X069/701

NATIONAL
QUALIFICATIONS
2001

MONDAY, 4 JUNE
9.00 AM – 11.30 AM

PHYSICS
ADVANCED HIGHER

Answer **all** questions.

Any necessary data may be found in the Data Sheet on page two.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Scottish Qualifications Authority.

SCOTTISH
QUALIFICATIONS
AUTHORITY

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}$ m	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}$ kg	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}$ kg	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}$m	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \text{F m}^{-1}$
Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\ \text{m s}^{-1}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \text{H m}^{-1}$
Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ \text{m s}^{-1}$			

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*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 10590	Infrared
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	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{5}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Marks

1. A car accelerates uniformly from rest from a point A and is timed over the distance AB as shown in Figure 1.

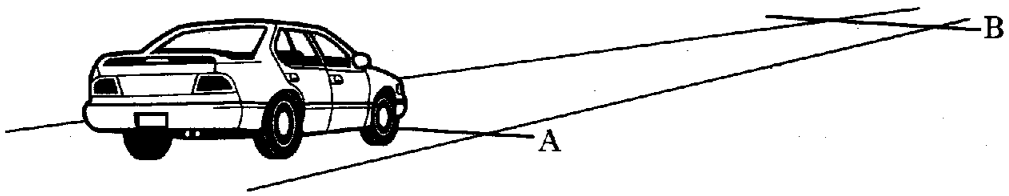

Figure 1

The results are as follows:

distance travelled, AB = (100 ± 1) m

time taken = (8·0 ± 0·4) s.

(*a*) Calculate:

(i) the acceleration of the car;

(ii) the percentage uncertainty in the acceleration. **4**

(*b*) The radius of each car wheel is 0·30 m.

Calculate the angular acceleration of a wheel as the car travels from A to B. **2**

(*c*) A small stone of mass 4·0 g is stuck in the tyre tread, as shown in Figure 2.

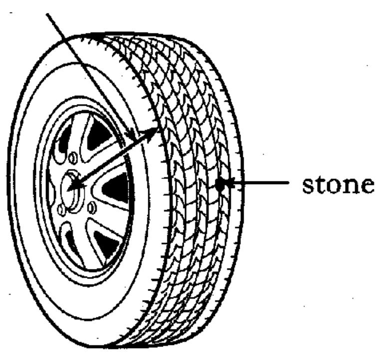

Figure 2

The stone is held in place by a radial frictional force which has a maximum value of 3·0 N.

(i) As the car's speed increases, the stone will eventually be released from the tread of the tyre. Explain why this happens.

(ii) Calculate the linear speed of the car just as the stone is released.

(iii) The stone works its way completely free of the tyre when it is at its highest point above road level. Describe the direction of the velocity of the stone just as it becomes free of the tyre tread. **5**

(11)

2. A flywheel is made from two large discs joined in the middle by a smaller disc of radius 20 mm.

The flywheel is free to rotate about a fixed axis through the centres of the discs. A thin, light cord is coiled 8 times round the inner disc, as shown in Figures 3 and 4.

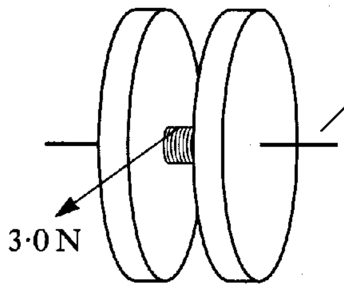

Figure 3

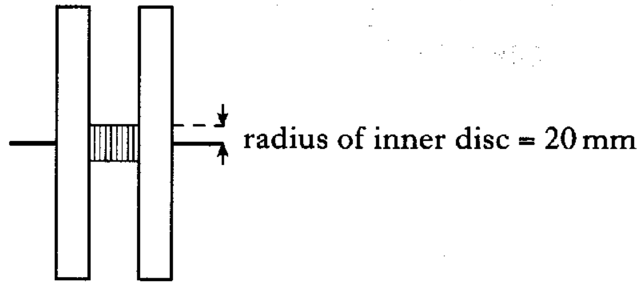

Figure 4

The flywheel is initially at rest.

A steady force of 3·0 N is applied to the end of the cord.

The cord takes 6·0 seconds to unwind fully.

(*a*) (i) Show that the angular acceleration of the flywheel is 2·8 rad s^{-2}.

(ii) Calculate the maximum angular velocity of the flywheel. **4**

(*b*) There is a constant frictional torque of 0·010 N m acting on the moving flywheel.

(i) Calculate the moment of inertia of the flywheel.

(ii) When the cord is fully unwound, it detaches from the flywheel.

Calculate:

(A) the angular deceleration of the flywheel;

(B) the time taken for the flywheel to stop rotating. **6**

(*c*) The thin cord is now replaced with a thicker cord of the **same length**. This thicker cord has to overlap itself when it is wound on the inner disc of the flywheel, as shown in Figures 5 and 6.

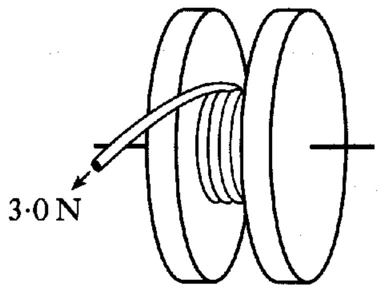

Figure 5

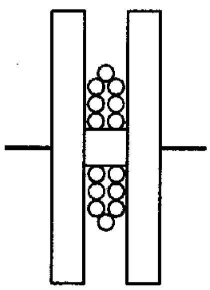

Figure 6

A constant force of 3·0 N is applied to the cord as before.

Will the time taken by the thicker cord to unwrap be longer, shorter or the same as the thin cord? **Explain your answer**.

Neglect the mass of the thicker cord. **2**

(12)

Marks

3. (*a*) Pallas is an asteroid or minor planet which orbits the Sun between Mars and Jupiter.

Details of Pallas are given below.

Diameter of Pallas = 522 km

Distance from the Sun = $4{\cdot}14 \times 10^{11}$ m

Mass of Pallas = $2{\cdot}18 \times 10^{20}$ kg

Time to orbit the Sun = 4·61 Earth years

(i) Calculate the gravitational field strength "g" at the surface of Pallas.

(ii) A future exploration might include putting a spacecraft in orbit around Pallas. Calculate the period of a spacecraft which orbits 10 km above the surface of Pallas. **5**

(*b*) (i) Relativistic mass is given by the equation

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where the symbols have their usual meanings.

Calculate the speed a spacecraft would have to reach if its relativistic mass were to be ten times greater than its rest mass.

(ii) Science fiction often describes spacecraft reaching speeds greater than the speed of light. Use the equation to show that it is not possible for a spacecraft to exceed the speed of light. **3**

(8)

[Turn over

Marks

4. (*a*) A mass is suspended from a spring and is at rest.

The mass is displaced 20 mm from its rest position, as shown in Figure 7.

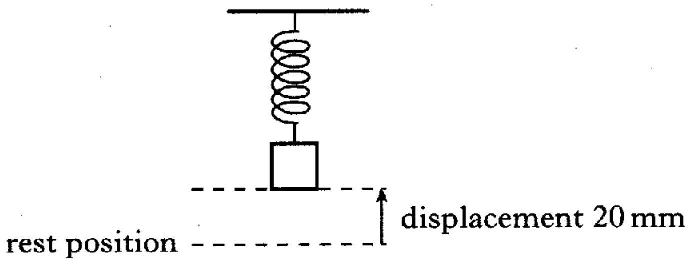

Figure 7

The mass is released.

A graph of the displacement y of the mass against time t is shown in Figure 8.

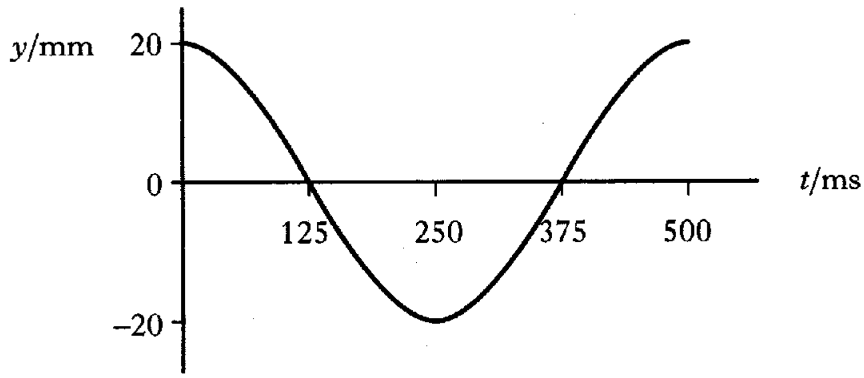

Figure 8

(i) Show, by calculation, that

$$\frac{d^2y}{dt^2} = -158y.$$

(ii) Sketch a graph of the velocity of the mass against time for the first period of the oscillation. Numerical values are required on both axes. **5**

(*b*) An object has a periodic motion and oscillates between A and B as shown in Figure 9.

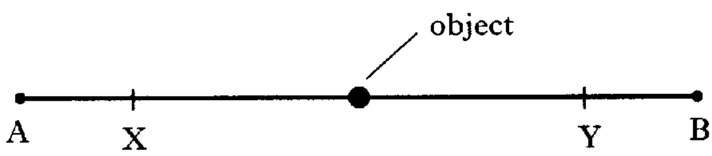

Figure 9

Between points X and Y the object moves with constant speed. Explain **fully** why the motion of the object cannot be described as simple harmonic. **2**

(7)

Marks

5. (*a*) Two positive point charges, each of magnitude 3·0 nC, are situated 0·20 m apart in air. Position X is midway between the two charges and Y is 0·10 m beyond the second charge, as shown in Figure 10.

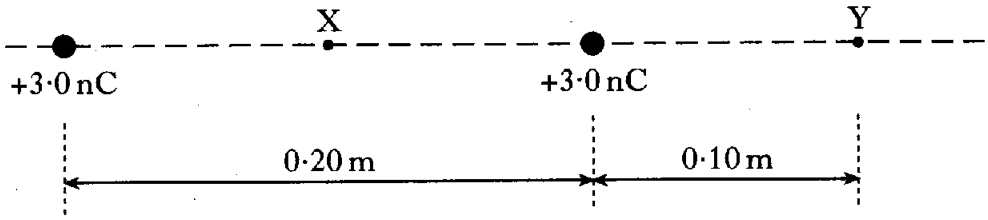

Figure 10

(i) Calculate the electric field strength:

(A) at X;

(B) at Y.

(ii) State what is meant by the term "electrostatic potential at a point".

(iii) Calculate the potential difference between X and Y. **8**

(*b*) The charges on three separate oil droplets are measured as

$-4{\cdot}5 \times 10^{-19}$ C; $-8{\cdot}0 \times 10^{-19}$ C; $-3{\cdot}2 \times 10^{-19}$ C.

Explain which one of these measurements is suspect. **2**

(10)

[Turn over

Marks

6. The force on a current carrying conductor in a magnetic field can be measured using a top pan balance.

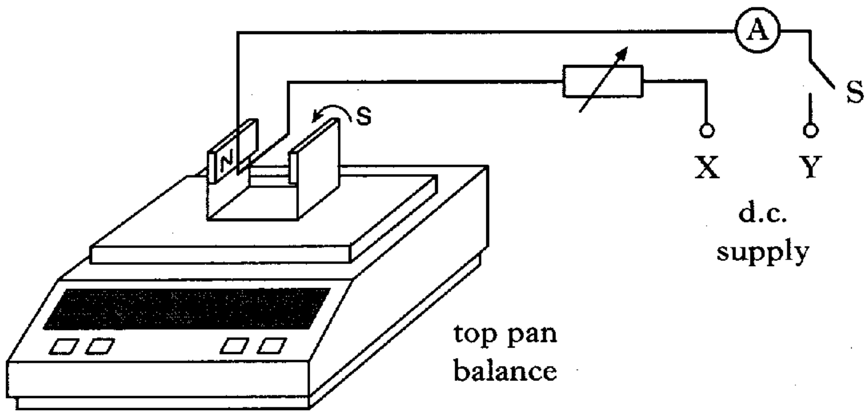

Figure 11

A magnet is placed on the balance. A rigid copper wire is clamped so that it remains in a fixed position between the poles of the magnet as shown in Figure 11.

(*a*) The reading on the balance increases when the switch S is closed.

State the polarities of X and Y. **1**

(*b*) With no current in the wire, the balance is zeroed.

The reading on the balance is recorded for several values of current. These readings and the associated uncertainties are shown in the following table.

Current/mA	0	100 ± 10	200 ± 10	300 ± 10	400 ± 10	500 ± 10	600 ± 10
Reading on balance/mg	0 ± 1	11 ± 1	25 ± 2	35 ± 2	48 ± 2	58 ± 3	75 ± 3

Figure 12 shows the corresponding graph with the best fit line for the readings.

(i) Calculate the gradient of this line.

(ii) Calculate the absolute uncertainty in the gradient. **5**

(*c*) The horizontal part of the rigid copper wire in the magnetic field has a length of 0·060 m. It is fixed at right angles to the direction of the magnetic induction. Use the information obtained from Figure 12 to calculate the magnetic induction between the poles of the magnet.

The uncertainty in the magnetic induction is **not** required. **3**

(9)

6. (continued)

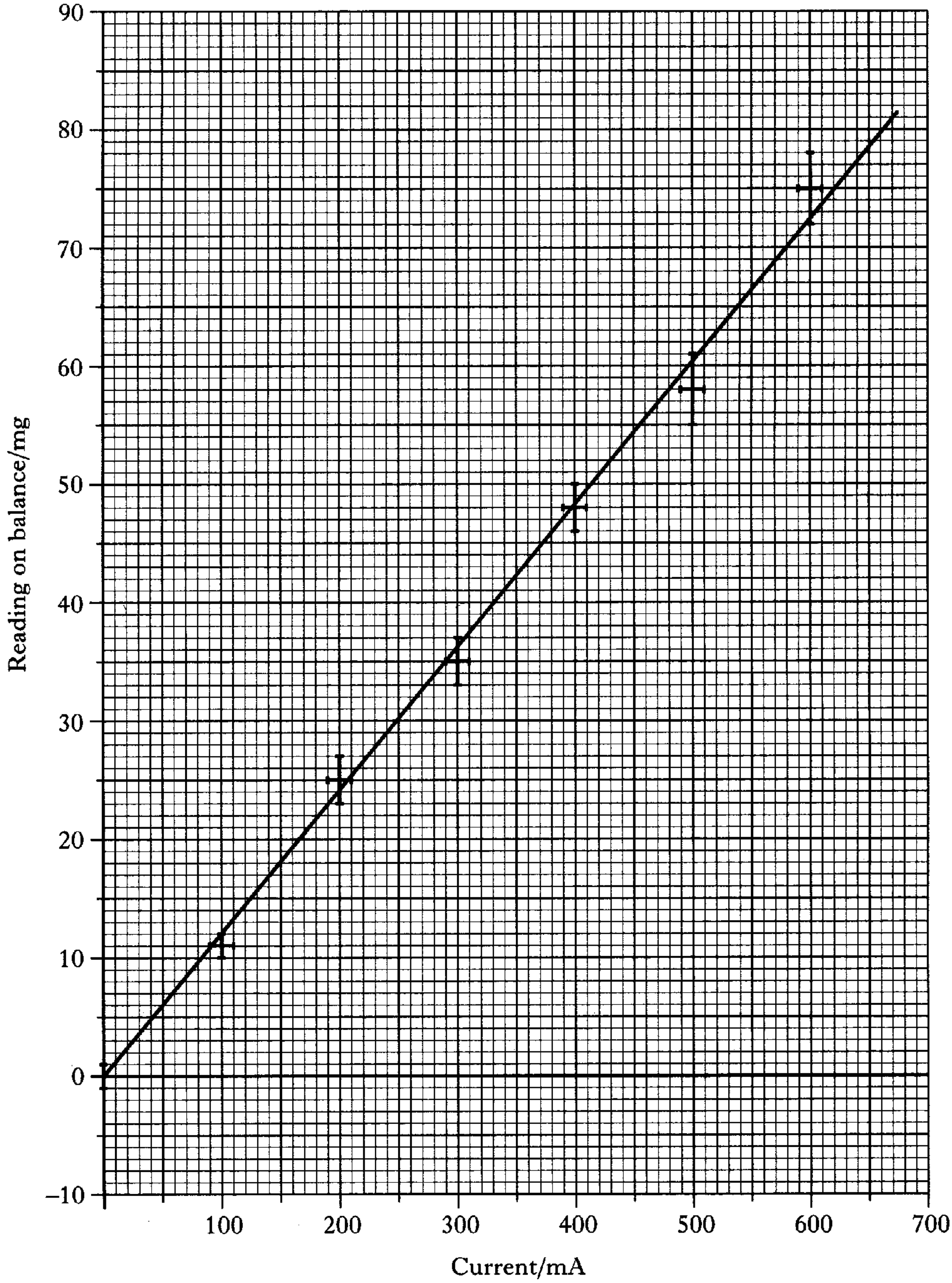

Figure 12

[Turn over

7. In a mass spectrometer, a positive ion passes through an electric field between two parallel plates P_1 and P_2 and through a narrow slit S as shown in Figure 13. The plates are 40 mm apart and there is a uniform magnetic field of magnetic induction B between the plates and in the region beyond the slit.

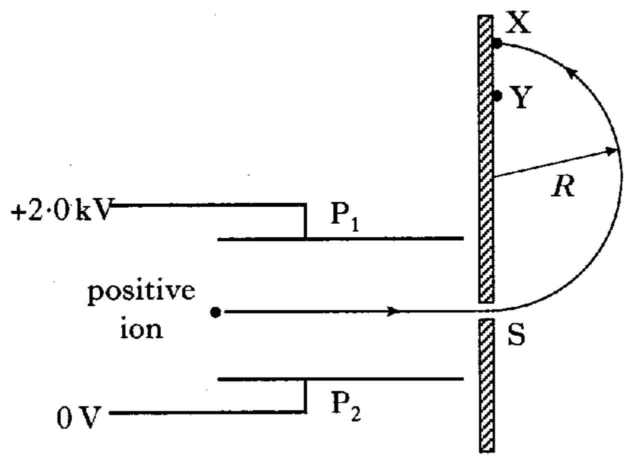

Figure 13

The ion travels with a uniform speed v in a straight line between the plates and moves into a semicircular path of radius R after it passes through the slit.

(*a*) State the direction of the magnetic induction B. **1**

(*b*) Show that the velocity v of the ion is given by

$$v = \frac{5 \cdot 0 \times 10^4}{B}$$ **2**

(*c*) (i) Explain why the ion follows a semicircular path in the region beyond the slit.

(ii) Show that the radius R of the semicircular path is given by

$$R = \frac{mv}{BQ}$$

where m = mass of the ion
and Q = the charge on the ion.

(iii) The ion reaches the point X in the region beyond the slit.
Use the following data to calculate the distance SX.

Mass of the ion = $3 \cdot 65 \times 10^{-26}$ kg
Charge on the ion = $+1 \cdot 6 \times 10^{-19}$ C
Magnetic induction = 0·50 T **6**

Marks

7. **(continued)**

(*d*) A second ion, with the same positive charge as the first ion, passes between the parallel plates and through slit S. The second ion travels in a semicircular path and reaches the point Y shown in Figure 13.

(i) Explain why the speed of this ion is the same as the first ion.

(ii) How does the mass of the second ion compare with the mass of the first ion? **Justify your answer**. 4

(13)

[Turn over

Marks

8. The circuit shown in Figure 14 contains an inductor, resistor and switch in series with a d.c. supply.

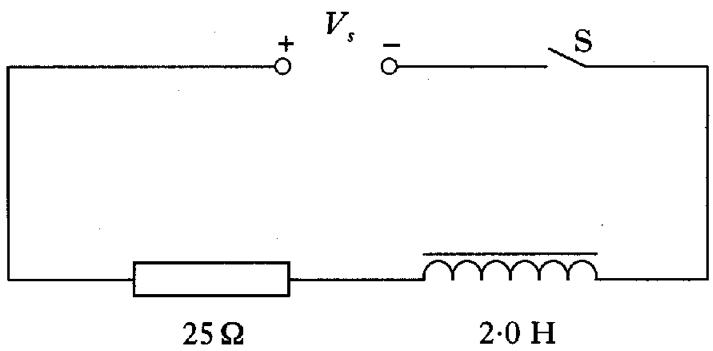

Figure 14

The 2·0 H inductor has negligible resistance.

Switch S is closed. The current reaches a maximum value of 400 mA after a time of 1·5 seconds.

(*a*) Explain why the current does not reach its maximum value immediately. **2**

(*b*) Calculate:

(i) the supply voltage V_s;

(ii) the maximum rate of change of current;

(iii) the maximum energy stored in the inductor. **6**

(*c*) Switch S is now opened and a spark occurs across the contacts of the switch. Explain why this happens. **2**

(10)

Marks

9. (*a*) A travelling wave is represented by the expression

$$y = 3 \cdot 5 \sin (62 \cdot 8t - 1 \cdot 25x)$$

where x and y are expressed in metres and t in seconds.

(i) Calculate the following for the travelling wave:

(A) the frequency in Hz;

(B) the wavelength.

(ii) The intensity of the wave doubles.

(A) Which of the quantities in the equation changes in value?

(B) Write down the equation which describes the wave with double the intensity. **7**

(*b*) An emergency vehicle, travelling at $22\,\mathrm{m\,s^{-1}}$, emits sound of frequency 1020 Hz. The vehicle approaches a stationary pedestrian, as shown in Figure 15.

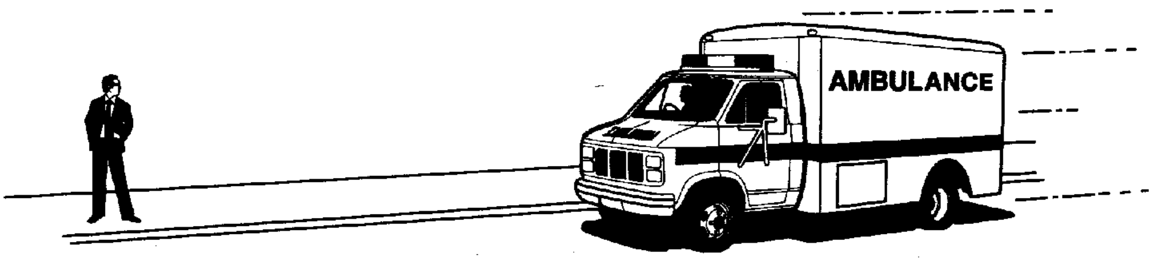

Figure 15

The frequency detected by a stationary observer when a sound source moves relative to the observer is given by

$$f = f_s \frac{v}{v \pm v_s}$$

where the symbols have their usual meanings.

Calculate the frequency heard by the stationary pedestrian as the emergency vehicle approaches. **2**

(9)

[Turn over

10. A thin air wedge is formed between two flat glass plates which are in contact at one end and separated by a thin copper wire at the other end.

The experimental arrangement in Figure 16 shows how interference fringes can be observed using a travelling microscope.

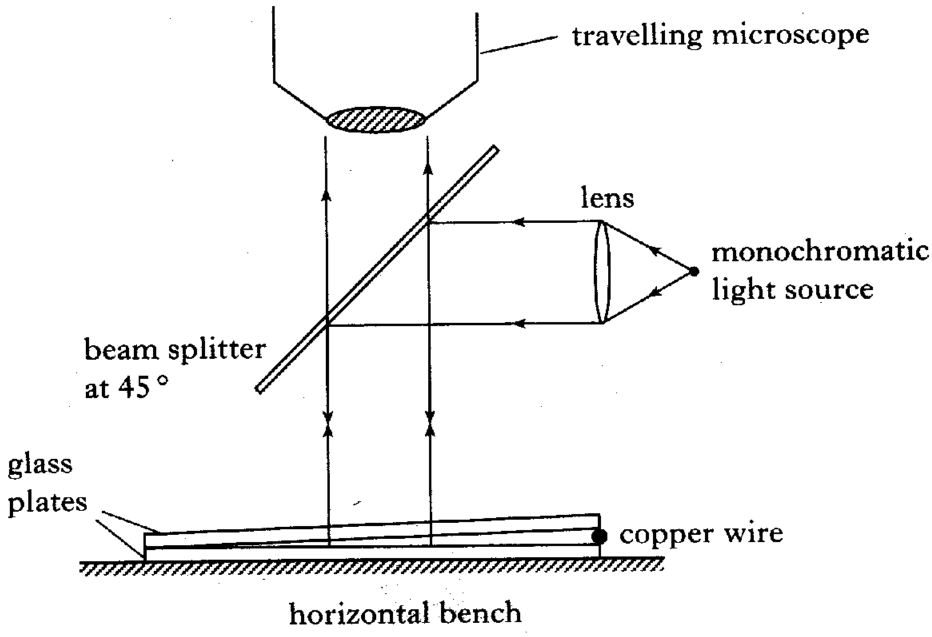

Figure 16

(*a*) In this arrangement, state whether the interference fringes are produced by division of amplitude or by division of wavefront. **1**

(*b*) Measurements are taken as follows:

separation of fringes	=	0·080 mm
length of each glass plate	=	75·0 mm
wavelength of monochromatic light	=	589 nm.

The separation of thin air wedge fringes is given by the expression

$$\Delta x = \frac{\lambda}{2\tan\theta}$$

where the symbols have their usual meanings.

Calculate the diameter of the copper wire. **2**

(*c*) Water enters the wedge and replaces all the air, as shown in Figure 17.

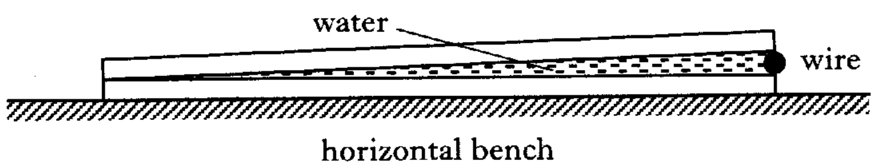

Figure 17

(i) Describe the change that occurs in the interference pattern.

(ii) Explain this change. **3**

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.

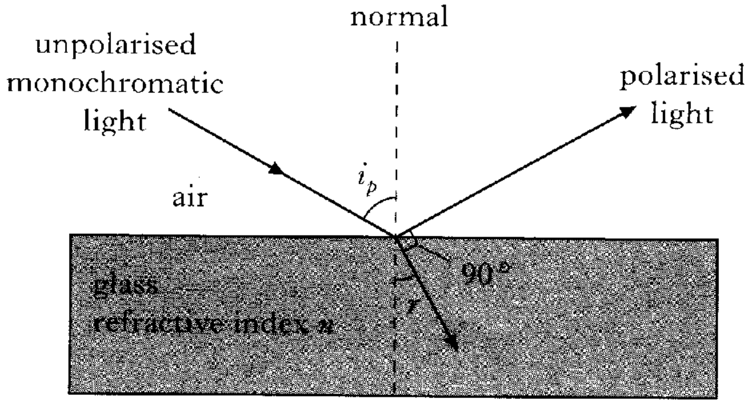

Figure 18

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.

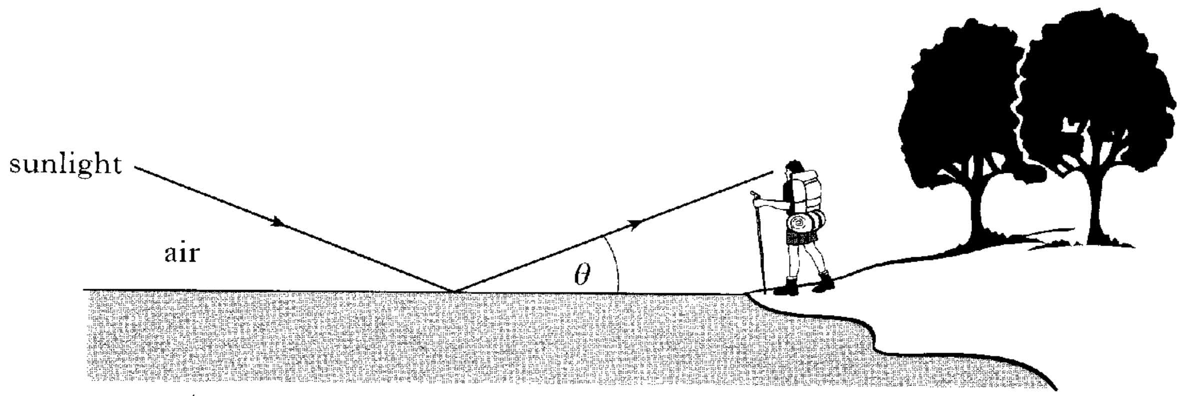

Figure 19

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

(5)

[*END OF QUESTION PAPER*]