

3220/202

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 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	Lasers		
	397	Ultraviolet	Element	Wavelength/nm	Colour
	389	Ultraviolet	Carbon dioxide	9550 } 10590 }	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

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

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

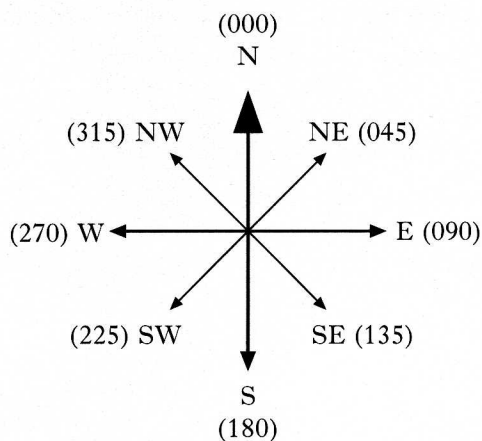
- (b) An aircraft of mass of 1000 kg has to reach a speed of 33 m s^{-1} before it takes off from a runway. The engine of the aircraft provides a constant thrust of 3150 N. A constant frictional force of 450 N acts on the aircraft as it moves along the runway.

(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 m s^{-1} due north (000). A wind with a speed of 12 m s^{-1} starts to blow **towards** the direction 40° west of north (320).



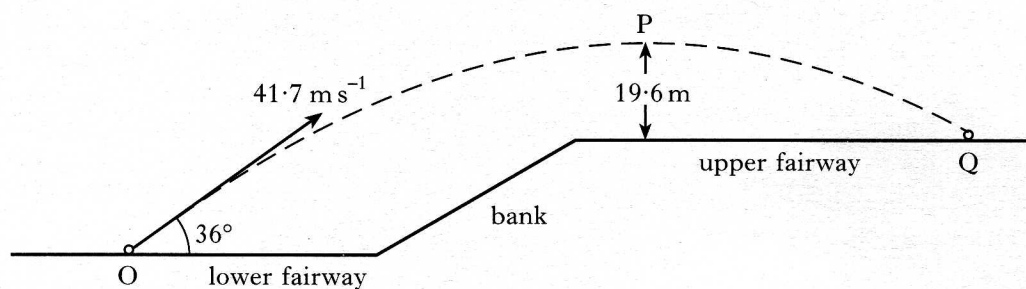
Find the magnitude and direction of the resultant velocity of the aircraft.

3

(9)

[Turn over]

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 m s^{-1} at 36° to the horizontal.

The ball reaches a maximum vertical height at point P above the upper fairway. Point P is 19.6 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:

(i) the horizontal component of the initial velocity of the ball;

(ii) the vertical component of the initial velocity of the ball.

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(b) Show that the time taken for the ball to travel from point O to point Q is 4.5 s .

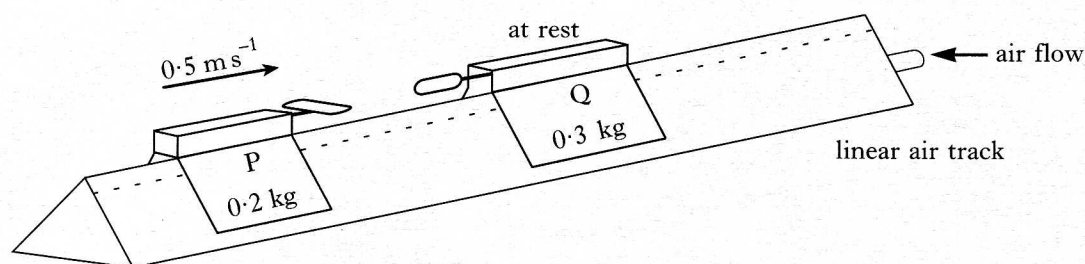
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(c) Calculate the horizontal distance travelled by the ball.

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(7)

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



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

It collides with vehicle Q, of mass 0.3 kg, which is initially at rest.

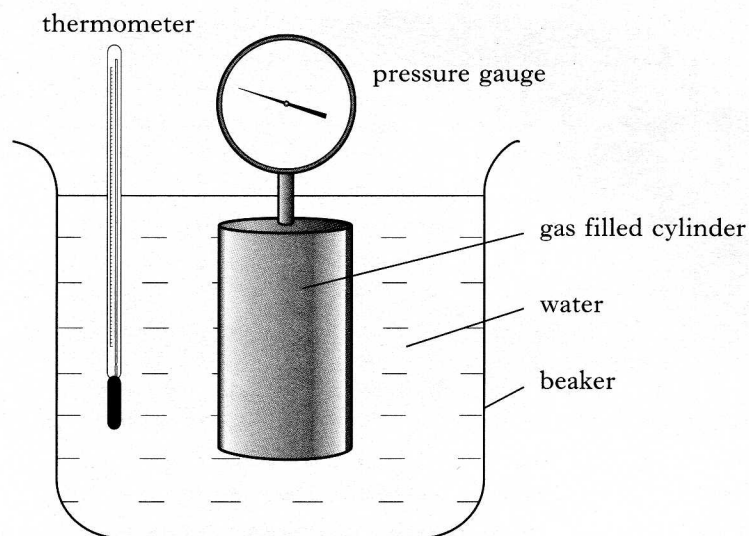
After the collision, the vehicles move in opposite directions. Vehicle Q moves off with a velocity of 0.4 m s^{-1} to the right.

- (a) Show that vehicle P rebounds with a speed of 0.1 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 s.
 - (i) Calculate the average force acting on vehicle P during the collision.
 - (ii) Sketch a graph showing how the force on vehicle P could vary with time while the two vehicles are in contact. 3

(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.

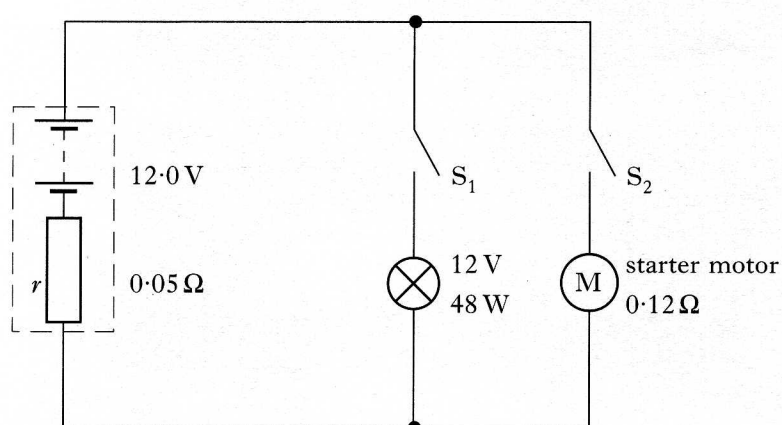


The cylinder is fully immersed in a beaker of water and the water is slowly heated.

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 m². 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? 2
Justify your answer. (7)

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

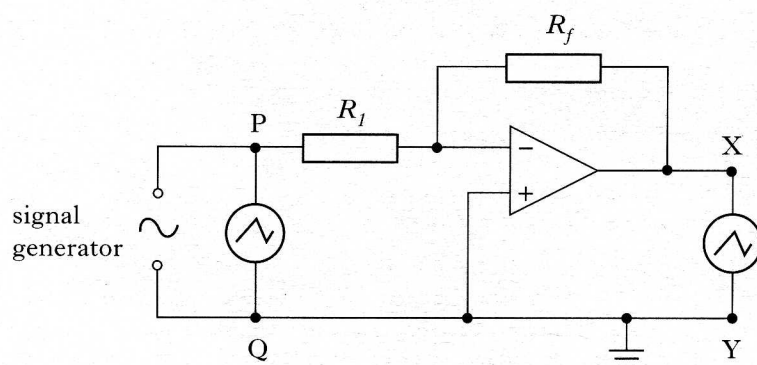


The battery has an e.m.f. of 12.0 V and an internal resistance r of $0.05\ \Omega$. The battery is connected across a 12 V , 48 W headlamp and a starter motor of resistance $0.12\ \Omega$ as shown.

- (a) State what is meant by “the battery has an e.m.f. of 12.0 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 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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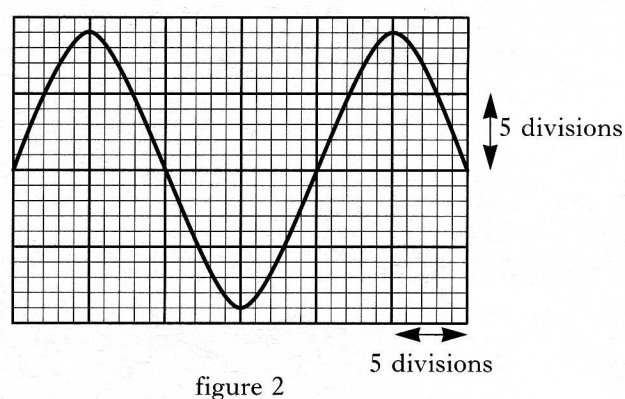
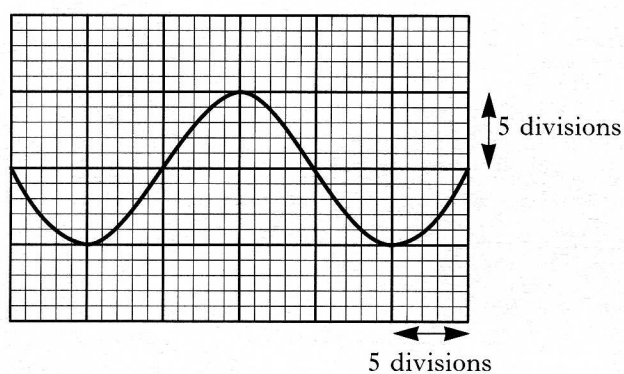
6. (a) An operational amplifier circuit is set up with oscilloscopes connected across PQ and XY as shown.



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.

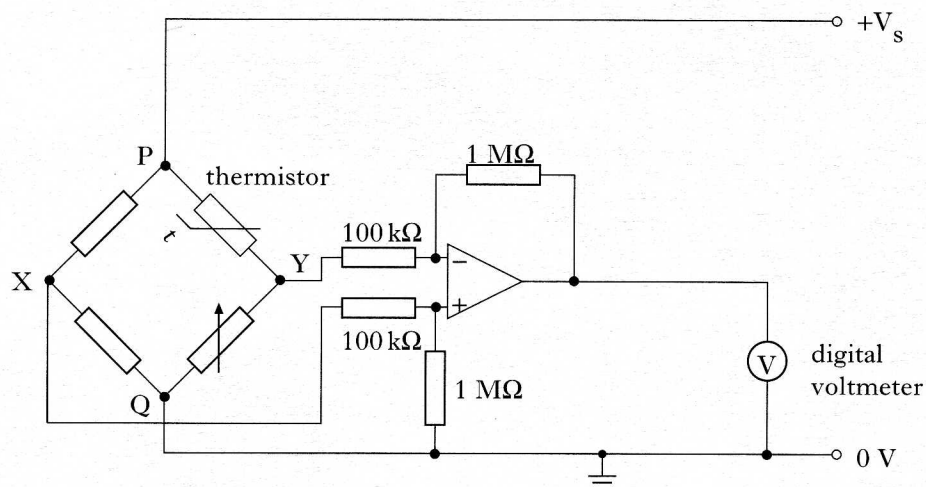


- Calculate the voltage gain of the amplifier.
- Calculate the r.m.s. value of the output voltage from the amplifier.
- Suggest suitable values for R_f and R_1 which would produce the trace shown in figure 2.

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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.



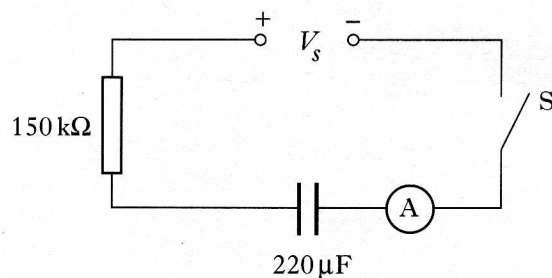
- (i) When the temperature of the thermistor is 23°C , the reading on the digital voltmeter is 0.00 V .
What is the value of the p.d. between X and Y?
- (ii) When the temperature of the thermistor is 26°C , the reading on the digital voltmeter is -0.18 V .
What is now the value of the p.d. between X and Y?
- (iii) State what happens to the reading on the digital voltmeter when the temperature of the thermistor falls to 20°C .

Justify your answer.

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(10)

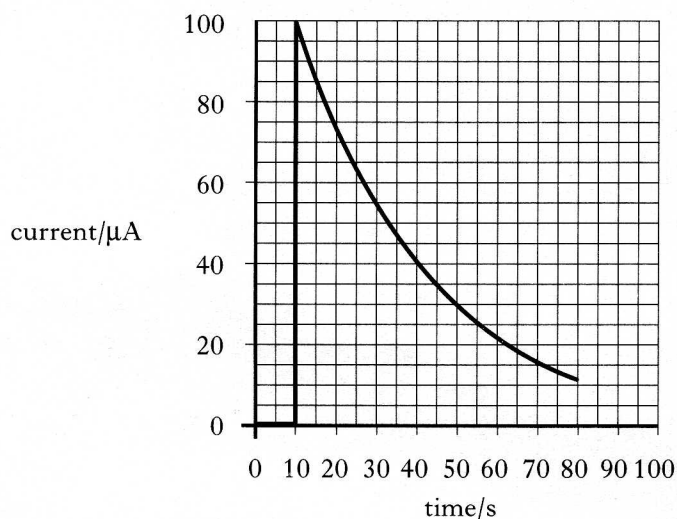
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7. (a) A capacitor of capacitance $220\mu\text{F}$ is connected in series with a $150\text{k}\Omega$ resistor, a switch and an ammeter. A d.c. power supply of negligible internal resistance is connected to the circuit as shown below.



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.

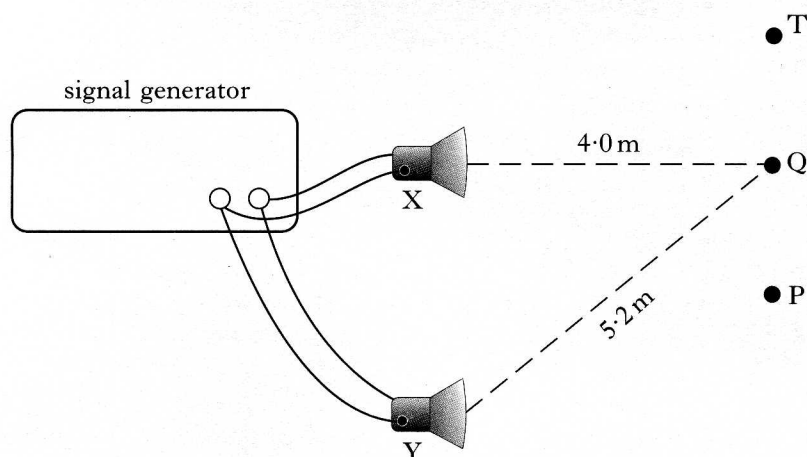


- (i) Calculate the voltage V_s of the d.c. power supply.
 - (ii) At what time on the stopclock does the p.d. across the resistor equal 6 V?
 - (iii) What is the p.d. across the capacitor when the p.d. across the resistor is 6 V?
- (b) A magazine article on the resuscitation of a heart attack victim 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.

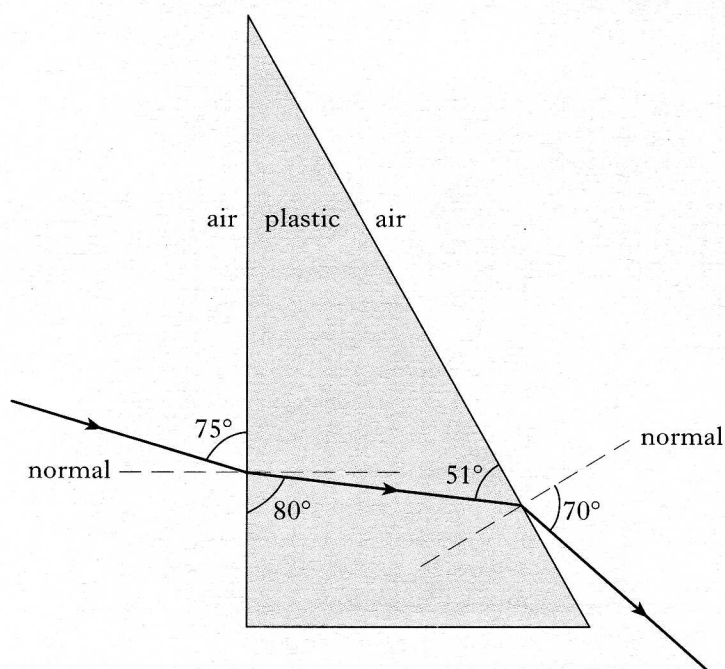
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- (b) The sound level meter is now fixed at Q.
The frequency of the output from the signal generator is increased steadily from 200 Hz to 1000 Hz.
- (i) What happens to the wavelength of the sound as the frequency of the output is increased?
- (ii) Explain why the sound level meter detects a series of maxima and minima as the frequency of the output is increased.

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(7)

[Turn over]

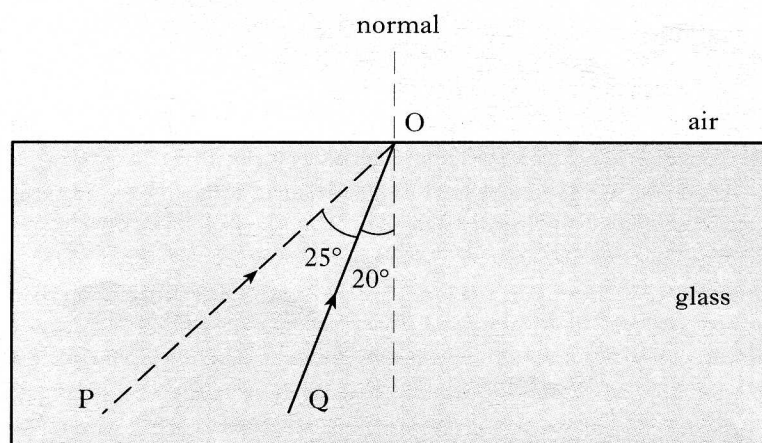
9. (a) The diagram below shows the refraction of a ray of red light as it passes through a plastic prism.



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.

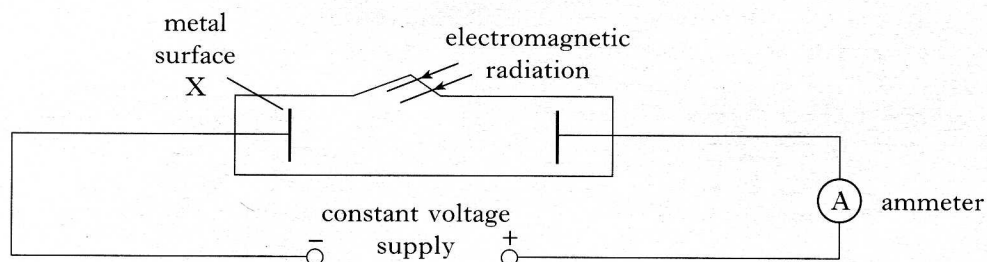
Copy and complete the diagram to show **all five** rays.

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.

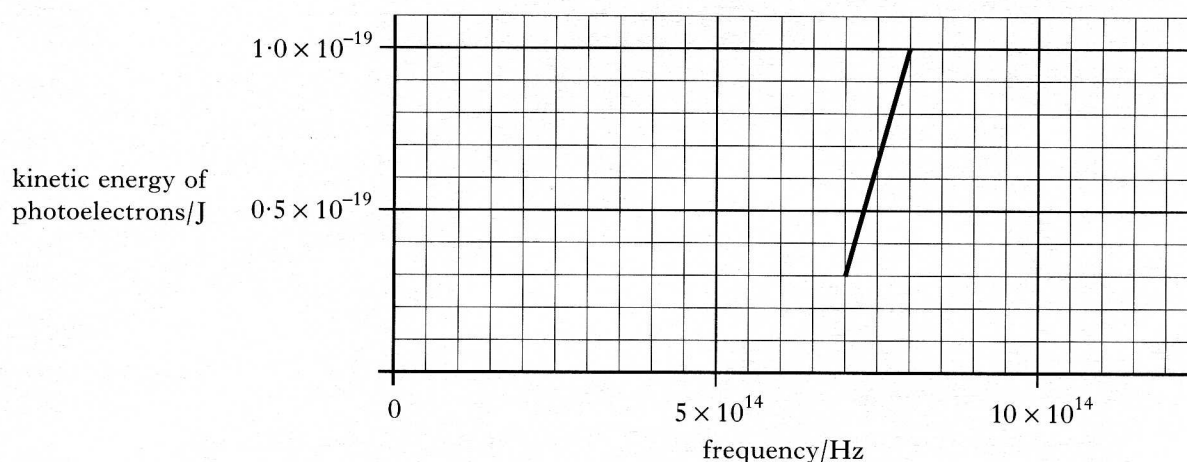
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(8)

10. (a) The apparatus shown below is used to investigate photoelectric emission from the metal surface X when electromagnetic radiation is shone on the surface.
- The frequency of the electromagnetic radiation can be varied.



- (i) When radiation of a certain frequency is shone on the metal surface X, a reading is obtained on the ammeter.
- Sketch a graph to show how the current in the circuit varies with the intensity of the radiation.
- (ii) Explain why there is no reading on the ammeter when the frequency of the radiation is decreased below a particular value.
- (b) The maximum kinetic energy of the photoelectrons emitted from metal X is measured for a number of different frequencies of the radiation.
- The graph shows how this kinetic energy varies with frequency.

3



- (i) Use the graph to find the threshold frequency for metal X.
- (ii) The table below gives the work function of different metals.

Metal	Work function/J
Potassium	3.2×10^{-19}
Calcium	4.3×10^{-19}
Zinc	6.9×10^{-19}
Gold	7.8×10^{-19}

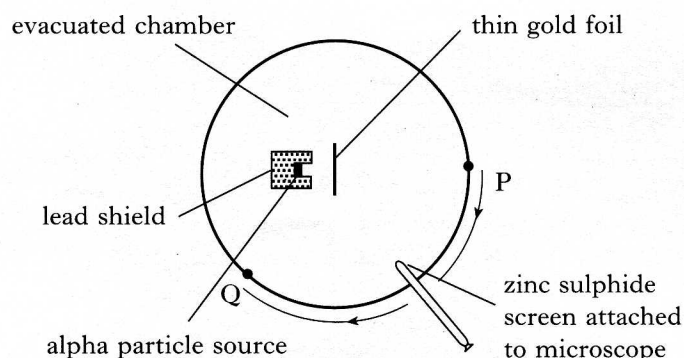
Which one of these metals was used in the investigation?

You must justify your answer using the information given in the table.

4

(7)

11. (a) The diagram shows the apparatus used by Rutherford to investigate the scattering of alpha particles by a gold foil.



From the observations made as the microscope and screen were moved from P to Q, Rutherford deduced that an atom has a nucleus which is:

- (A) positively charged;
- (B) massive;
- (C) much smaller than the volume of the atom.

Explain how the observations from the scattering experiment led to these three deductions.

3

- (b) A pupil reads in a textbook about the possible effects of a source of gamma rays and neutrons on one type of body tissue. A table in the textbook provided information relating to the radiations and absorbed doses for this body tissue. This table is shown below.

Type of radiation	Quality factor	Absorbed dose/ μGy
gamma	1	200
neutrons	3	100

- (i) Calculate the total dose equivalent received by the body tissue.
- (ii) Calculate the thickness of lead which would have to surround the above source to reduce the absorbed dose from the gamma rays to $25\mu\text{Gy}$.

The half-value thickness of lead for the gamma radiation is 8 mm.

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(8)

[END OF QUESTION PAPER]