X069/701

NATIONAL QUALIFICATIONS 2008

FRIDAY, 23 MAY
1.00 PM – 3.30 PM

PHYSICS
ADVANCED HIGHER

Reference may be made to the Physics Data Booklet.

Answer **all** questions.

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

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.

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DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8$ 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
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}$ m	Mass of alpha particle	m_α	$6{\cdot}645 \times 10^{-27}$ kg
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}$ m	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}$ C
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}$ m s^{-1}	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}$ F m^{-1}
Speed of sound in air	v	$3{\cdot}4 \times 10^{2}$ m s^{-1}	Permeability of free space	μ_0	$4\pi \times 10^{-7}$ H m^{-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	Magnesium Fluoride	1·38

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*/ J kg^{-1} 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.

1. A centrifuge is used to separate out small particles suspended in a liquid. Figure 1 shows the rotating part of the centrifuge which includes two test tubes containing the liquid.

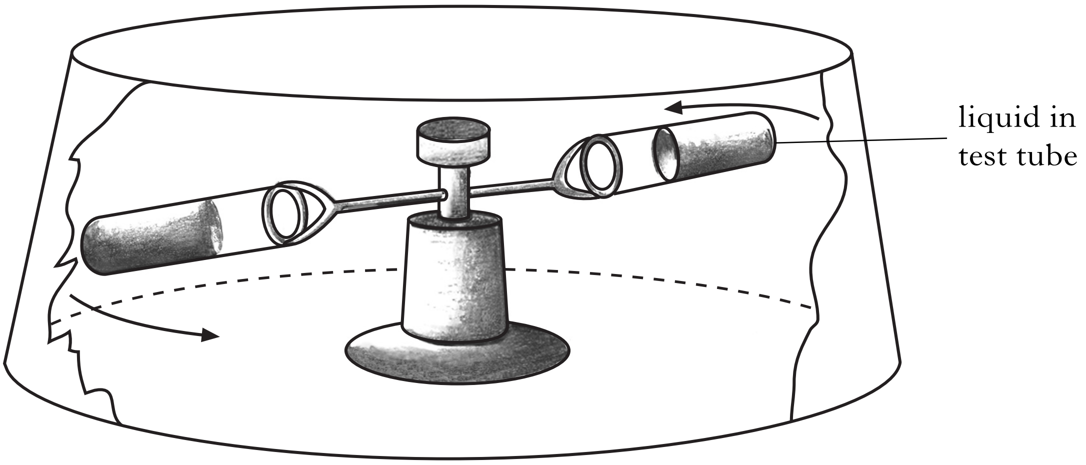

Figure 1

The rotating part starts from rest and reaches a maximum angular velocity of 1200 rad s^{-1} in a time of 4 seconds.

The average moment of inertia of the rotating part is $5{\cdot}1 \times 10^{-4} \text{ kg m}^2$.

(*a*) (i) Calculate the angular acceleration of the rotating part. **2**

(ii) Calculate the average unbalanced torque applied during this time. **2**

(iii) How many **revolutions** are made during this time? **3**

(*b*) Figure 2 shows an overhead view of the rotating part.

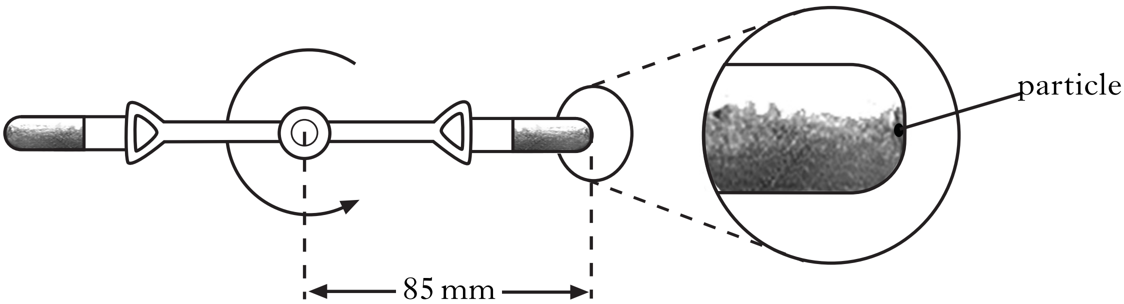

Figure 2

The expanded view shows the position of a single particle of mass $5{\cdot}3 \times 10^{-6} \text{ kg}$.

(i) Calculate the central force acting on the particle at the maximum angular velocity. **2**

(ii) What provides the central force acting on this particle? **1**

1. (continued)

(*c*) At rest the test tubes in the centrifuge are in a vertical position as shown in Figure 3.

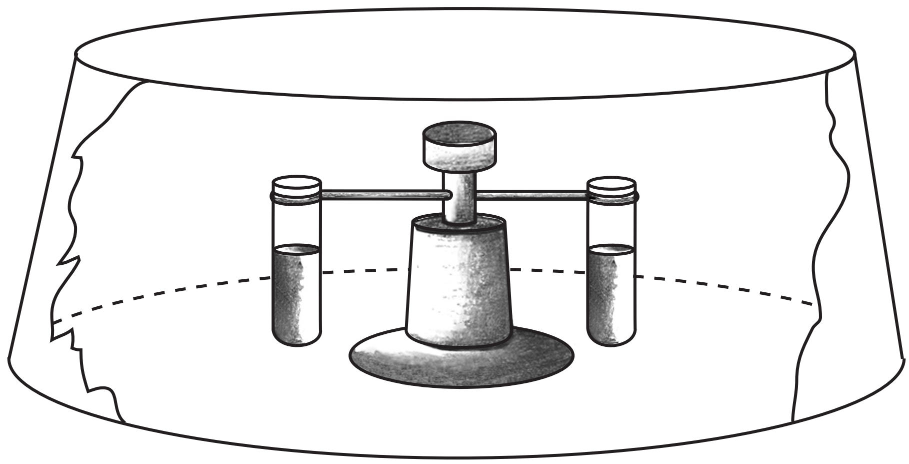

Figure 3

Does the moment of inertia of the rotating part increase, decrease, or stay the same during the acceleration of the rotating part? Justify your answer. **2**

(12)

[Turn over

Marks

2. (*a*) The gravitational field strength g on the surface of Mars is $3{\cdot}7\,\mathrm{N\,kg^{-1}}$.
The mass of Mars is $6{\cdot}4 \times 10^{23}\,\mathrm{kg}$.
Show that the radius of Mars is $3{\cdot}4 \times 10^{6}\,\mathrm{m}$. **2**

(*b*) (i) A satellite of mass m has an orbit of radius R. Show that the angular velocity ω of the satellite is given by the expression

$$\omega = \sqrt{\frac{\mathrm{GM}}{R^3}}$$

where the symbols have their usual meanings. **2**

(ii) A satellite remains above the same point on the equator of Mars as the planet spins on its axis.

Figure 4 shows this satellite orbiting at a height of $1{\cdot}7 \times 10^{7}\,\mathrm{m}$ above the Martian surface.

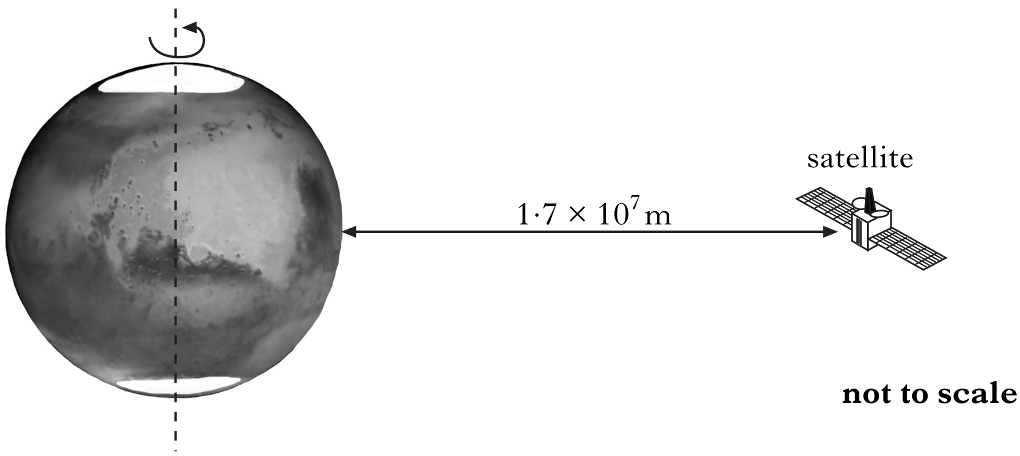

Figure 4

Calculate the angular velocity of the satellite. **2**

(iii) Calculate the length of one Martian day. **2**

(*c*) The following table gives data about three planets orbiting the Sun.

Planet	Radius R of orbit around the Sun/10^9m	Orbit period T around the Sun/years
Venus	108	0·62
Mars	227	1·88
Jupiter	780	12·0

Use **all** the data to show that T^2 is directly proportional to R^3 for these three planets. **3**

(11)

Marks

3. A simple pendulum consists of a lead ball on the end of a long string as shown in Figure 5.

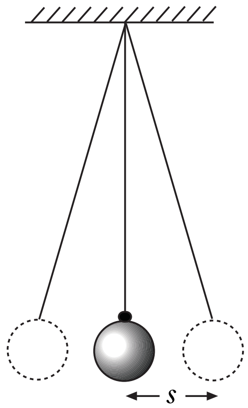

Figure 5

The ball moves with simple harmonic motion. At time t the displacement s of the ball is given by the expression

$$s = 2 \cdot 0 \times 10^{-2} \cos 4 \cdot 3t$$

where s is in metres and t in seconds.

(*a*) (i) State the definition of *simple harmonic motion*. **1**

(ii) Calculate the period of the pendulum. **2**

(*b*) Calculate the maximum speed of the ball. **2**

(*c*) The mass of the ball is $5 \cdot 0 \times 10^{-2}$ kg and the string has negligible mass.

Calculate the total energy of the pendulum. **2**

(*d*) The period T of a pendulum is given by the expression

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where L is the length of the pendulum.

Calculate the length of this pendulum. **2**

(*e*) In the above case, the assumption has been made that the motion is not subject to *damping*.

State what is meant by *damping*. **1**

(10)

[Turn over

Marks

4. (*a*) Electrons can exhibit wave-like behaviour. Give **one** example of evidence which supports this statement. **1**

(*b*) The Bohr model of the hydrogen atom suggests a nucleus with an electron occupying one of a series of stable orbits.

A nucleus and the first two stable orbits are shown in Figure 6.

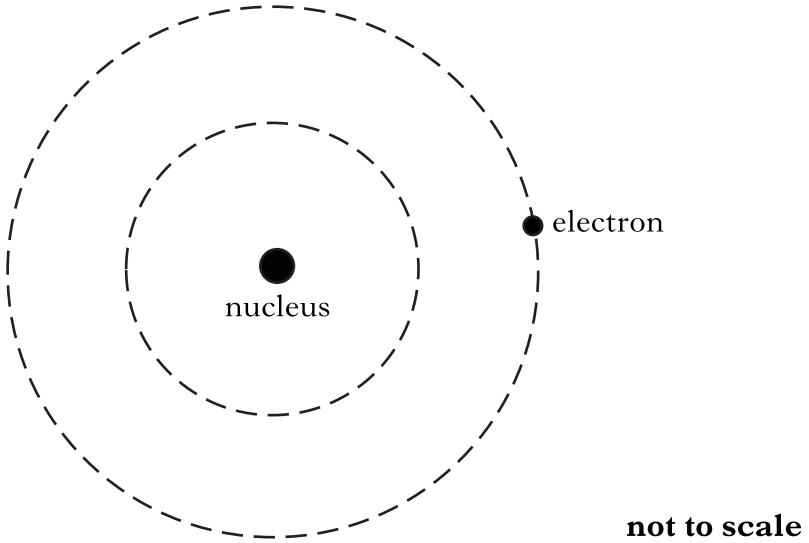

Figure 6

(i) Calculate the angular momentum of the electron in the second stable orbit. **2**

(ii) Starting with the relationship

$$mrv = \frac{nh}{2\pi}$$

show that the circumference of the second stable orbit is equal to two electron wavelengths. **2**

(iii) The circumference of the second stable orbit is $1 \cdot 3 \times 10^{-9}$ m.

Calculate the speed of the electron in this orbit. **2**

(7)

Marks

5. (*a*) Two point charges Q_1 and Q_2 each has a charge of $-4{\cdot}0\,\mu C$. The charges are $0{\cdot}60$ m apart as shown in Figure 7.

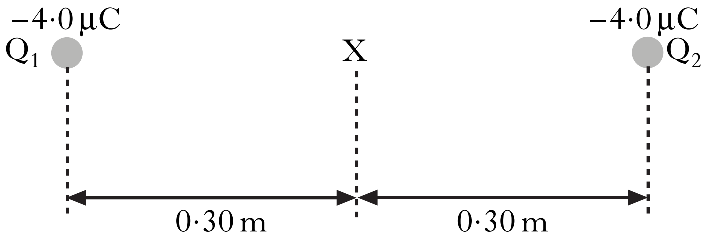

Figure 7

(i) Draw a diagram to show the electric field lines between charges Q_1 and Q_2. **1**

(ii) Calculate the electrostatic potential at point X, midway between the charges. **2**

(*b*) A third point charge Q_3 is placed near the two charges as shown in Figure 8.

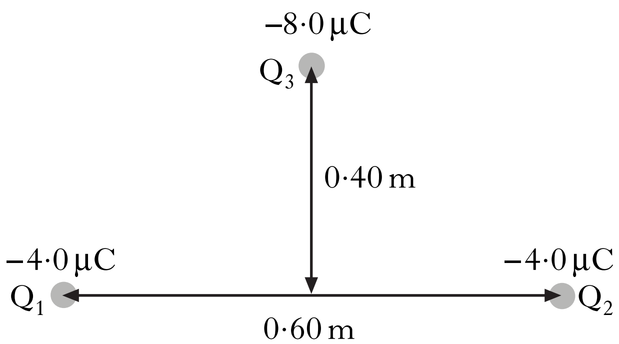

Figure 8

(i) Show that the force between charges Q_1 and Q_3 is $1{\cdot}2$ N. **2**

(ii) Calculate the **magnitude** and **direction** of the resultant force on charge Q_3 due to charges Q_1 and Q_2. **2**

(7)

[Turn over

6. A student investigates the relationship between the force exerted on a wire in a magnetic field and the current in the wire.

A pair of magnets is fixed to a yoke and placed on a top pan Newton balance. A rigid copper wire is suspended between the poles of the magnets. The wire is fixed at 90° to the magnetic field, as shown in Figure 9.

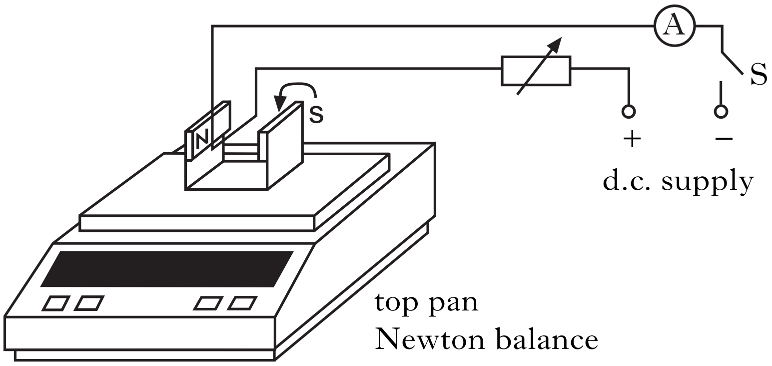

Figure 9

With switch S open the balance is set to zero.

Switch S is closed. The resistor is adjusted and the force recorded for several values of current.

The results are given in the table below.

Current/A	0·50	1·00	1·50	2·00	2·50
Force/10^{-3} N	0·64	0·85	2·56	3·07	3·87

The uncertainty in the current is ± 0·01 A.

The uncertainty in the force is ± 0·03 × 10^{-3} N.

Figure 10, on *Page eleven*, shows the corresponding graph with the best fit straight line for the results.

(*a*) (i) Show that the gradient of the line is 1·7 × 10^{-3} N A^{-1}. **1**

(ii) Calculate the absolute uncertainty in the gradient of the line. **3**

(iii) The length of wire in the magnetic field is 52 mm. Use the information obtained from the graph to calculate the magnitude of the magnetic induction.

The uncertainty in the magnetic induction is **not** required. **2**

(*b*) In the student's evaluation it is stated that the line does not pass through the origin.

(i) Suggest a possible reason for this. **1**

(ii) Suggest **one** improvement to the experiment to reduce the absolute uncertainty in the gradient of the line. **1**

(8)

6. (continued)

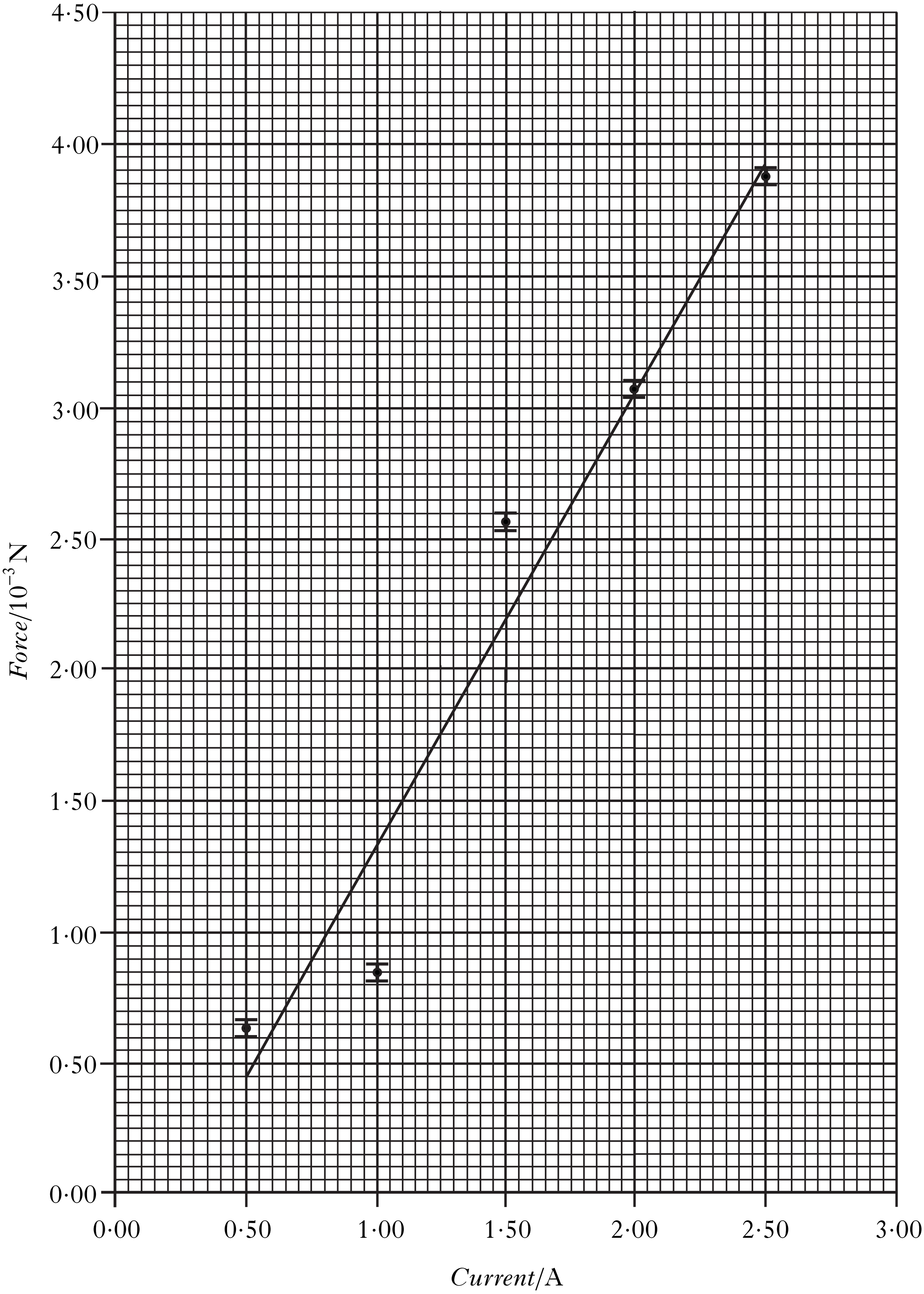

Figure 10

[Turn over

Marks

7. An inductor of negligible resistance is connected in the circuit shown in Figure 11.

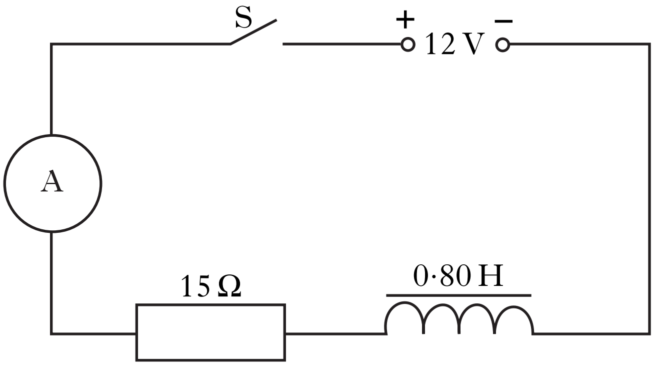

Figure 11

(*a*) The inductor has an inductance of 0·80 H.
Switch S is closed.

(i) Explain why there is a time delay before the current reaches its maximum value. **1**

(ii) Calculate the maximum current in the circuit. **2**

(iii) Calculate the maximum energy stored in the inductor. **2**

(iv) Calculate the rate of change of current when the current in the circuit is 0·12 A. **3**

(*b*) Switch S is opened and the iron core is removed from the inductor. Switch S is now closed.

(i) Will the maximum current be bigger, smaller or the same as the maximum current calculated in (*a*)(ii)? **1**

(ii) Explain any change in the time delay to reach the maximum current. **2**

(iii) Explain why the maximum energy stored in the inductor is less than in (*a*)(iii). **1**

(*c*) The iron core is replaced in the inductor. The d.c. supply is replaced with a variable frequency supply as shown in Figure 12.

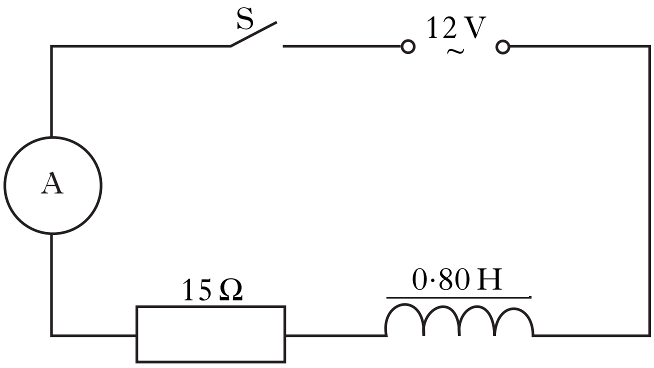

Figure 12

Sketch a graph to show how the current in the circuit varies with the frequency of the supply. Numerical values are not required. **1**

(13)

8. (*a*) Two protons are separated by a distance of 22 μm.

(i) Show by calculation that the gravitational force between these protons is negligible compared to the electrostatic force. **4**

(ii) Why is the strong force negligible between these protons? **1**

(*b*) A particle of charge q travels directly towards a fixed stationary particle of charge Q.

At a large distance from charge Q the moving particle has an initial velocity v.

The moving particle momentarily comes to rest at a distance of closest approach r_c as shown in Figure 13.

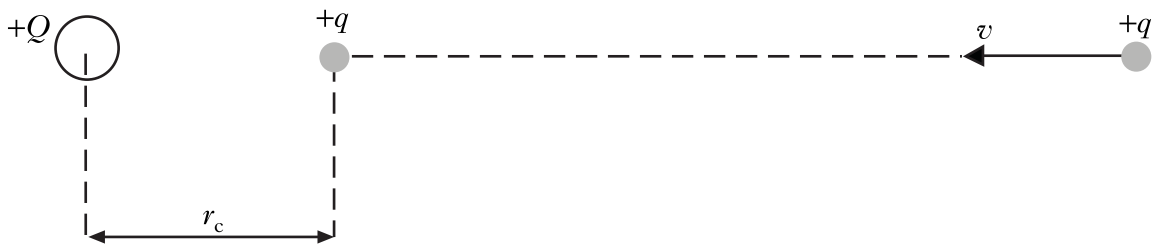

Figure 13

Show that the initial velocity of the moving particle is given by

$$v = \sqrt{\frac{qQ}{2\pi\varepsilon_0 m r_c}}$$

where the symbols have their usual meaning. **2**

(*c*) An alpha particle is fired towards a target nucleus which is fixed and stationary. The initial velocity of the alpha particle is $9{\cdot}63 \times 10^6\,\mathrm{m\,s^{-1}}$ and the distance of closest approach is $1{\cdot}12 \times 10^{-13}\,\mathrm{m}$.

(i) Calculate the charge on the target nucleus. **3**

(ii) Calculate the number of protons in the target nucleus. **2**

(iii) The target is the nucleus of an element. Identify this element. **1**

(13)

[Turn over

9. (*a*) The driver of a sports car approaches a building where an alarm is sounding as shown in Figure 14.

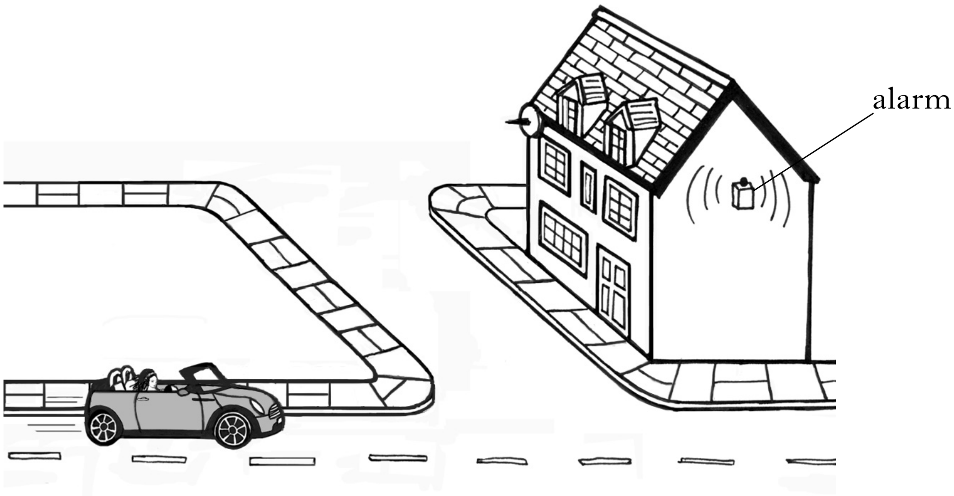

Figure 14

The speed of the car is $25 \cdot 0\, \mathrm{m\,s^{-1}}$ and the frequency of the sound emitted by the alarm is 1250 Hz.

(i) Explain in terms of wavefronts why the sound heard by the driver does not have a frequency of 1250 Hz. You may wish to include a diagram to support your answer. **2**

(ii) Calculate the frequency of the sound from the alarm heard by the driver. **2**

Marks

9. (continued)

(*b*) The spectrum of light from most stars contains lines corresponding to helium gas.

Figure 15(*a*) shows the helium spectrum from the Sun.

Figure 15(*b*) shows the helium spectrum from a distant star.

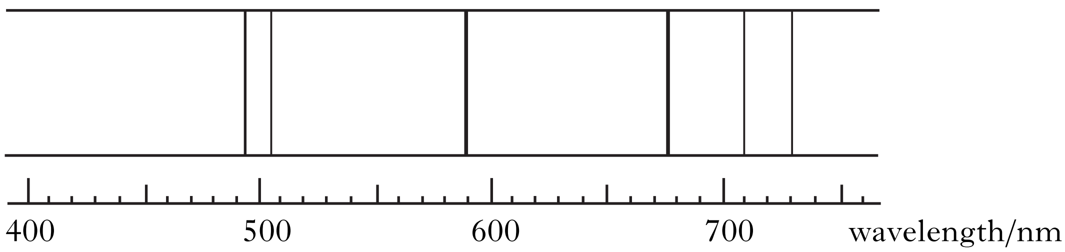

Figure 15(*a*)

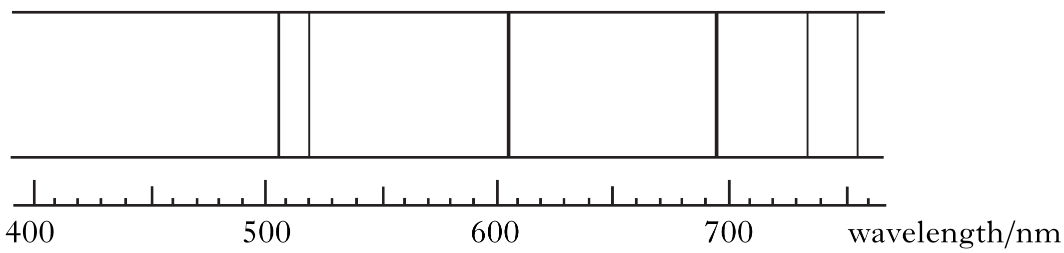

Figure 15(*b*)

By comparing these spectra, what conclusion can be made about the distant star? Justify your answer. **2**

(6)

[Turn over

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.

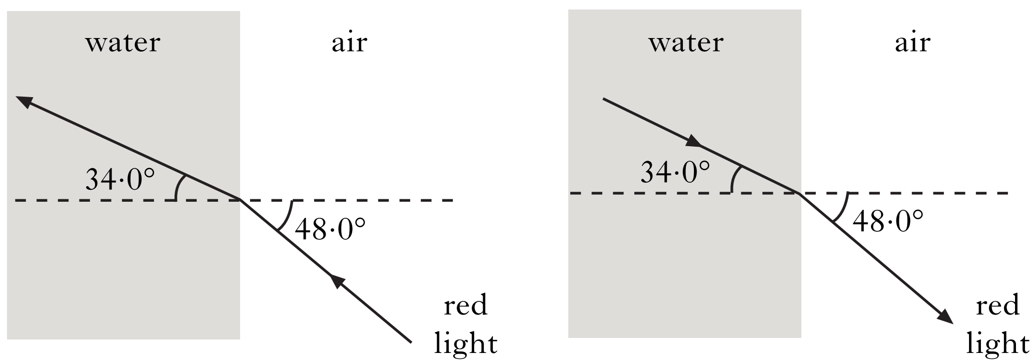

Figure 16

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.

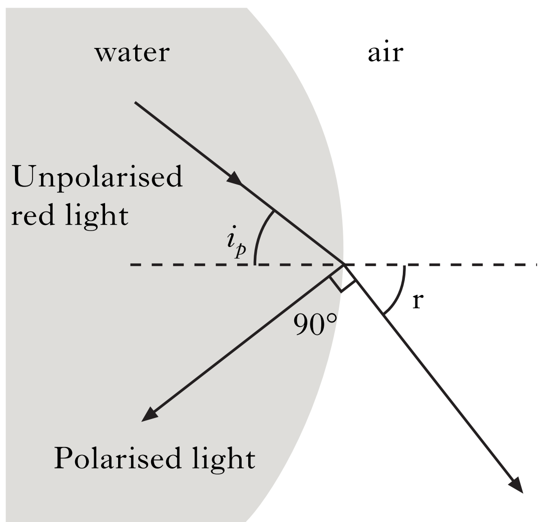

Figure 17

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**

10. (continued)

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

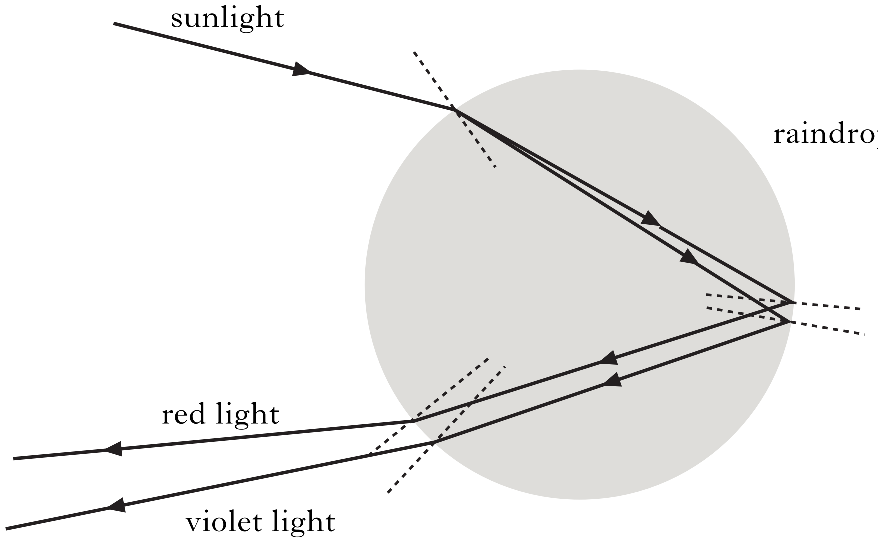

Figure 18

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

11. Light from a helium-neon laser is incident on a double slit. A pattern of light and dark fringes is observed on a screen 3·50 m beyond the slits as shown in Figure 20.

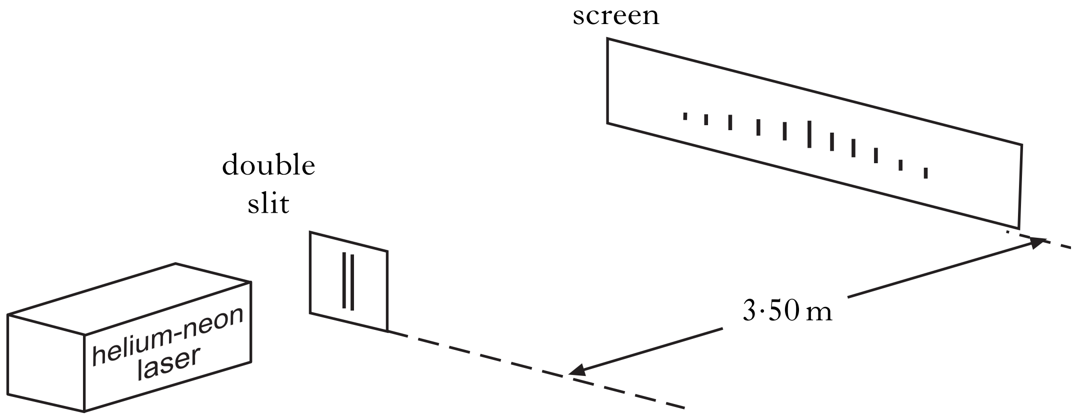

Figure 20

(*a*) State whether these fringes are caused by division of amplitude or division of wavefront. **1**

(*b*) The distance between two adjacent bright fringes on the screen is 7·20 mm. Calculate the separation of the two slits. **2**

(*c*) The distance between the double slit and screen is increased to 5·50 m. The distance between the fringes is remeasured and the calculation of the slit separation is repeated.

(i) Explain **one** advantage of moving the screen further away from the double slit. **2**

(ii) State **one** disadvantage of moving the screen further away from the double slit. **1**

(6)

[*END OF QUESTION PAPER*]

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