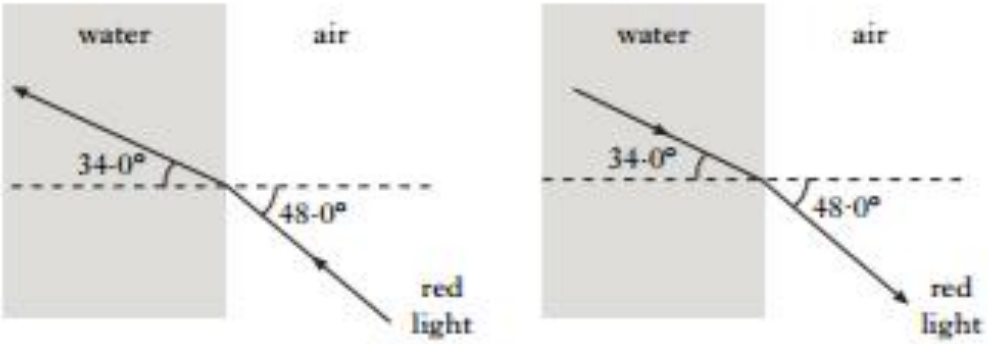


Figure 16

The refractive index n for red light travelling from air to water is 1·33. Show that the refractive index μ for red light travelling from **water** to **air** is 0·752. **1**

(iii) Figure 17 shows a ray of unpolarised red light incident on a water-air interface.

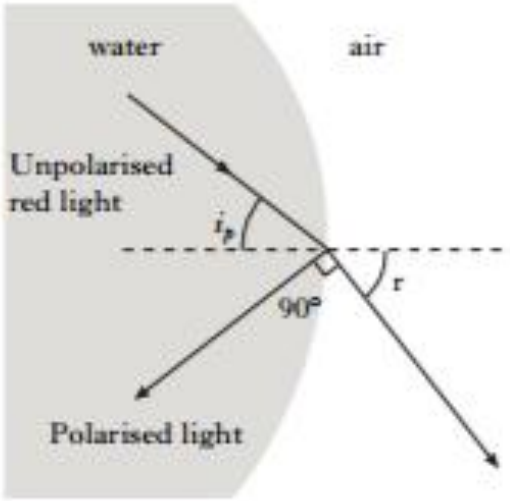


Figure 17

For light travelling from water to air,

$$\mu = \tan i_p$$

where i_p is the Brewster angle.

Calculate the Brewster angle for red light at this water-air interface. **1**

Marks

10. (continued)

(*b*) A rainbow is produced when light follows the path in a raindrop as shown in Figure 18.

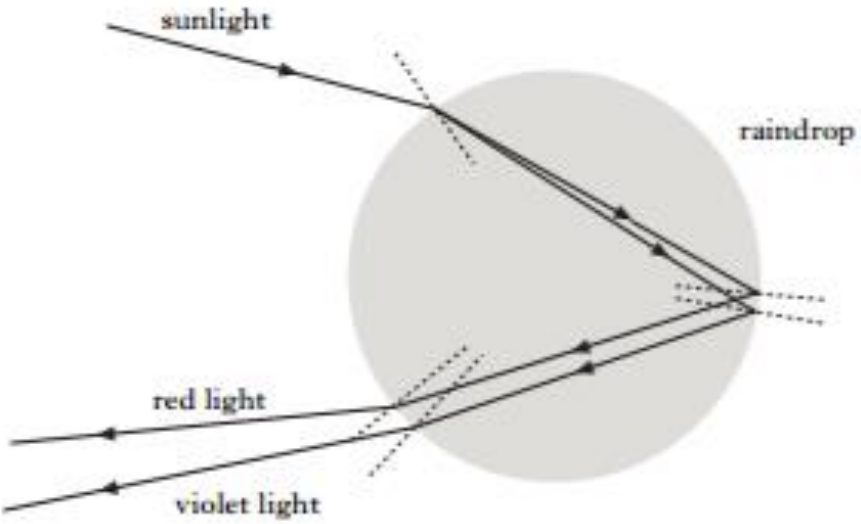


Figure 18

The light emerging from the raindrop is polarised.

The refractive index, μ, at a water to air interface is 0·752 for red light and 0·745 for violet light.

Calculate the difference in Brewster's angle for these two colours. **2**

(*c*) Rainbows produce light that is 96% polarised. A photographer plans to take a photograph of a rainbow. Her camera has a polarising filter in front of the lens as shown in Figure 19.

Figure 19

She directs her camera at the rainbow and slowly rotates the filter to see which is the best image to take.

Describe what happens to the image of the rainbow as she slowly rotates her filter through 180°. **2**

(7)

Marks

10. (*a*) A thin coating of magnesium fluoride is applied to the surface of a camera lens.

Figure 15 shows an expanded view of this coating on the glass lens.

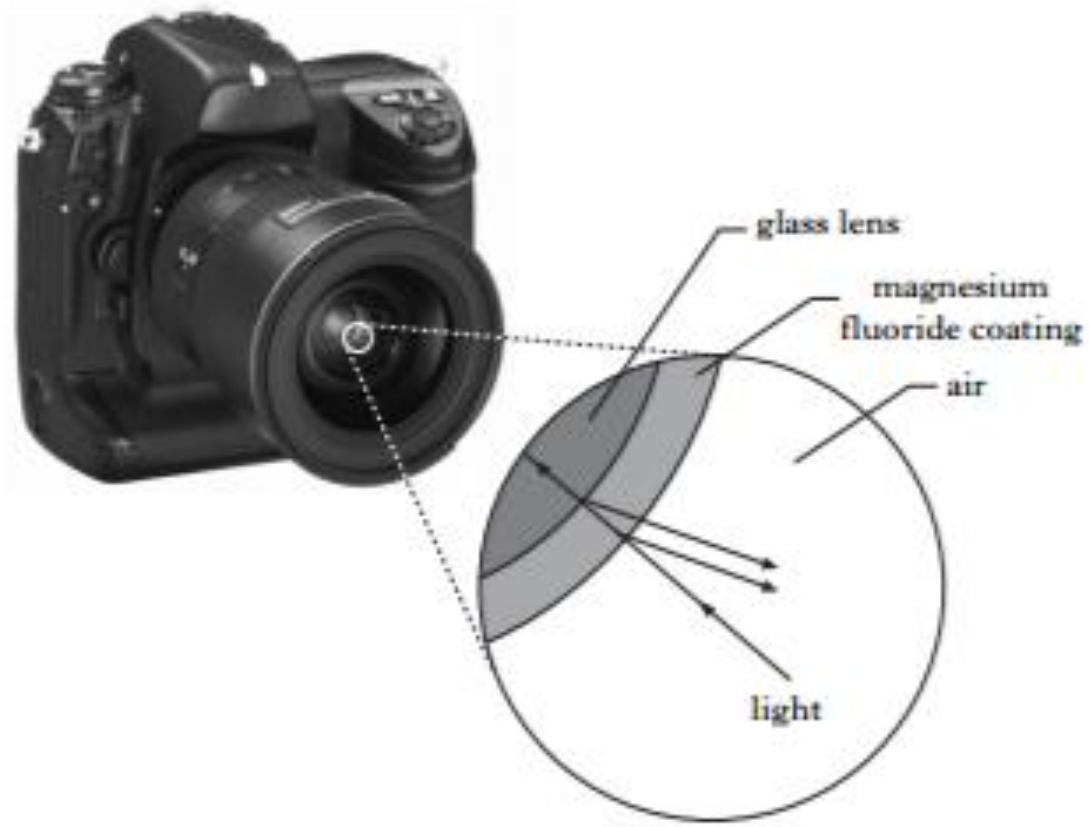


Figure 15

Monochromatic light is incident on the lens and some light reflects from the front and rear surfaces of the coating as shown in Figure 15.

(i) State the phase change undergone by the light reflected from:

(A) the front surface of the coating;

(B) the rear surface of the coating. 1

(ii) Explain, in terms of optical path difference, why this coating can make the lens non-reflecting for a particular wavelength of light. 2

(iii) Why is it desirable that camera lenses should reflect very little light? 1

(iv) A particular lens has a magnesium fluoride coating of thickness $1{\cdot}05 \times 10^{-7}$ m.

Calculate the wavelength of light for which this lens is non-reflecting. 2

Marks

11. (*a*) State the difference between plane polarised light and unpolarised light. **1**

(*b*) The digital display on a calculator consists of many small segments of liquid crystal material.

A "0" changes to an "8" when the middle segment switches from light to dark as shown in Figure 20.

Figure 20

To make one segment of a 7-segment display, a slice of liquid crystal is placed between a piece of polarising material and a mirror. Figure 21 shows this arrangement for the **middle segment only**.

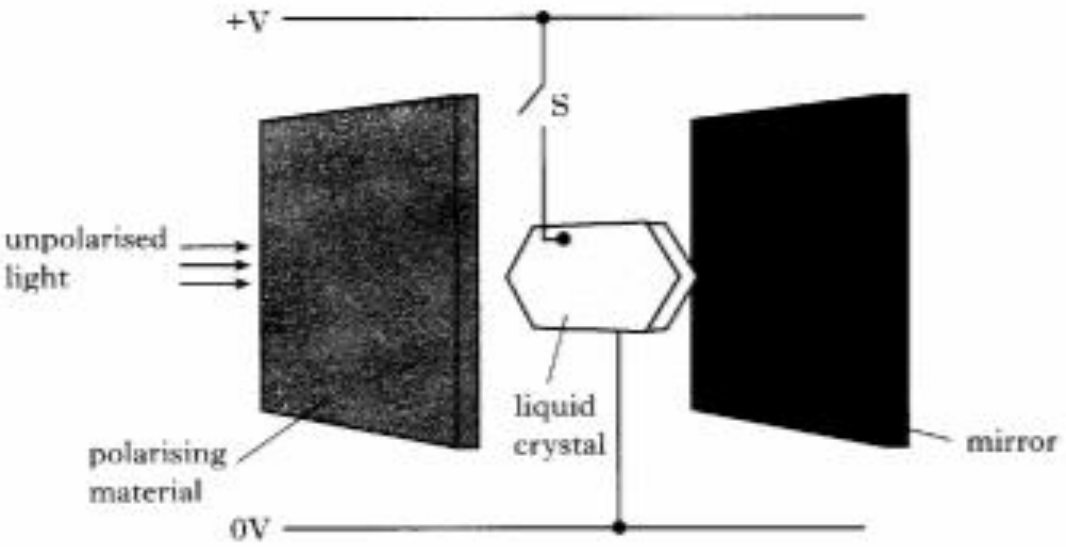


Figure 21

The following table summarises the effect of switch S.

Switch S	*Response of liquid crystal*
open	transmits polarised light
closed	does not transmit polarised light

(i) Explain why the liquid crystal appears dark when switch S is closed. **2**

(ii) State what happens to the switch when an "8" is changed to a "0". **1**

Marks

11. (continued)

(*c*) A student sees a row of numbers displayed on a calculator through a separate piece of polarising material as shown in Figure 22.

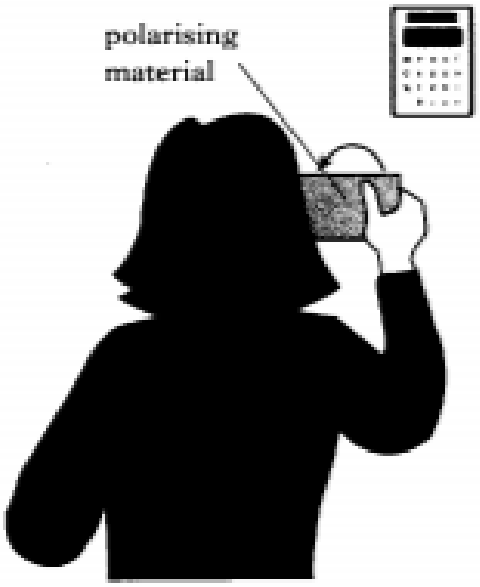


Figure 22

The student rotates the piece of polarising material through 180°. Explain what is seen as the polarising material is rotated. **2**

(6)

Marks

12. A television aerial is shown in Figure 15.

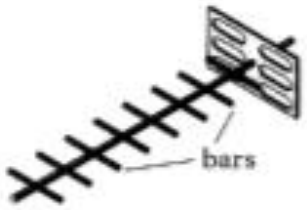


Figure 15

(*a*) Instructions for installing the aerial state

"The television waves received are plane polarised. The aerial does not pick up a strong signal unless the plane of the bars is the same as the plane of polarisation of the television waves."

(i) Explain the term *plane polarised.*

(ii) The aerial is installed and connected to a television.

The television has a clear picture when the bars of the aerial are horizontal as shown in Figure 15.

The aerial is now slowly rotated until the bars are vertical as shown in Figure 16.

Figure 16

Describe what happens to the television picture during this rotation. **2**

(*b*) Unpolarised light strikes the surface of a transparent material at the Brewster angle i_p, as shown in Figure 17. The reflected light is plane polarised.

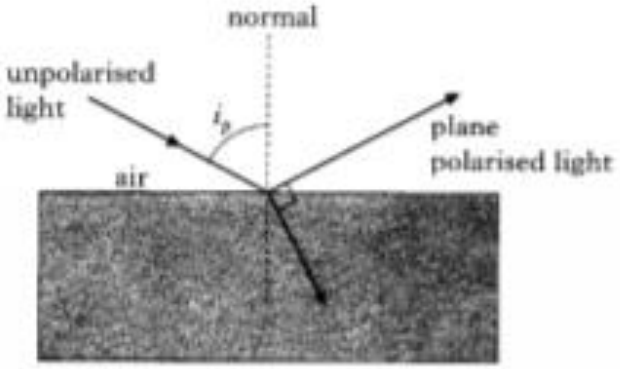


Figure 17

(i) Derive the expression

$$n = \tan i_p$$

where n is the refractive index of the transparent material.

(ii) Calculate the Brewster angle for perspex. **4**

12. (*a*) State the difference between plane polarised light and unpolarised light. **1**

(*b*) Figure 20 shows two polarising filters.

The first filter is called the polariser and the second the analyser.

The direction of the transmission axis is shown for each filter.

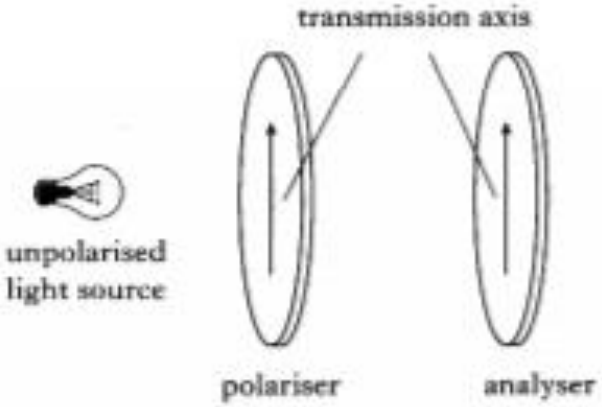


Figure 20

Unpolarised light is passed through the two filters.

The transmission axis of the analyser is now turned to different positions as shown in Figure 21.

Analyser setting	*Position of analyser's transmission axis*	*Intensity of transmitted light/W m^{-2}*
A		5·0
B		
C		
D		
E		

Figure 21

The intensity of transmitted light when the analyser is at setting A is 5·0 W m^{-2}.

State possible values for the intensity of the transmitted light when the transmission axis of the analyser is at settings B, C, D and E. **2**

Marks

12. (continued)

(*c*) Light can be polarised by reflection from a sheet of glass.

For a particular angle of incidence i_p, the reflected ray is totally plane polarised. This situation is represented in Figure 22.

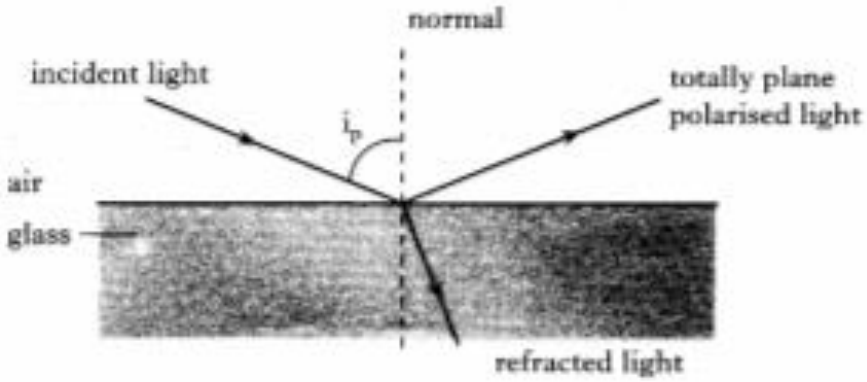


Figure 22

Show that,

$$\tan i_p = n$$

where n is the refractive index of the glass. **2**

(5)

Marks

11. (*a*) State the difference between polarised and unpolarised light. **1**

(*b*) Unpolarised monochromatic light is incident on a glass block of refractive index n at an angle i_p, as shown in Figure 18.

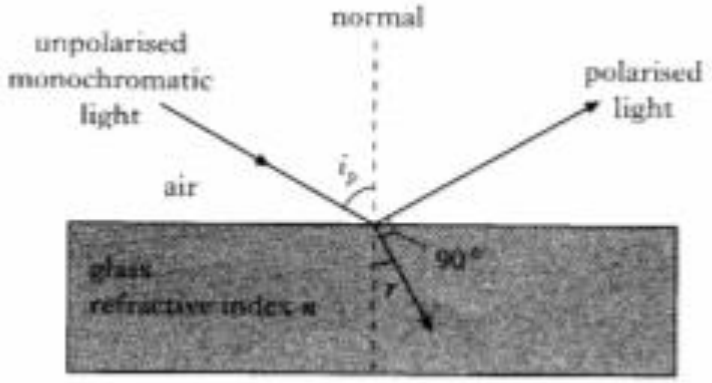


Figure 18

Light is refracted by the glass at angle r and polarised light is reflected by the glass.

Derive the expression

$$n = \tan i_p$$ where i_p is known as Brewster's angle. **2**

(*c*) Sunlight is reflected from the surface of a loch as shown in Figure 19.

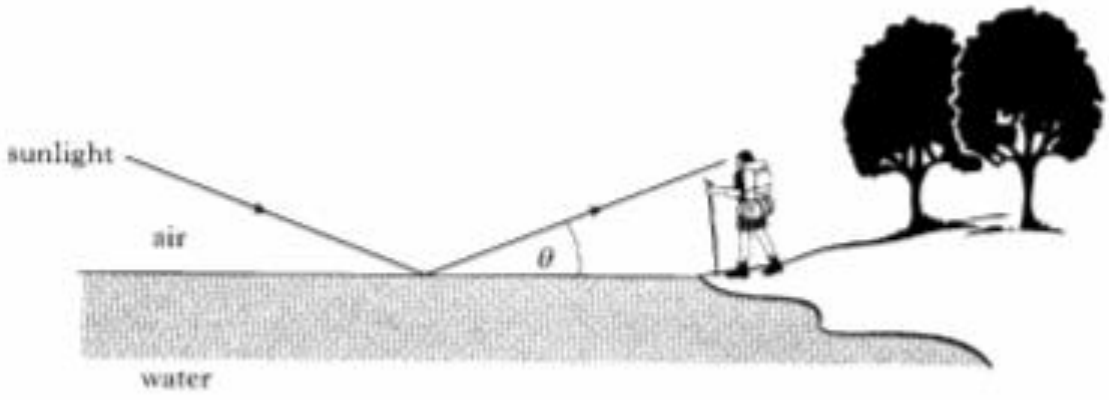


Figure 19

Calculate the angle θ at which the water reflects plane polarised light to the observer on the shore. **2**

(5)