X069/701

NATIONAL QUALIFICATIONS 2005

TUESDAY, 24 MAY
1.00 PM – 3.30 PM

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.

LIB X069/701 6/3/4970

DATA SHEET

COMMON PHYSICAL QUANTITIES

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

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*	*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			
	389	Ultraviolet	*Element*	*Wavelength*/nm	*Colour*
Sodium	589	Yellow	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.

Marks

1. A compact disc (CD) stores information on the surface as shown in Figure 1.

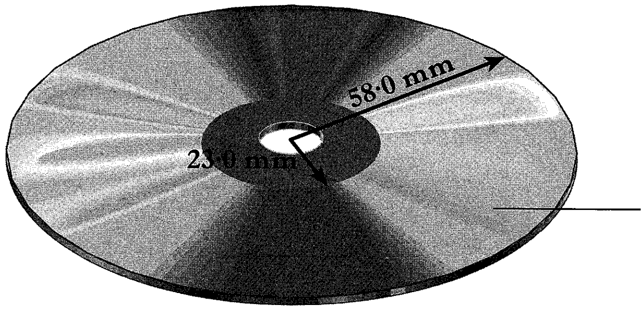

Figure 1

The information is retrieved by an optical reader which moves outwards as the CD rotates, as shown in Figure 2.

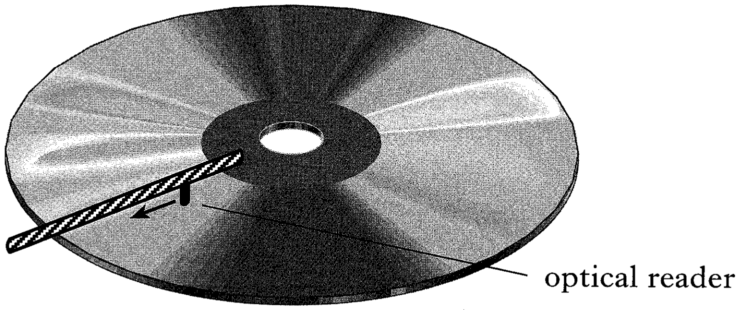

Figure 2

The part of the CD below the reader must always have a tangential speed of $1{\cdot}30\,\mathrm{m\,s^{-1}}$.

(*a*) The reader starts at a radius of 23·0 mm from the centre of the CD. Calculate the angular velocity of the CD at the start. **2**

(*b*) Show that the CD rotates at $22{\cdot}4\,\mathrm{rad\,s^{-1}}$ when the reader reaches the outer edge of the disc. **1**

(*c*) Explain why the angular velocity of the CD decreases as the CD plays. **1**

(*d*) The CD makes a total of $2{\cdot}80 \times 10^4$ revolutions from start to finish.

(i) Show that the total angular displacement of the CD is $1{\cdot}76 \times 10^5$ radians. **1**

(ii) Calculate the average angular acceleration of the CD as the disc is played from start to finish. **2**

(iii) Calculate the total playing time of the CD. **2**

(9)

[Turn over

Marks

2. A playground roundabout has a radius of 2·0 m and a moment of inertia of 500 kg m^2 about its axis of rotation. A child of mass 25 kg runs tangentially to the stationary roundabout and jumps on to its outer edge, as shown in Figure 3.

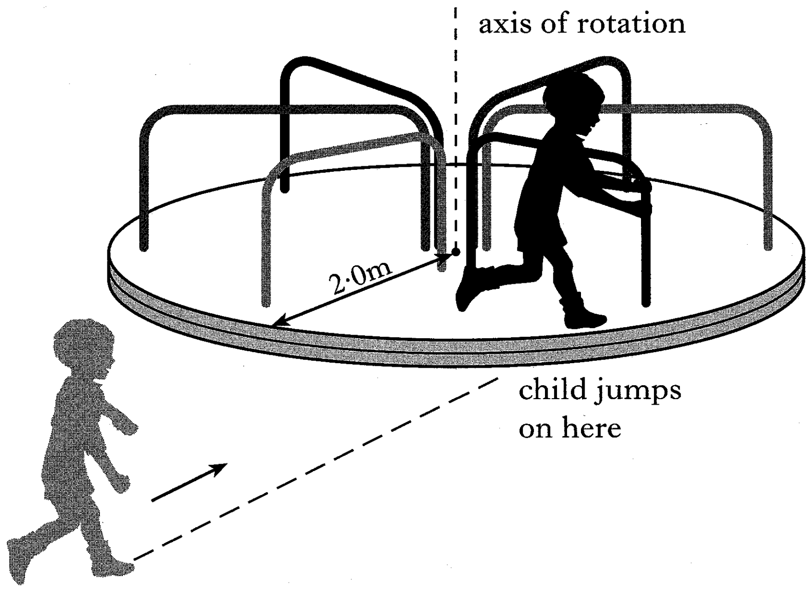

Figure 3

(*a*) Show that, with the child at the outer edge, the combined moment of inertia of the roundabout and child is 600 kg m^2. **2**

(*b*) State what is meant by *conservation of angular momentum*. **1**

(*c*) At the point of jumping on to the roundabout, the tangential speed of the child is 2·4 m s^{-1}. At this **point**, calculate:

(i) the linear momentum of the child; **1**

(ii) the angular momentum of the child about the axis of rotation of the roundabout. **1**

(*d*) Calculate the angular velocity of the roundabout and child just after the child jumps on. **2**

(*e*) Calculate the loss of kinetic energy as the child jumps on to the roundabout. **2**

(*f*) The roundabout with the child onboard makes half a complete revolution before coming to rest.

Calculate the frictional torque acting on the roundabout. **3**

(12)

Marks

3. (*a*) (i) A satellite orbits a planet of mass M. The orbital radius of the satellite is R and the orbital period is T.
Show that

$$T^2 = \frac{4\pi^2 R^3}{GM}.$$ **2**

(ii) Calculate the time taken by the Moon to make one complete orbit of the Earth. **2**

(*b*) A satellite orbits 400 km above the Earth's surface as shown in Figure 4.

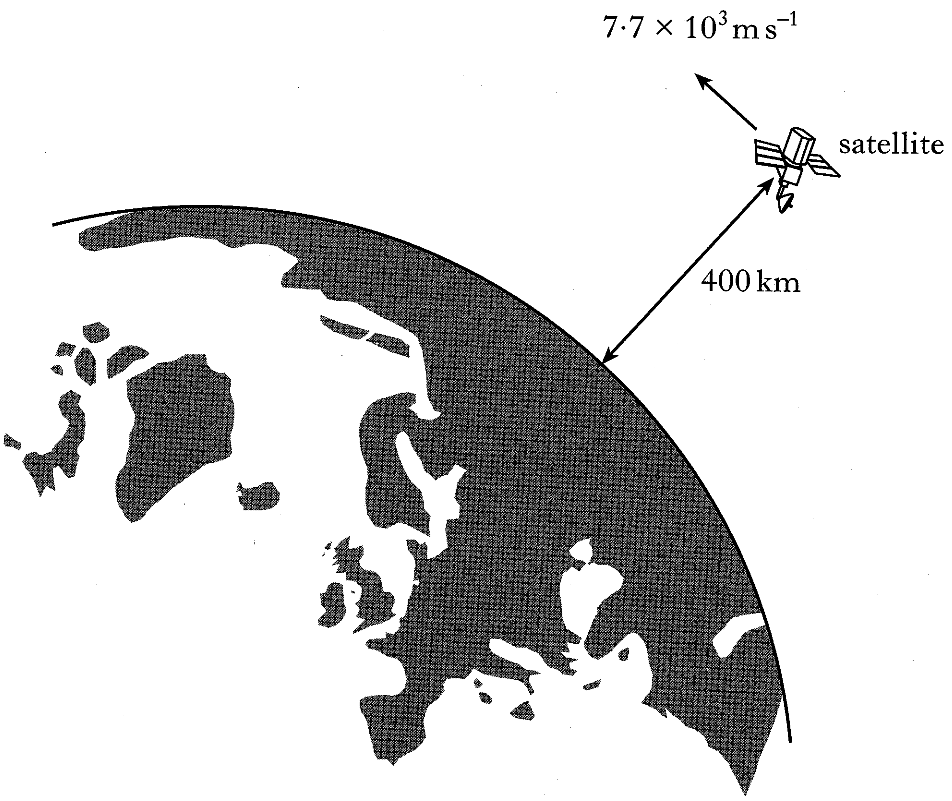

Figure 4

The satellite has a mass of 900 kg and a speed of $7 \cdot 7 \times 10^3\,\mathrm{m\,s^{-1}}$.

(i) Show that the potential energy of the satellite is $-5 \cdot 3 \times 10^{10}$ J. **2**

(ii) Calculate the total energy of the satellite. **2**

(8)

[Turn over

Marks

4. The flexible paper cone of a loudspeaker vibrates, producing a sound. The loudspeaker has a small cap at the centre of the cone as shown in Figure 5.

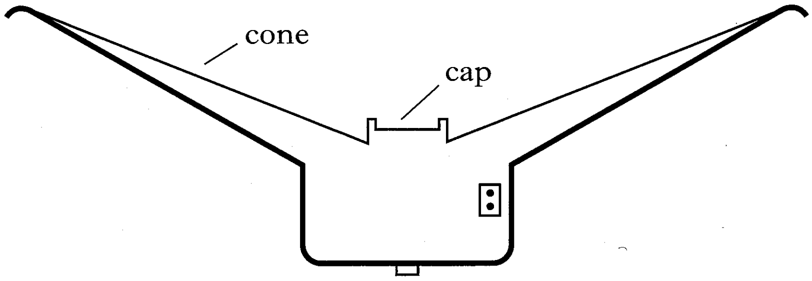

Figure 5

The cone and cap vibrate with simple harmonic motion when the loudspeaker is connected to a signal generator.

(*a*) State what is meant by *simple harmonic motion.* **1**

(*b*) At a particular frequency, the velocity of the cap, in $m\,s^{-1}$, is given by the expression

$$v = 0{\cdot}50 \cos 625t.$$

(i) Calculate the frequency of the sound emitted by the loudspeaker. **2**

(ii) Calculate the amplitude of vibration of the loudspeaker cap. **2**

(*c*) A small polystyrene sphere is placed on the cap of the loudspeaker as shown in Figure 6.

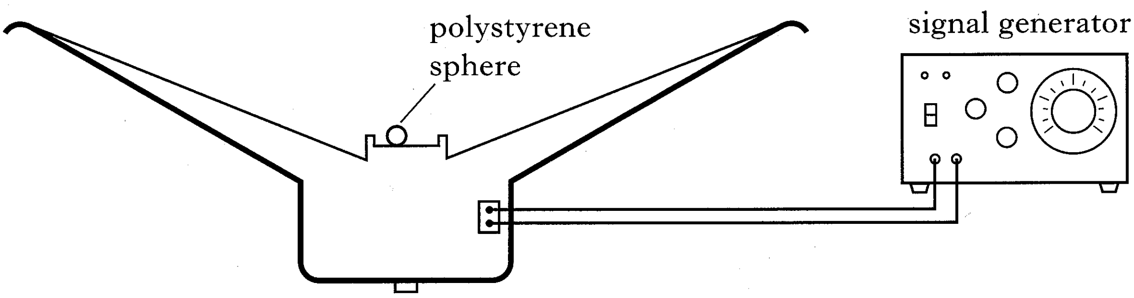

Figure 6

The frequency of the signal generator is slowly increased from zero. At low frequencies the polystyrene sphere stays in contact with the cap. At one particular frequency the sphere just loses contact with the cap. State the maximum acceleration of the cap when this occurs. Justify your answer. **2**

(7)

Marks

5. (*a*) Two point charges with values +4·0 μC and −6·0 μC are placed 5·0 mm apart. Point X lies on the line between the charges as shown in Figure 7.

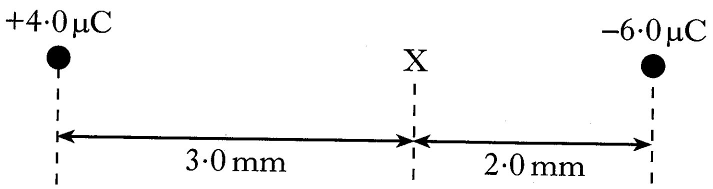

Figure 7

(i) Calculate the magnitude of the electric field strength at point X. **2**

(ii) State the direction of the electric field at point X. **1**

(*b*) A hollow uncharged metal cylinder is placed midway between two parallel plates which are connected to a d.c. power supply as shown in Figure 8.

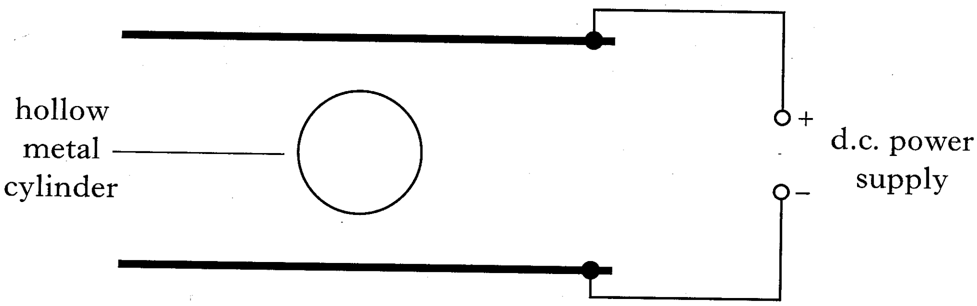

Figure 8

(i) Copy and complete the above diagram showing:

(A) the electric field lines in the space between the parallel plates; **2**

(B) the charge distribution induced on the cylinder. **1**

(ii) Coaxial cable consists of a central wire surrounded by a metal mesh, as shown in Figure 9.

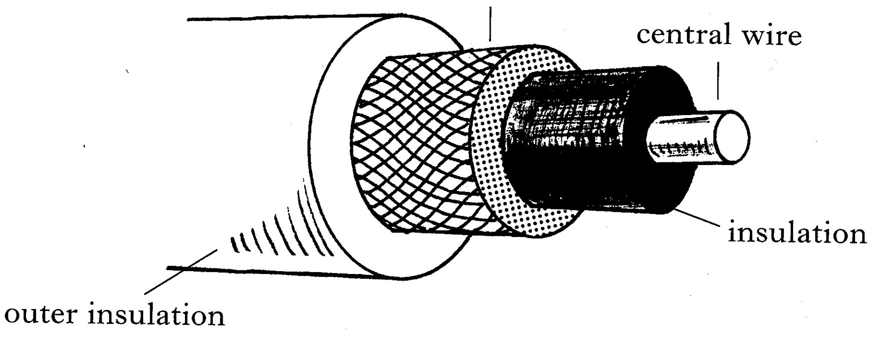

Figure 9

Explain why coaxial cable is designed in this way. **1**

(7)

Marks

6. In an evacuated tube a beam of electrons is deflected by an electric field between two parallel plates as shown in Figure 10.

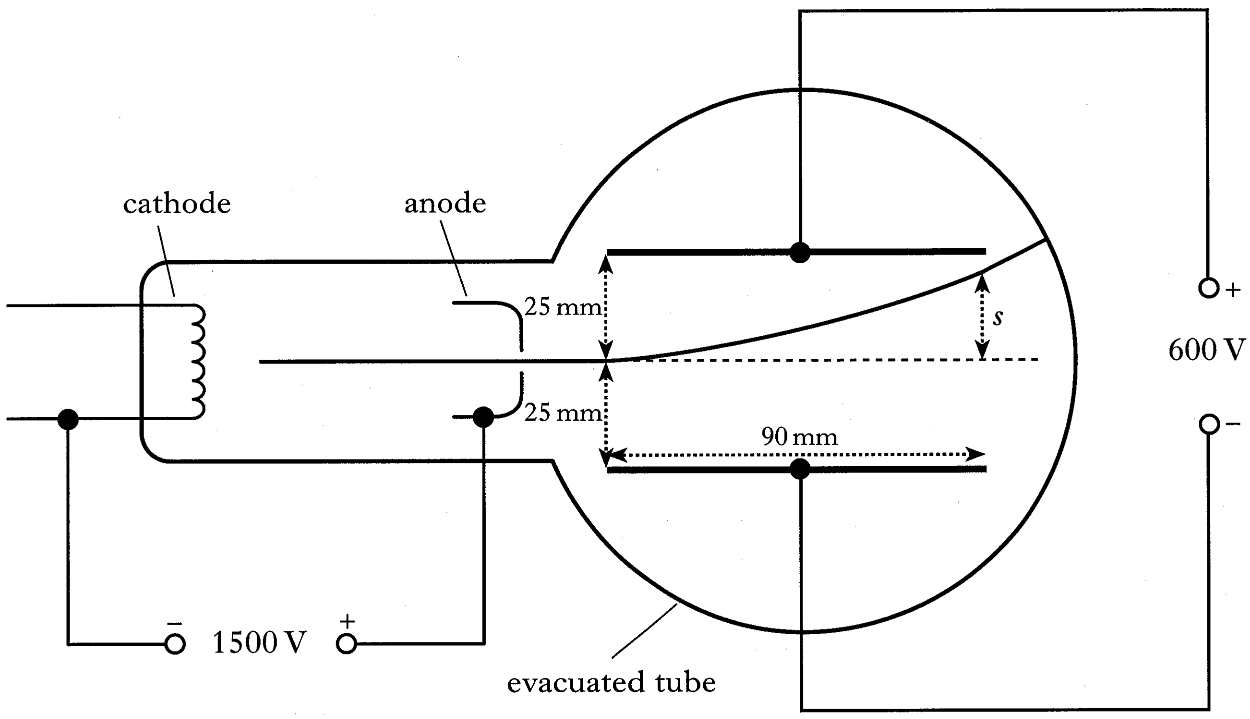

Figure 10

The electrons start from rest at the cathode and are accelerated towards the anode by a potential difference of 1500 V. Electrons enter the electric field at a point midway between the two parallel deflecting plates. The deflecting plates are 90 mm long and 50 mm apart. There is a potential difference of 600 V between the deflecting plates.

(*a*) Show that the speed of an electron at the anode is $2{\cdot}3 \times 10^7\,\mathrm{m\,s^{-1}}$. **2**

(*b*) Calculate the time an electron takes to pass between the deflecting plates. **2**

(*c*) (i) Show that the force which deflects the electron is $1{\cdot}9 \times 10^{-15}\,\mathrm{N}$. **2**

(ii) Calculate the vertical deflection *s* of an electron as it leaves the space between the deflecting plates. **3**

6. (continued)

(*d*) Explain, in terms of forces, why the path of the electron is:

(i) curved in the space between the plates; **2**

(ii) straight in the space beyond the plates. **1**

(*e*) The anode voltage is now reduced. State what happens to the value of the vertical deflection s. You must justify your answer. **2**

(14)

[Turn over

Marks

7. A charged particle moves with a speed of $2{\cdot}0 \times 10^6\,\mathrm{m\,s^{-1}}$ in a circular orbit in a uniform magnetic field, shown in Figure 11.

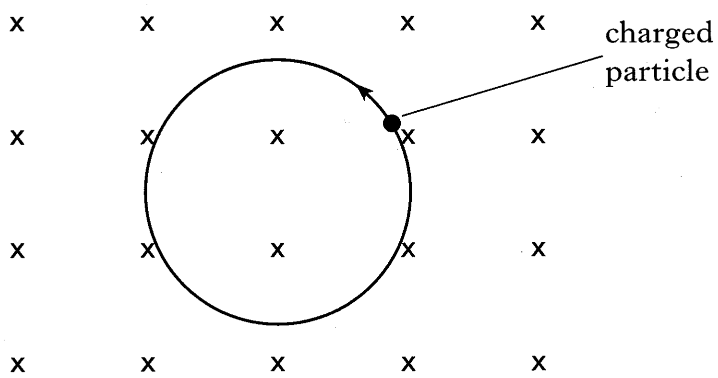

Figure 11

The magnetic induction is $1{\cdot}5\,\mathrm{T}$ and is directed into the page. The circular orbit has a radius of $13{\cdot}9\,\mathrm{mm}$.

(*a*) (i) State whether the charge on the particle is positive or negative. **1**

(ii) Calculate the charge to mass ratio of the particle. **3**

(iii) Identify the charged particle. You must justify your answer using information from the data sheet. **2**

(*b*) An electron enters a uniform magnetic field at an angle to the magnetic field lines as shown in Figure 12.

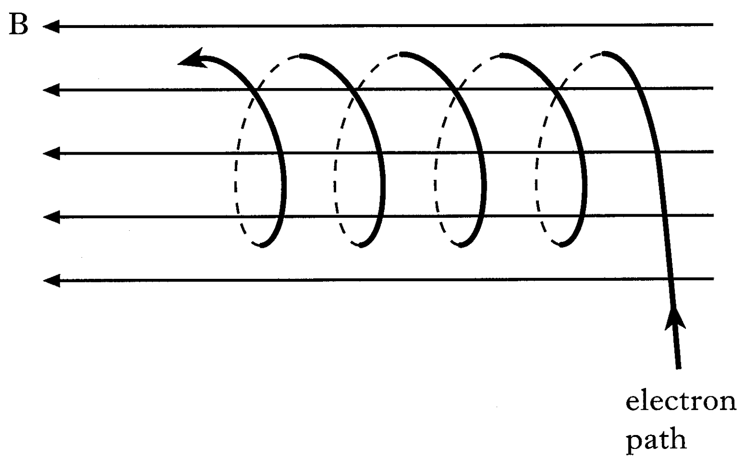

Figure 12

Explain the shape of the electron path in the magnetic field. **2**

7. (continued)

Marks

(*c*) Charged particles which enter the Earth's atmosphere near the North pole collide with air molecules. The light emitted in this process is called the Aurora Borealis.

In Figure 13, the Earth's magnetic field is indicated by continuous lines which show the magnetic field direction in the region surrounding the Earth.

The extent of the Earth's atmosphere is also shown.

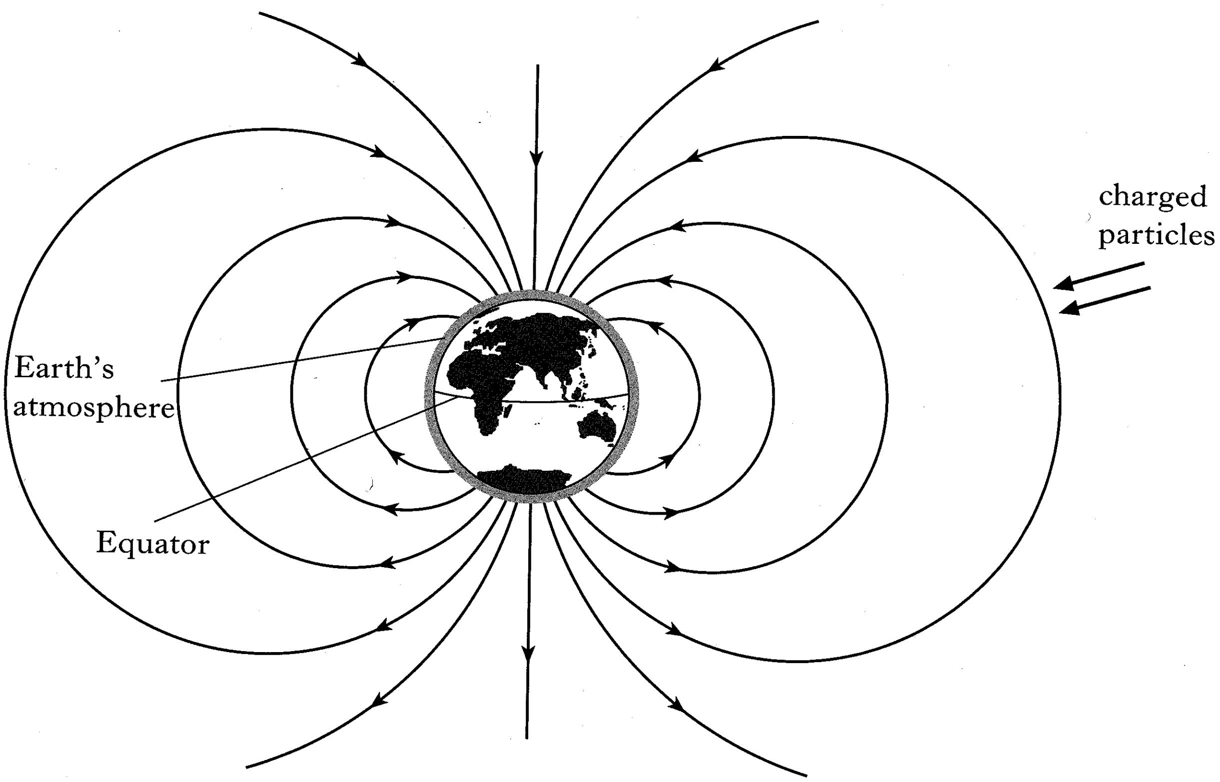

Figure 13

Charged particles approach the Earth in the direction shown in Figure 13. Explain why these particles do **not** cause an aurora above the Equator. 2

(10)

[Turn over

Marks

8. (*a*) A coil of wire has an inductance of 2·0 H. State what is meant by *an inductance of 2·0 H*. 1

(*b*) Figure 14 shows a circuit containing an inductor with negligible resistance, a resistor, switch and d.c. power supply connected in series. The d.c. power supply has negligible internal resistance.

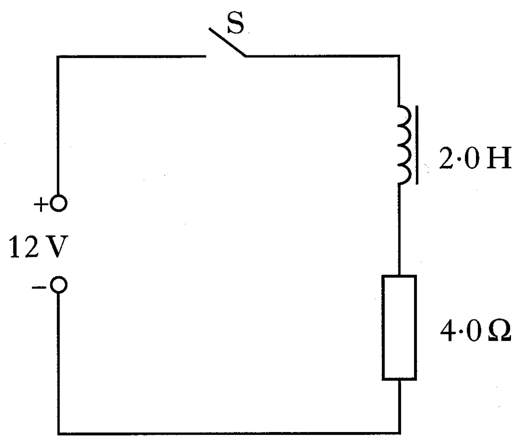

Figure 14

Calculate the rate of change of current immediately after switch S is closed. 2

(*c*) A similar circuit, with some component values changed, is shown in Figure 15.

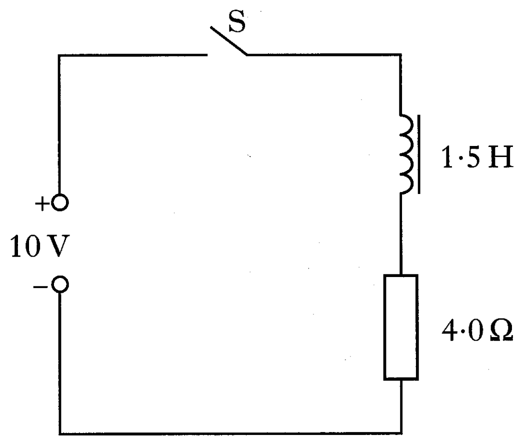

Figure 15

(i) Switch S is closed.

State **two** ways that the current in this circuit differs from the current in the circuit shown in Figure 14. **Justify your answers**. 2

(ii) Calculate the maximum energy stored in the 1·5 H inductor. 2

8. (continued)

(*d*) An airport metal detector consists of two fixed coils as shown in Figure 16.

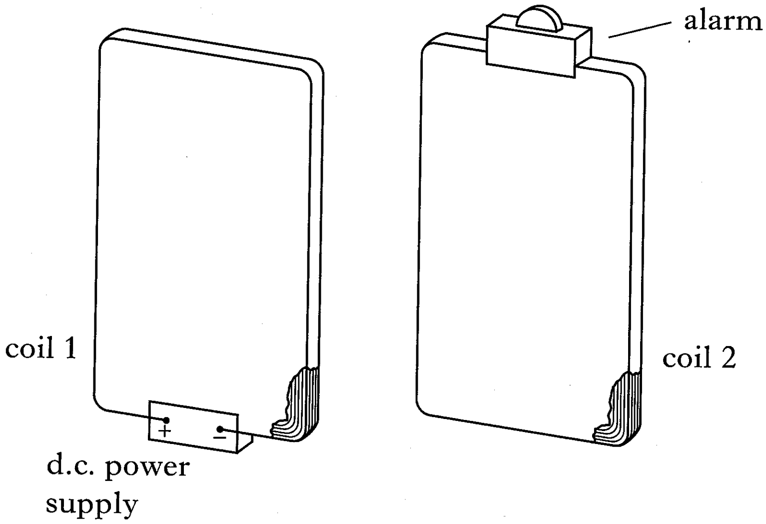

Figure 16

A d.c. power supply provides a current in coil 1.

Coil 2 has no power supply but is connected to an alarm. The alarm triggers when there is a current in coil 2.

A passenger wearing a gold bracelet walks between the coils as shown in Figure 17.

Figure 17

Explain why:

(i) a current is induced in the gold bracelet; **1**

(ii) this triggers the alarm. **1**

(9)

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

$$y = 2 \cdot 0 \times 10^{-4} \sin(1570t - 4 \cdot 6x)$$

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

(i) Calculate the frequency of the wave. **2**

(ii) A wave with the same frequency and four times the intensity travels in the opposite direction.

Write down the equation which represents this wave. **2**

(*b*) A train emits a sound of frequency 800 Hz as it passes through a station. The sound is heard by a person on the station platform as shown in Figure 18.

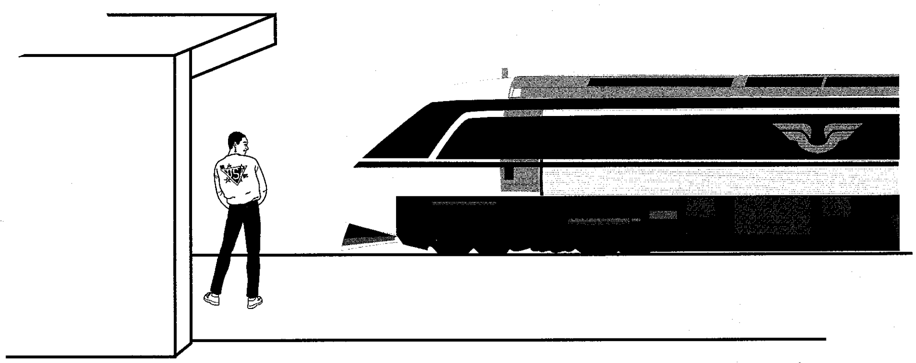

Figure 18

(i) Describe how the frequency of the sound, heard by the person, changes as the train passes through the station. **1**

(ii) Explain, in terms of wavefronts, why this frequency change occurs. You may wish to include a diagram as part of your answer. **2**

(iii) At one instant the person hears a sound of frequency 760 Hz. Calculate the speed of the train relative to the person on the platform at this time. **2**

(9)

Marks

10. A student sets up a Young's slits experiment in order to measure the wavelength of monochromatic light emitted by a laser. The light from the laser passes through a double slit before reaching a screen, where a pattern of light and dark fringes is seen, as shown in Figure 19.

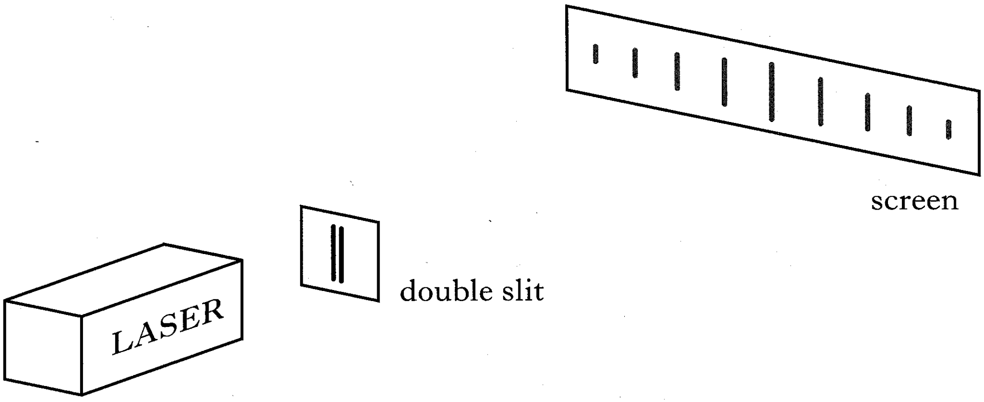

Figure 19

The student records the following measurements:

double slit separation = $0{\cdot}25 \pm 0{\cdot}01$ mm
distance between double slits and screen = $3{\cdot}91 \pm 0{\cdot}01$ m
distance between two adjacent bright fringes = $8{\cdot}0 \pm 0{\cdot}5$ mm.

(*a*) (i) Calculate the wavelength of the laser light. **2**

(ii) Show that the absolute uncertainty in the calculated wavelength is $\pm 4 \times 10^{-8}$ m. **2**

(iii) State why an answer of $\pm 3{\cdot}78 \times 10^{-8}$ m for part (*a*)(ii) would **not** be acceptable. **1**

(*b*) The student now measures the distance between 9 bright fringes (8 spaces). The result is

distance between 9 fringes (8 spaces) = $64{\cdot}0 \pm 0{\cdot}5$ mm.

Calculate the new absolute uncertainty in wavelength, assuming the other measurements remain unchanged. **2**

(*c*) (i) The student then suggests that measuring the distance between 12 bright fringes would significantly reduce the absolute uncertainty in the wavelength. Explain why this is **not** correct. **1**

(ii) State which measurement must be made more accurately to reduce significantly the absolute uncertainty in the wavelength. **1**

(9)

[Turn over

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.

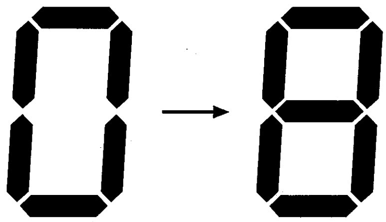

Figure 20

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**.

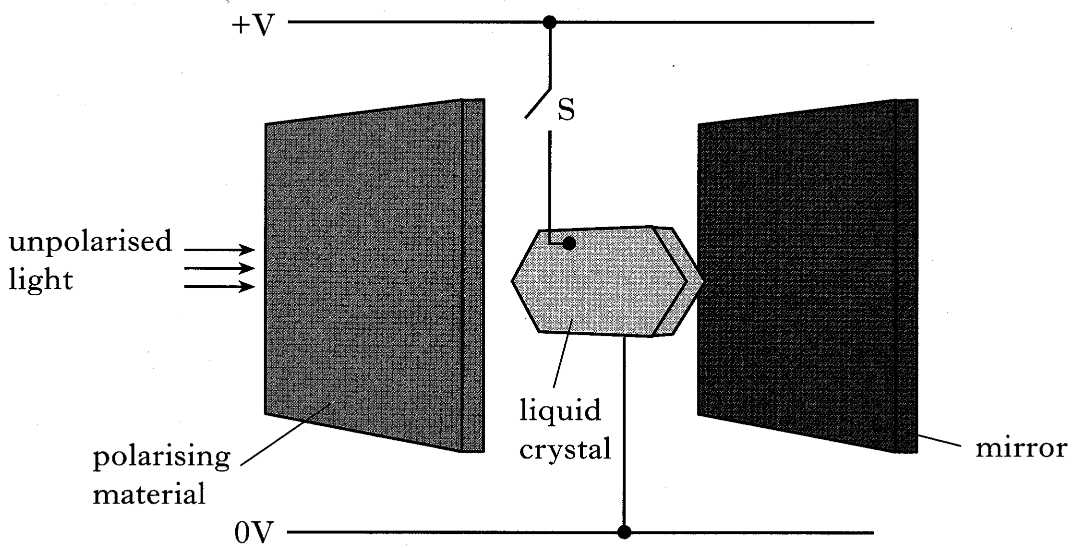

Figure 21

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.

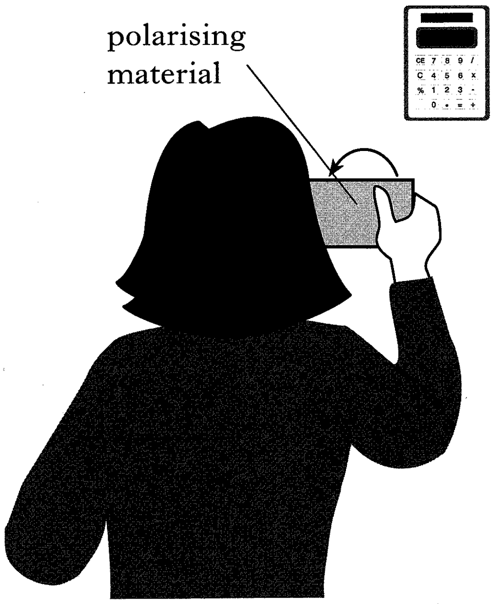

Figure 22

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

(6)

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