

**3220/202**

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SCOTTISH  
CERTIFICATE OF  
EDUCATION  
1997

THURSDAY, 15 MAY  
1.00 PM – 3.30 PM

PHYSICS  
HIGHER GRADE  
Paper II

**Read carefully**

- 1 All questions should be attempted.
- 2 Enter the question number clearly in the margin beside each question.
- 3 Any necessary data will be found in the Data Sheet on page two.
- 4 Care should be taken not to give an unreasonable number of significant figures in the final answers to calculations.
- 5 Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Scottish Qualifications Authority.

**DATA SHEET**  
COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	$c$	$3.00 \times 10^8 \text{ m s}^{-1}$	Mass of electron	$m_e$	$9.11 \times 10^{-31} \text{ kg}$
Charge on electron	$e$	$-1.60 \times 10^{-19} \text{ C}$	Mass of neutron	$m_n$	$1.675 \times 10^{-27} \text{ kg}$
Gravitational acceleration	$g$	$9.8 \text{ m s}^{-2}$	Mass of proton	$m_p$	$1.673 \times 10^{-27} \text{ kg}$
Planck's constant	$h$	$6.63 \times 10^{-34} \text{ J s}$			

**REFRACTIVE INDICES**

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Glycerol	1.47
Glass	1.51	Water	1.33
Ice	1.31	Air	1.00
Perspex	1.49		

**SPECTRAL LINES**

Element	Wavelength/nm	Colour	Element	Wavelength/nm	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	<i>Lasers</i>		
	397	Ultraviolet	<i>Element</i>	<i>Wavelength/nm</i>	<i>Colour</i>
	389	Ultraviolet	Carbon dioxide	9550 } 10590 }	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

**PROPERTIES OF SELECTED MATERIALS**

Substance	Density/ $\text{kg m}^{-3}$	Melting Point/ K	Boiling Point/ K	Specific Heat Capacity/ $\text{J kg}^{-1} \text{ K}^{-1}$	Specific Latent Heat of Fusion/ $\text{J kg}^{-1}$	Specific Latent Heat of Vaporisation/ $\text{J kg}^{-1}$
Aluminium	$2.70 \times 10^3$	933	2623	$9.02 \times 10^2$	$3.95 \times 10^5$	....
Copper	$8.96 \times 10^3$	1357	2853	$3.86 \times 10^2$	$2.05 \times 10^5$	....
Glass	$2.60 \times 10^3$	1400	....	$6.70 \times 10^2$	....	....
Ice	$9.20 \times 10^2$	273	....	$2.10 \times 10^3$	$3.34 \times 10^5$	....
Glycerol	$1.26 \times 10^3$	291	563	$2.43 \times 10^3$	$1.81 \times 10^5$	$8.30 \times 10^5$
Methanol	$7.91 \times 10^2$	175	338	$2.52 \times 10^3$	$9.9 \times 10^4$	$1.12 \times 10^6$
Sea Water	$1.02 \times 10^3$	264	377	$3.93 \times 10^3$	....	....
Water	$1.00 \times 10^3$	273	373	$4.19 \times 10^3$	$3.34 \times 10^5$	$2.26 \times 10^6$
Air	1.29	....	....	....	....	....
Hydrogen	$9.0 \times 10^{-2}$	14	20	$1.43 \times 10^4$	....	$4.50 \times 10^5$
Nitrogen	1.25	63	77	$1.04 \times 10^3$	....	$2.00 \times 10^5$
Oxygen	1.43	55	90	$9.18 \times 10^2$	....	$2.40 \times 10^5$

The gas densities refer to a temperature of 273 K and a pressure of  $1.01 \times 10^5 \text{ Pa}$ .

1. (a) An object starts from rest and moves with constant acceleration  $a$ . After a time  $t$ , the velocity  $v$  and displacement  $s$  are given by

$$v = at \text{ and } s = \frac{1}{2}at^2 \text{ respectively.}$$

Use these relationships, to show that

$$v^2 = 2as.$$

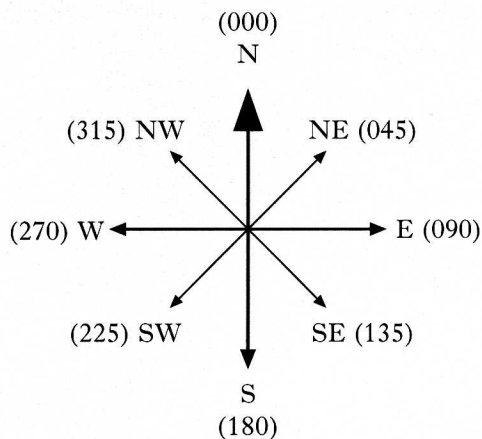
2

- (b) An aircraft of mass of 1000 kg has to reach a speed of  $33 \text{ m s}^{-1}$  before it takes off from a runway. The engine of the aircraft provides a constant thrust of 3150 N. A constant frictional force of 450 N acts on the aircraft as it moves along the runway.

- (i) Calculate the acceleration of the aircraft along the runway.  
 (ii) The aircraft starts from rest. What is the minimum length of runway required for a take-off?

4

- (c) During a flight the aircraft is travelling with a velocity of  $36 \text{ m s}^{-1}$  due north (000). A wind with a speed of  $12 \text{ m s}^{-1}$  starts to blow **towards** the direction  $40^\circ$  west of north (320).



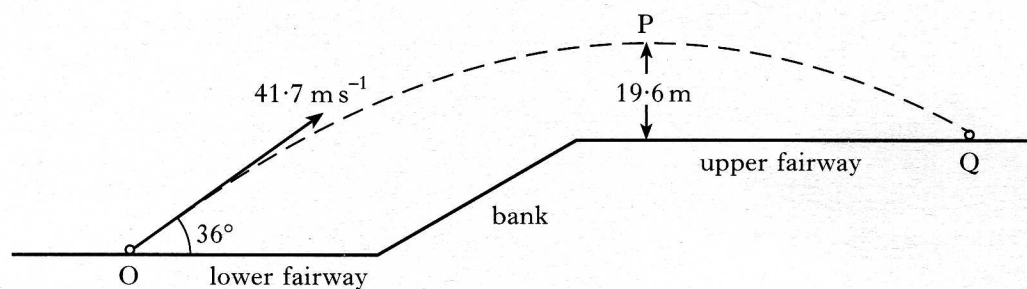
Find the magnitude and direction of the resultant velocity of the aircraft.

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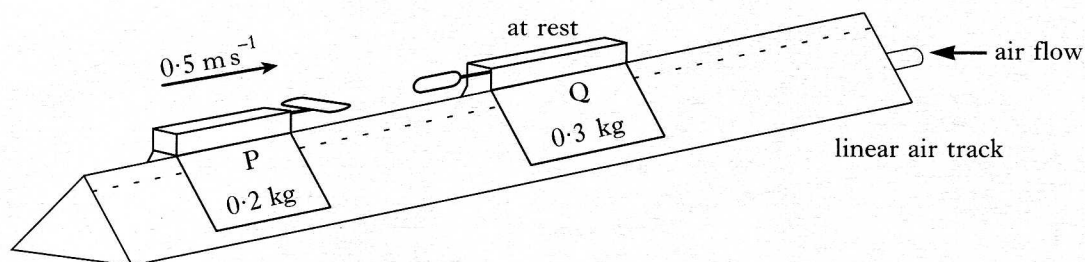
2. The fairway on a golf course is in two horizontal parts separated by a steep bank as shown below.



A golf ball at point O is given an initial velocity of  $41.7 \text{ m s}^{-1}$  at  $36^\circ$  to the horizontal. The ball reaches a maximum vertical height at point P above the upper fairway. Point P is  $19.6 \text{ m}$  above the upper fairway as shown. The ball hits the ground at point Q. The effect of air friction on the ball may be neglected.

- (a) Calculate:
- the horizontal component of the initial velocity of the ball;
  - the vertical component of the initial velocity of the ball. 2
- (b) Show that the time taken for the ball to travel from point O to point Q is  $4.5 \text{ s}$ . 3
- (c) Calculate the horizontal distance travelled by the ball. 2
- (7)**

3. The diagram below shows two vehicles P and Q on a linear air track.



Vehicle P, of mass  $0.2 \text{ kg}$ , is projected with a velocity of  $0.5 \text{ m s}^{-1}$  to the right along the linear air track.

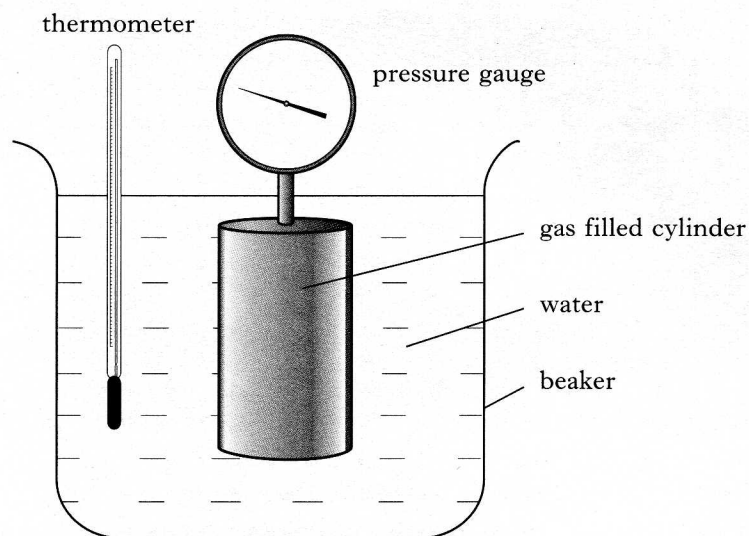
It collides with vehicle Q, of mass  $0.3 \text{ kg}$ , which is initially at rest.

After the collision, the vehicles move in opposite directions. Vehicle Q moves off with a velocity of  $0.4 \text{ m s}^{-1}$  to the right.

- (a) Show that vehicle P rebounds with a speed of  $0.1 \text{ m s}^{-1}$  after the collision. 2
- (b) Calculate the change in momentum of vehicle P as a result of the collision. 2
- (c) During the collision, a timing device records the time of contact between the two vehicles as  $0.06 \text{ s}$ .
- (i) Calculate the average force acting on vehicle P during the collision. 3
- (ii) Sketch a graph showing how the force on vehicle P could vary with time while the two vehicles are in contact. (7)

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4. A pupil uses the apparatus shown in the diagram to investigate the relationship between the pressure and the temperature of a fixed mass of gas at constant volume.

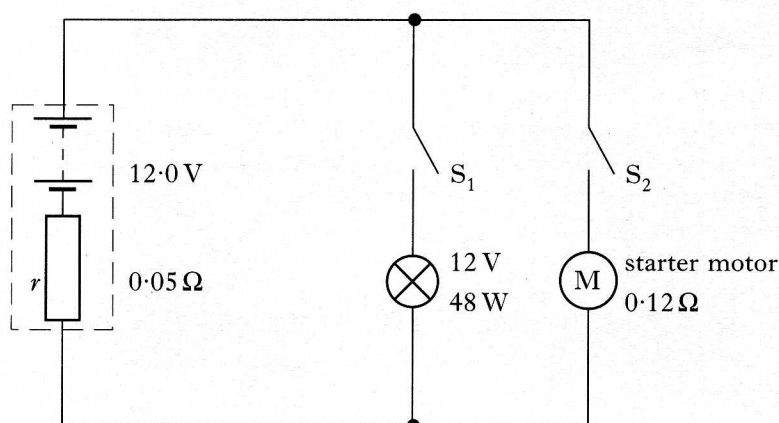


The cylinder is fully immersed in a beaker of water and the water is slowly heated.

You may assume that the volume of the cylinder does not change as the temperature of the water changes.

- (a) Explain why the cylinder must be fully immersed in the beaker of water. 1
- (b) The pressure of the gas in the cylinder is 100 kPa when the gas is at a temperature of 17 °C. Calculate the pressure of the gas in the cylinder when the temperature of the gas is 75 °C. 2
- (c) The base of the cylinder has an area of 0.001 m<sup>2</sup>.  
What is the force exerted by the gas on the base when the temperature of the gas is 75 °C? 2
- (d) What happens to the density of the gas in the cylinder as the temperature increases from 17 °C to 75 °C?  
Justify your answer. 2
- (7)**

5. The diagram shows a circuit for part of the electrical system of a car.

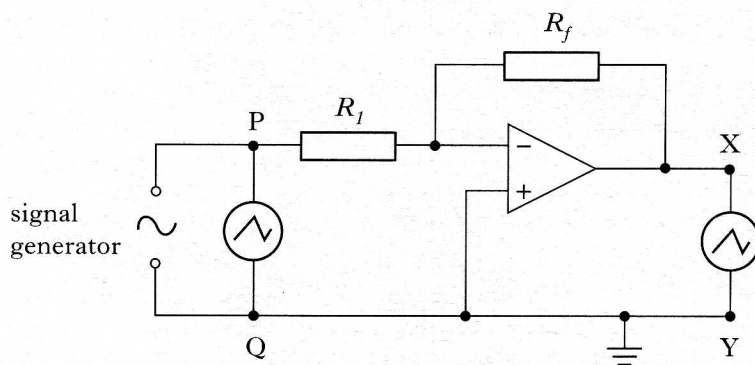


The battery has an e.m.f. of  $12.0\text{ V}$  and an internal resistance  $r$  of  $0.05\ \Omega$ . The battery is connected across a  $12\text{ V}$ ,  $48\text{ W}$  headlamp and a starter motor of resistance  $0.12\ \Omega$  as shown.

- (a) State what is meant by “the battery has an e.m.f. of  $12.0\text{ V}$ ”. 1
- (b) (i) What is the resistance of the headlamp when used at its rated voltage?  
(ii) Show that there is a p.d. of  $11.8\text{ V}$  across the headlamp when switch  $S_1$  is closed and switch  $S_2$  is open. Assume that the resistance of the headlamp does not change. 4
- (c) Both switches  $S_1$  and  $S_2$  are now closed.  
Assuming that the resistance of the headlamp does not change, calculate:
- (i) the total resistance of the circuit;  
(ii) the current from the battery. 4
- (9)**

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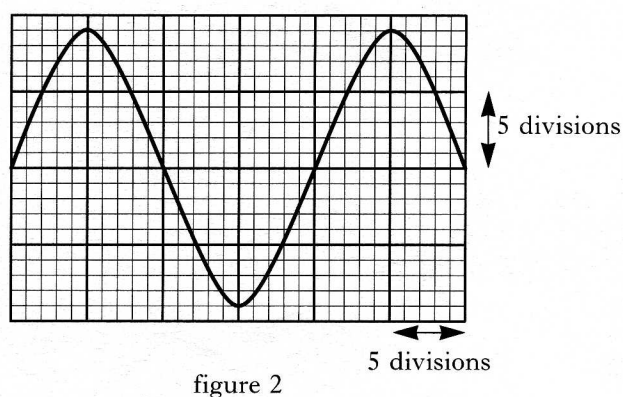
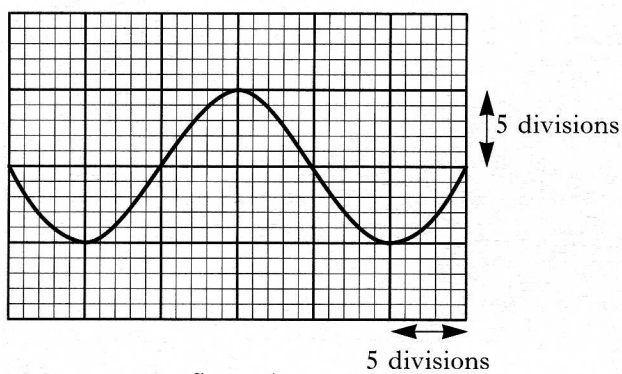
6. (a) An operational amplifier circuit is set up with oscilloscopes connected across PQ and XY as shown.



The trace on the oscilloscope connected across PQ is shown in figure 1 below. The Y-gain setting of this oscilloscope is 2 mV/division.

The trace on the oscilloscope connected across XY is shown in figure 2 below. The Y-gain setting of this oscilloscope is 30 mV/division.

The time base on each oscilloscope is set at 0.1 ms/division.

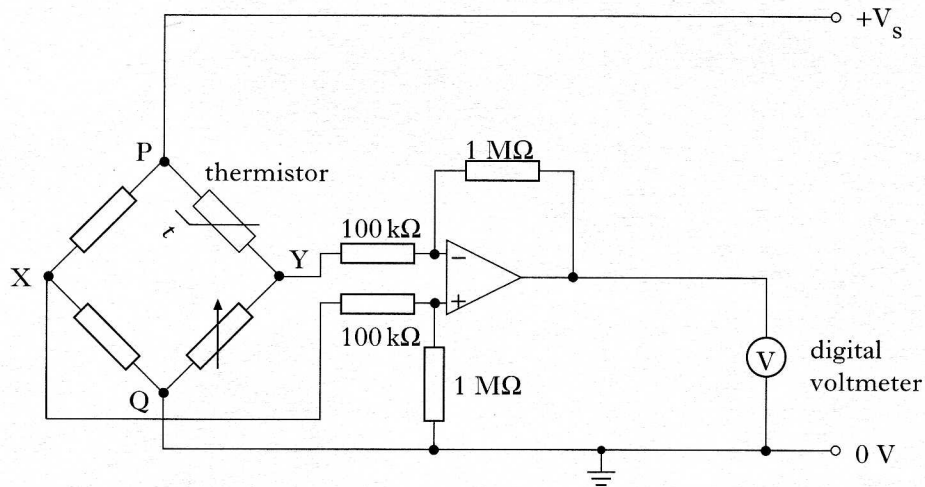


- (i) Calculate the voltage gain of the amplifier.
- (ii) Calculate the r.m.s. value of the output voltage from the amplifier.
- (iii) Suggest suitable values for  $R_f$  and  $R_1$  which would produce the trace shown in figure 2.

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## 6. (continued)

- (b) An electronic circuit is used to monitor temperature during an experiment. The circuit includes a Wheatstone bridge and an operational amplifier operating in the differential mode. One of the components of the Wheatstone bridge is a thermistor.

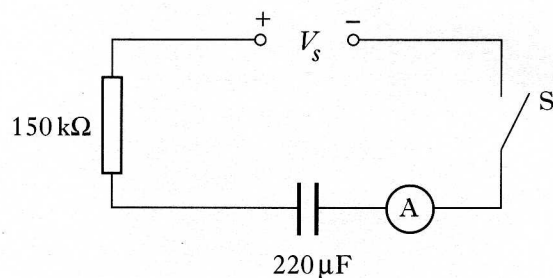


- (i) When the temperature of the thermistor is  $23^\circ\text{C}$ , the reading on the digital voltmeter is  $0.00\text{ V}$ .  
What is the value of the p.d. between X and Y?
- (ii) When the temperature of the thermistor is  $26^\circ\text{C}$ , the reading on the digital voltmeter is  $-0.18\text{ V}$ .  
What is now the value of the p.d. between X and Y?
- (iii) State what happens to the reading on the digital voltmeter when the temperature of the thermistor falls to  $20^\circ\text{C}$ .  
Justify your answer.

5  
(10)

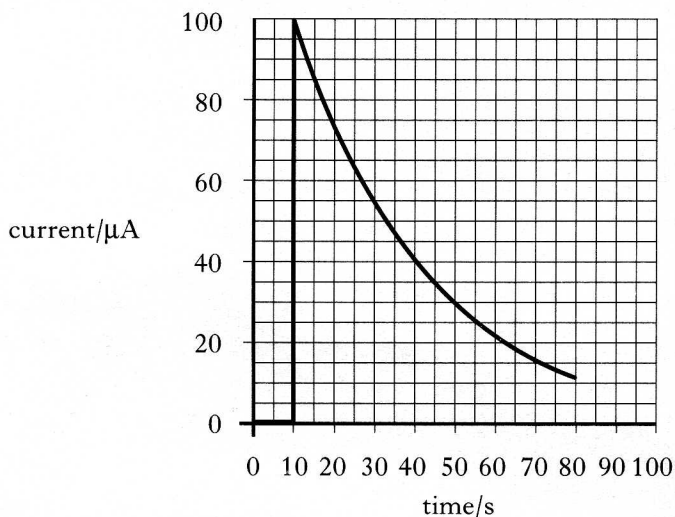
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7. (a) A capacitor of capacitance  $220\ \mu\text{F}$  is connected in series with a  $150\ \text{k}\Omega$  resistor, a switch and an ammeter. A d.c. power supply of negligible internal resistance is connected to the circuit as shown below.



A stopclock is started and after 10 seconds the switch S is closed. Ammeter readings are noted at regular intervals until a time of 80 s is shown on the stopclock.

The graph below shows how the current in the circuit varies with time.

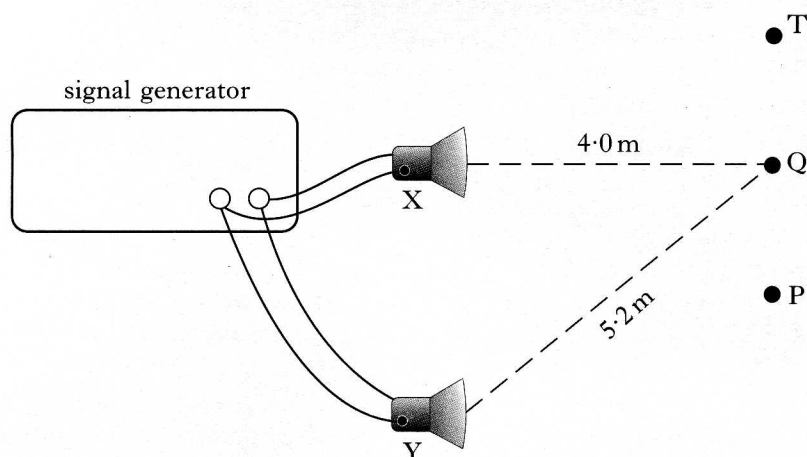


- (i) Calculate the voltage  $V_s$  of the d.c. power supply.
  - (ii) At what time on the stopclock does the p.d. across the resistor equal 6 V?
  - (iii) What is the p.d. across the capacitor when the p.d. across the resistor is 6 V?
- (b) A magazine article on the resuscitation of a heart attack victim describes the equipment used. This equipment uses a  $16\ \mu\text{F}$  capacitor which is charged until the p.d. across it is 6 kV. The capacitor is then fully discharged to give the heart a shock. The discharge time is 2 ms.
- (i) When the capacitor is fully charged, calculate:
    - (A) the charge stored;
    - (B) the energy stored.
  - (ii) Calculate the average current during discharge.

5

6  
(11)

8. Two identical loudspeakers X and Y are set up in a room which has been designed to eliminate the reflection of sound. The loudspeakers are connected to the same signal generator as shown.



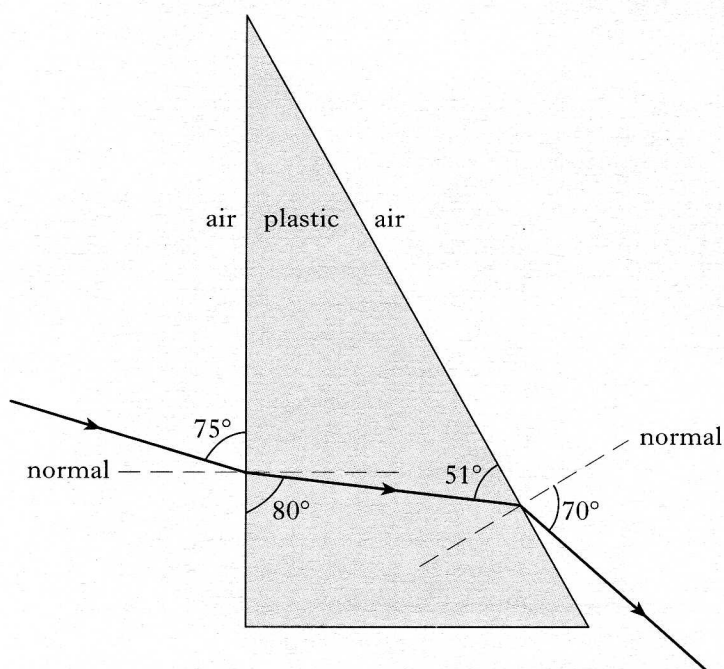
- (a) (i) When a sound level meter is moved from P to T, maxima and minima of sound intensity are detected.  
Explain, in terms of waves, why the maxima and minima are produced.
- (ii) The sound level meter detects a maximum at P.  
As the sound level meter is moved from P, it detects a minimum then a maximum then another minimum when it reaches Q.  
Calculate the wavelength of the sound used.
- (b) The sound level meter is now fixed at Q.  
The frequency of the output from the signal generator is increased steadily from 200 Hz to 1000 Hz.
- (i) What happens to the wavelength of the sound as the frequency of the output is increased?
- (ii) Explain why the sound level meter detects a series of maxima and minima as the frequency of the output is increased.

4

3  
(7)

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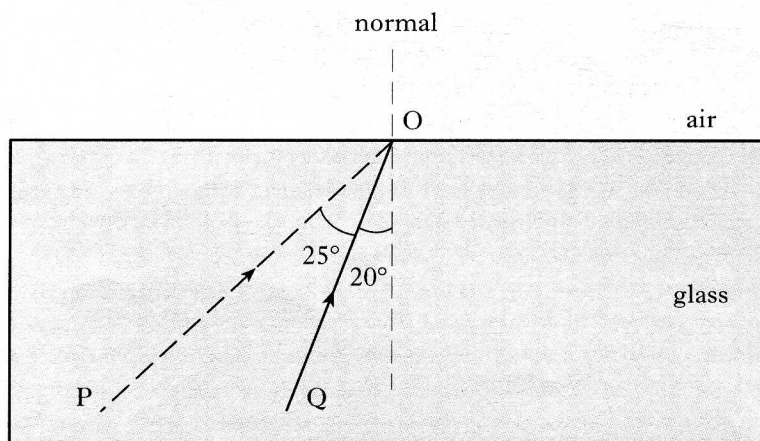
9. (a) The diagram below shows the refraction of a ray of red light as it passes through a plastic prism.



Calculate the refractive index of the plastic for this red light.

2

- (b) The refractive index of a glass block is found to be 1.44 when red light is used.
- What is the value of the critical angle for this red light in the glass?
  - The diagram shows the paths of two rays of this red light, PO and QO, in the glass block.



When rays PO and QO strike the glass-air boundary, **three** further rays of light are observed.

Copy and complete the diagram to show **all five** rays.

**Clearly indicate** which of the three rays came from P and which came from Q.

The values of all angles should be shown on the diagram.

6  
(8)

