X069/701

NATIONAL
QUALIFICATIONS
2007

WEDNESDAY, 16 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 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.

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DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8\ \mathrm{m\ s^{-2}}$	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	$6{\cdot}67 \times 10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Speed of light in vacuum	c	$3{\cdot}0 \times 10^8\ \mathrm{m\ s^{-1}}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
Speed of sound in air	v	$3{\cdot}4 \times 10^2\ \mathrm{m\ s^{-1}}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$

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*/ $\mathrm{kg\ m^{-3}}$	*Melting Point*/ K	*Boiling Point*/ K	*Specific Heat Capacity*/ $\mathrm{J\ kg^{-1}\ K^{-1}}$	*Specific Latent Heat of Fusion*/ $\mathrm{J\ kg^{-1}}$	*Specific Latent Heat of Vaporisation*/ $\mathrm{J\ kg^{-1}}$
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*) A particle has displacement $s = 0$ at time $t = 0$ and moves with constant acceleration a.

The velocity of the object is given by the equation $v = u + at$, where the symbols have their usual meanings.

Using calculus, derive an equation for the displacement s of the object as a function of time t. **2**

(*b*) A cyclotron accelerates protons to a velocity of $2{\cdot}80 \times 10^{8}\,\mathrm{m\,s^{-1}}$.

Calculate the relativistic energy of a proton at this velocity. **4**

(6)

[Turn over

Marks

2. (*a*) A turntable consists of a uniform disc of radius 0·15 m and mass 0·60 kg.

(i) Calculate the moment of inertia of the turntable about the axis of rotation shown in Figure 1. **2**

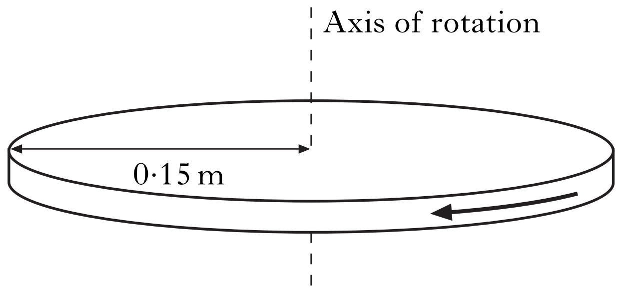

Figure 1

(ii) The turntable accelerates uniformly from rest until it rotates at 45 revolutions per minute. The time taken for the acceleration is 1·5 s.

(A) Show that the angular velocity after 1·5 s is 4·7 rad s^{-1}. **1**

(B) Calculate the angular acceleration of the turntable. **2**

(iii) When the turntable is rotating at 45 revolutions per minute, its motor is disengaged. The turntable continues to rotate freely with negligible friction.

A small mass of 0·20 kg is dropped onto the turntable at a distance of 0·10 m from the centre, as shown in Figure 2.

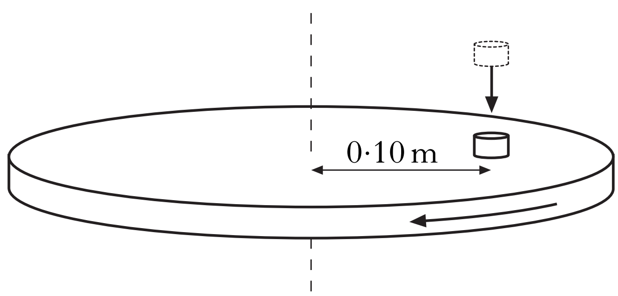

Figure 2

The mass remains in this position on the turntable due to friction, and the turntable and mass rotate together.

Calculate the new angular velocity of the turntable and mass. **3**

Marks

2. (*a*) (continued)

(iv) The experiment is repeated, but the mass is dropped at a distance greater than 0·10 m from the centre of the turntable. The mass slides off the turntable.

Explain why this happens. **2**

(*b*) An ice-skater spins with her arms and one leg outstretched as shown in Figure 3(*a*). She then pulls her arms and leg close to her body as shown in Figure 3(*b*).

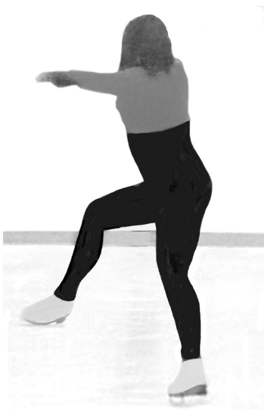

Figure 3(*a*)

Figure 3(*b*)

State what happens to her angular velocity during this manoeuvre.

Justify your answer. **2**

(12)

[Turn over

Marks

3. (*a*) The Moon orbits the Earth due to the gravitational force between them.

(i) Calculate the magnitude of the gravitational force between the Earth and the Moon. **2**

(ii) Hence calculate the tangential speed of the Moon in its orbit around the Earth. **2**

(iii) Define the term *gravitational potential* at a point in space. **1**

(iv) Calculate the potential energy of the Moon in its orbit. **2**

(v) Hence calculate the total energy of the Moon in its orbit. **2**

(*b*) (i) Derive an expression for the escape velocity from the surface of an astronomical body. **2**

(ii) Calculate the escape velocity from the surface of the Moon. **2**

(13)

Marks

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

(*b*) The motion of a piston in a car engine closely approximates to simple harmonic motion.

In a typical engine, the top of a piston moves up and down between points A and B, a distance of 0·10 m, as shown in Figure 4.

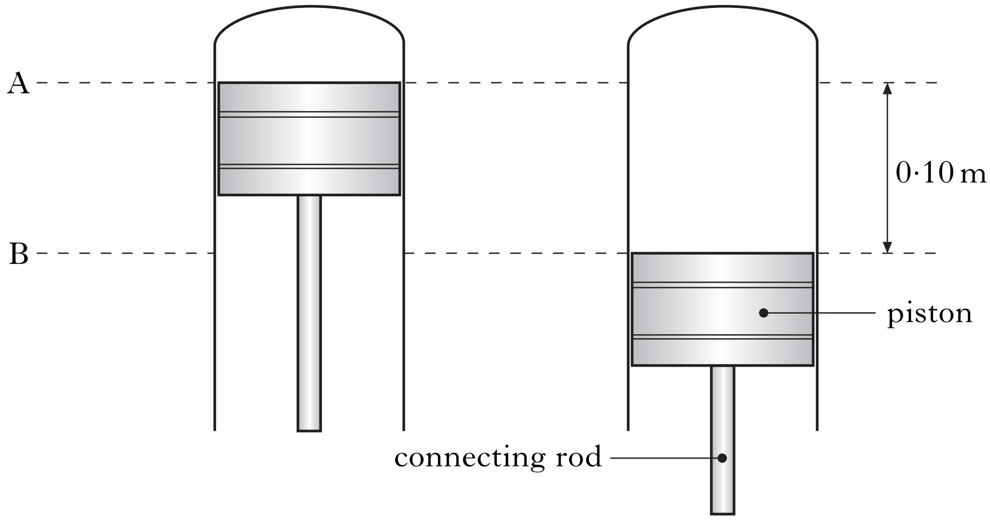

Figure 4

The frequency of the piston's motion is 100 Hz.

Write down an equation which describes how the displacement of the piston from its central position varies with time. Numerical values are required. **2**

(*c*) Calculate the maximum acceleration of the piston. **2**

(*d*) The mass of the piston is 0·48 kg.

Calculate the maximum force applied to the piston by the connecting rod. **2**

(*e*) Calculate the maximum kinetic energy of the piston. **2**

(9)

[Turn over

5. (*a*) Figure 5 shows a point charge of +5·1 nC.

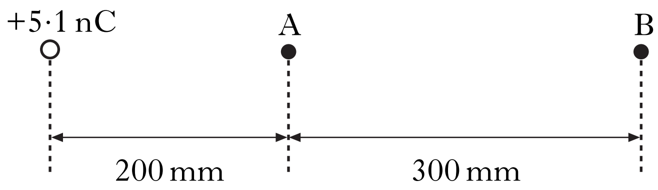

Figure 5

Point A is a distance of 200 mm from the point charge.
Point B is a distance of 300 mm from point A as shown in Figure 5.

(i) Show that the potential at point A is 230 V. **1**

(ii) Calculate the potential difference between A and B. **2**

(*b*) A conducting sphere on an insulating support is some distance away from a negatively charged rod as shown in Figure 6.

Figure 6

Using diagrams, or otherwise, describe a procedure to charge the sphere positively by induction. **2**

5. (continued)

(*c*) A charged oil drop of mass $1{\cdot}2 \times 10^{-14}$ kg is stationary between two horizontal parallel plates.

There is a potential difference of $4{\cdot}9$ kV between the parallel plates.

The plates are 80 mm apart as shown in Figure 7.

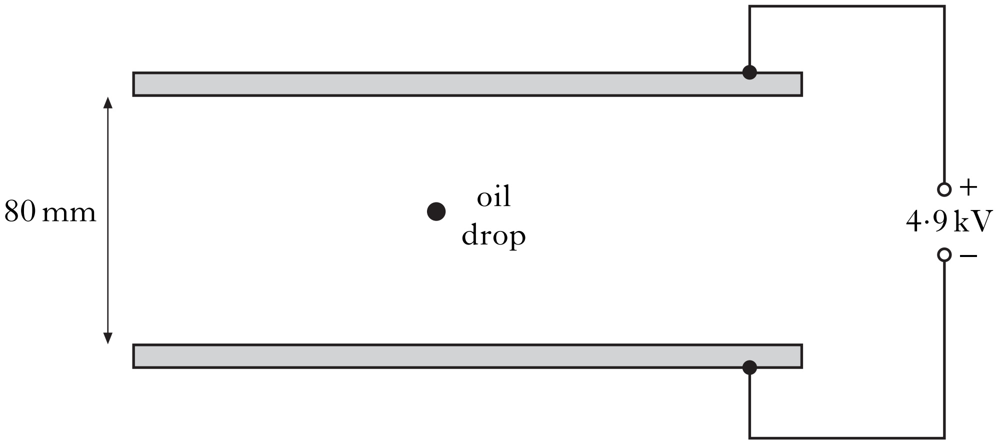

Figure 7

(i) Draw a labelled diagram to show the forces acting on the oil drop. **1**

(ii) Calculate the charge on the oil drop. **3**

(iii) How many excess electrons are on the oil drop? **1**

(*d*) The results of Millikan's oil drop experiment led to the idea of quantisation of charge.

A down quark has a charge of $-5{\cdot}3 \times 10^{-20}$ C. Explain how this may conflict with Millikan's conclusion. **1**

(11)

[Turn over

Marks

6. The shape of the Earth's magnetic field is shown in Figure 8.

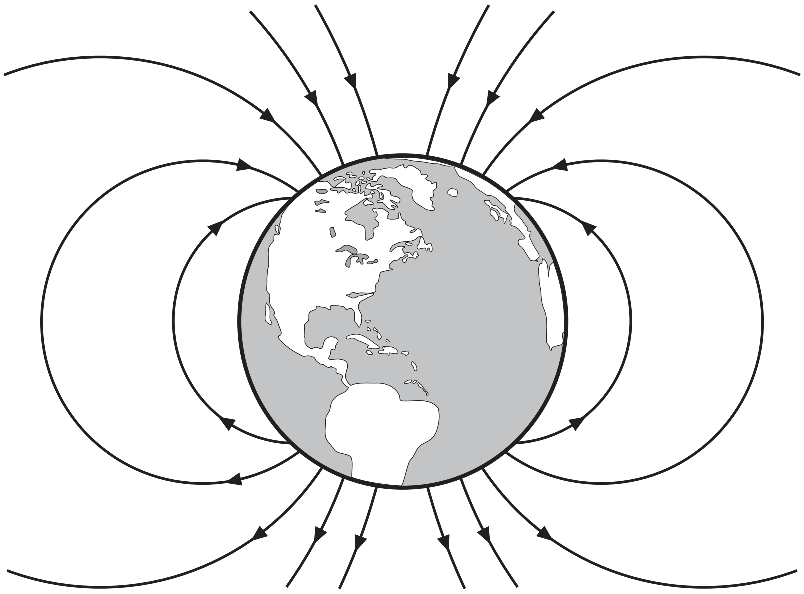

Figure 8

At a particular location in Scotland the field has a magnitude of $5 \cdot 0 \times 10^{-5}$ T directed into the Earth's surface at an angle of 69° as shown in Figure 9.

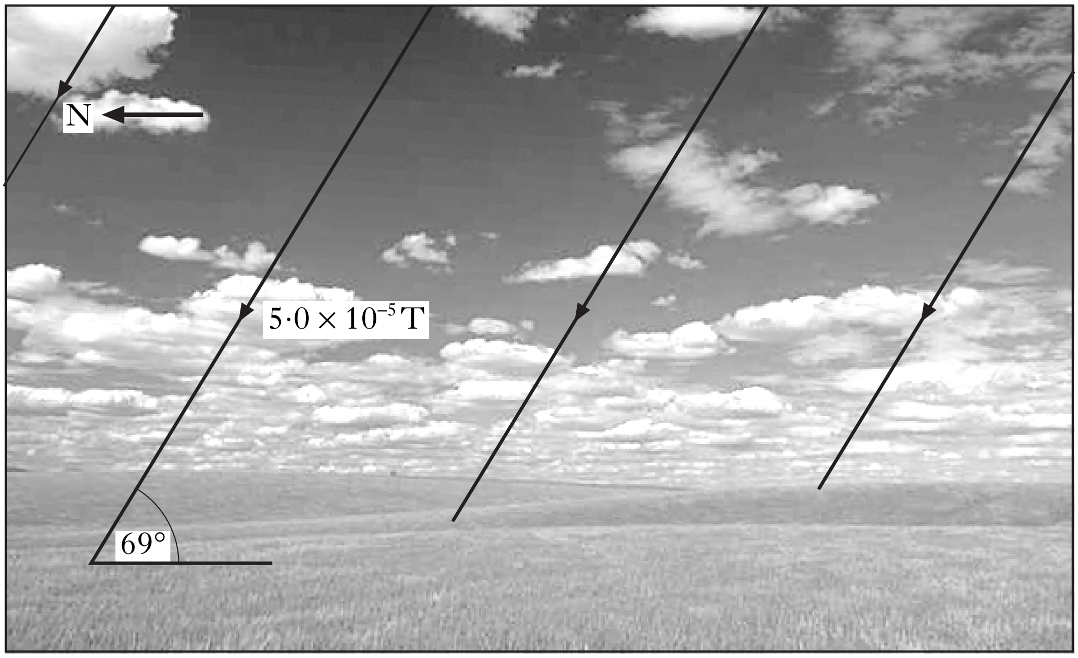

Figure 9

(*a*) Show that the component of the field perpendicular to the Earth's surface is $4 \cdot 7 \times 10^{-5}$ T. **1**

6. (continued)

(*b*) At this location a student sets up a circuit containing a straight length of copper wire lying horizontally in the North – South direction as shown in Figure 10.

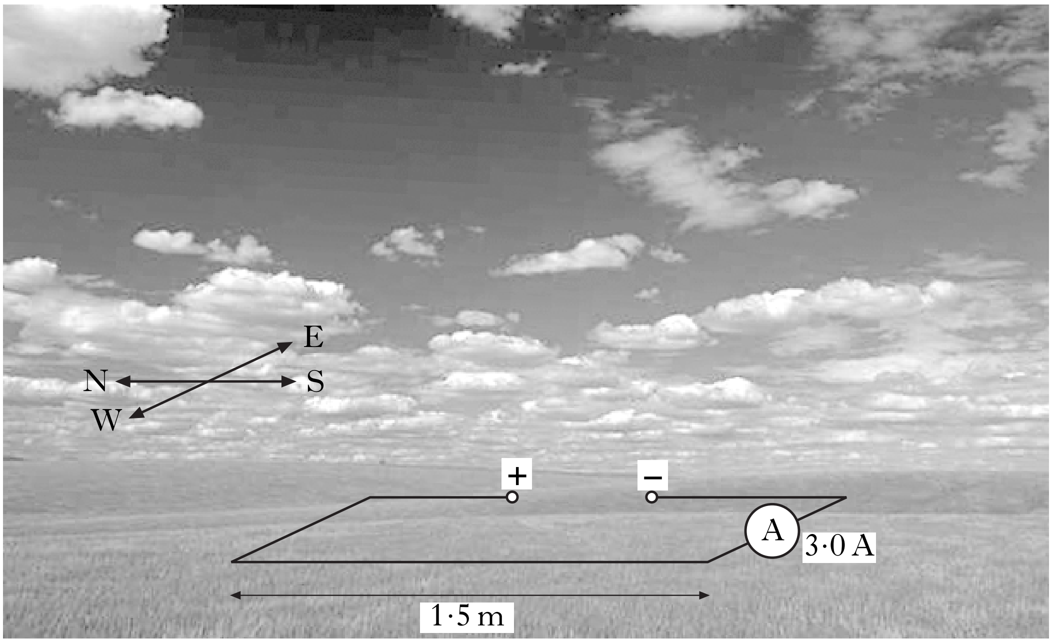

Figure 10

The length of the wire is 1·5 m and the current in the circuit is 3·0 A.

(i) Calculate the magnitude of the force acting on the wire due to the Earth's magnetic field. **2**

(ii) State the direction of this force. **1**

(*c*) The wire is now tilted through an angle of 69° so that it is parallel to the direction of the Earth's magnetic field.

Determine the force on the wire due to the Earth's magnetic field. **1**

(*d*) A long straight current carrying wire produces a magnetic field. The current in this wire is 3·0 A.

(i) Calculate the distance from the wire at which the magnitude of the magnetic field is $5{\cdot}0 \times 10^{-5}$ T. **2**

(ii) Describe the shape of this magnetic field. **1**

(8)

[Turn over

Marks

7. (*a*) Figure 11 shows a d.c. power supply in series with a switch, lamp and inductor.

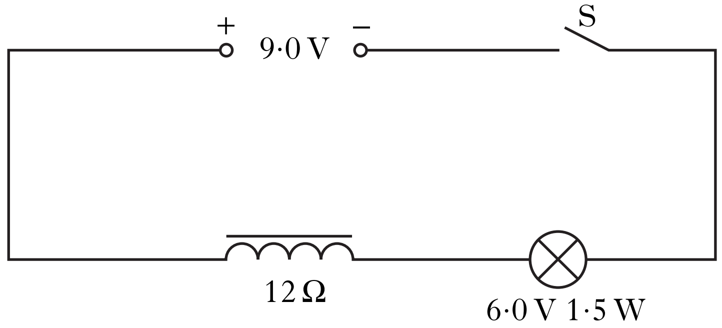

Figure 11

The inductor consists of a coil of wire with a resistance of 12 Ω.
The lamp is rated at 6·0 V 1·5 W.
The 9·0 V d.c. power supply has negligible internal resistance.

(i) Explain why the lamp does not reach its maximum brightness immediately after the switch is closed. **2**

(ii) When the lamp reaches its maximum brightness it is operating at its stated power rating.

Calculate the current in the circuit. **1**

(iii) The maximum energy stored in the inductor is 75 mJ.

Calculate the inductance of the inductor. **2**

(iv) The inductor in Figure 11 is replaced with another inductor which has the same type of core and wire, but with twice as many turns.

State the effect this has on:

(A) the maximum current;

(B) the time to reach maximum current. **2**

7. (continued)

(*b*) Figure 12 shows a neon lamp connected to an inductor, switch and a 1·5 V cell.

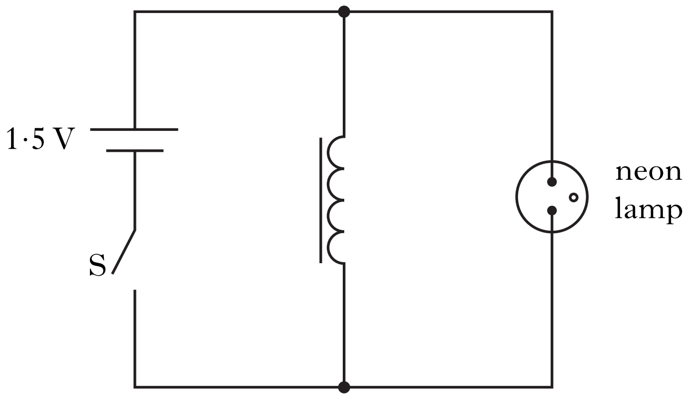

Figure 12

A neon lamp needs a potential difference of at least 80 V across it before it lights.
The switch is closed for 5 seconds.
The switch is then opened and the neon lamp flashes **briefly**.

Explain this observation. **2**

(9)

[Turn over

Marks

8. An electron travelling at $9{\cdot}5 \times 10^{7}\,\mathrm{m\,s^{-1}}$ enters a uniform magnetic field B at an angle of $60\,°$ as shown in Figure 13.

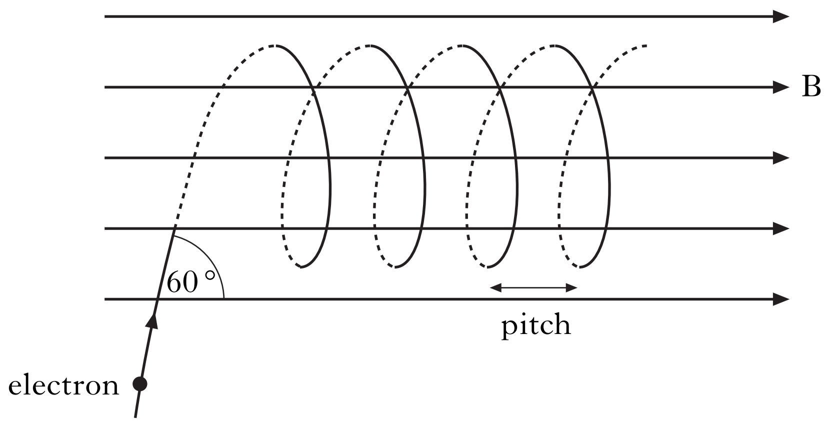

Figure 13

The electron moves in a helical path in the magnetic field.

(*a*) (i) Calculate the component of the electron's initial velocity:

(A) parallel to the magnetic field; **1**

(B) perpendicular to the magnetic field. **1**

(ii) By making reference to **both** components, explain why the electron moves in a helical path. **2**

(*b*) (i) The magnetic field has a magnetic induction of $0{\cdot}22\,\mathrm{T}$.

Show that the radius of the helix is $2{\cdot}1 \times 10^{-3}\,\mathrm{m}$. **2**

(ii) Calculate the time taken for the electron to make one complete revolution. **2**

(iii) The distance between adjacent loops in the helix is called the pitch as shown in Figure 13.

Calculate the pitch of the helix. **2**

(*c*) A proton enters the magnetic field with the same initial speed and direction as the electron shown in Figure 13. The magnetic field remains unchanged.

State **two** ways that the path of the proton in the magnetic field is different from the path of the electron. **2**

(12)

Marks

9. (*a*) A water wave travels with a speed of $0{\cdot}060\,\mathrm{m\,s^{-1}}$ in the positive x direction. Figure 14 represents the water wave at one instant in time.

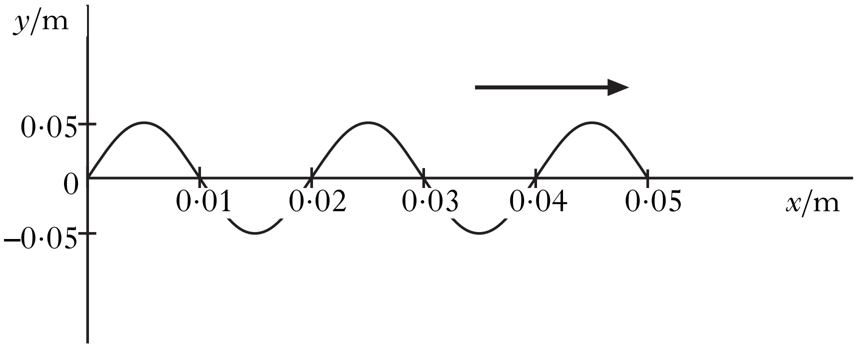

Figure 14

Write down an equation for the vertical displacement y of a point on the water surface in terms of the horizontal displacement x and time t.

Numerical values are required. **2**

(*b*) Write down an equation for an identical wave travelling in the opposite direction. **1**

(*c*) The amplitude of the wave gradually decreases.

Calculate the amplitude of the water wave when the intensity of the wave has decreased by 50%. **2**

(5)

[Turn over

Marks

10. (*a*) A thin coating of magnesium fluoride is applied to the surface of a camera lens.

Figure 15 shows an expanded view of this coating on the glass lens.

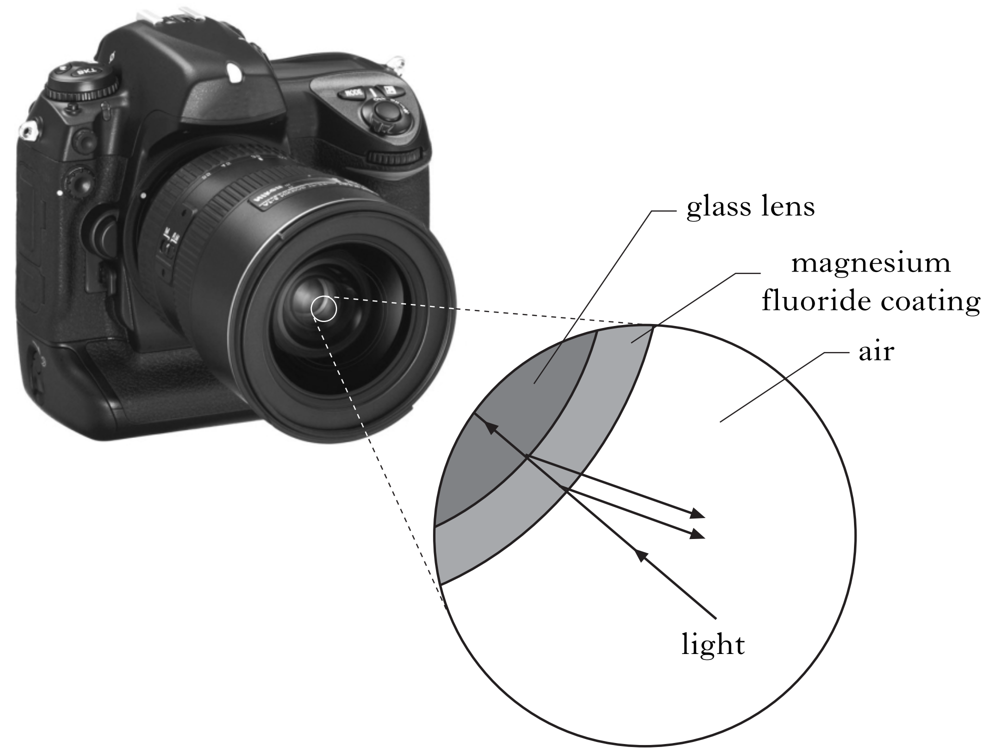

Figure 15

Monochromatic light is incident on the lens and some light reflects from the front and rear surfaces of the coating as shown in Figure 15.

(i) State the phase change undergone by the light reflected from:

(A) the front surface of the coating;

(B) the rear surface of the coating. **1**

(ii) Explain, in terms of optical path difference, why this coating can make the lens non-reflecting for a particular wavelength of light. **2**

(iii) Why is it desirable that camera lenses should reflect very little light? **1**

(iv) A particular lens has a magnesium fluoride coating of thickness $1{\cdot}05 \times 10^{-7}$m.

Calculate the wavelength of light for which this lens is non-reflecting. **2**

10. (continued)

(*b*) A thin air wedge is formed between two glass plates which are in contact at one end and separated by a thin metal wire at the other end.

Figure 16 shows sodium light being reflected down onto the air wedge. A travelling microscope is used to view the resulting interference pattern.

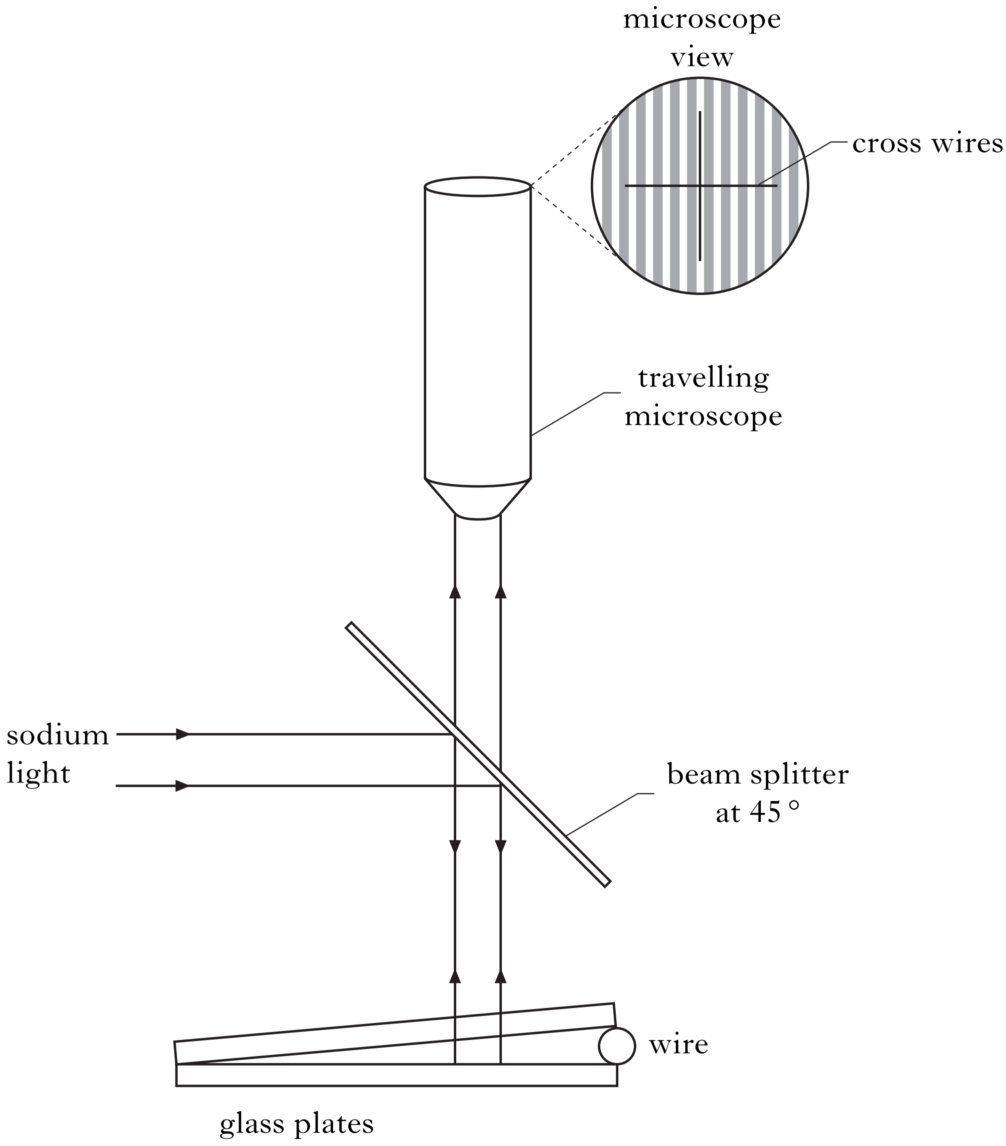

Figure 16

Explain how the diameter of the wire is determined using measurements obtained with this apparatus.

Assume the sodium light is monochromatic.

Your answer should include:

- the measurements required
- any data required
- the equation used. **2**

(8)

Marks

11. The apparatus shown in Figure 17 is set up to measure the speed of transverse waves on a stretched string.

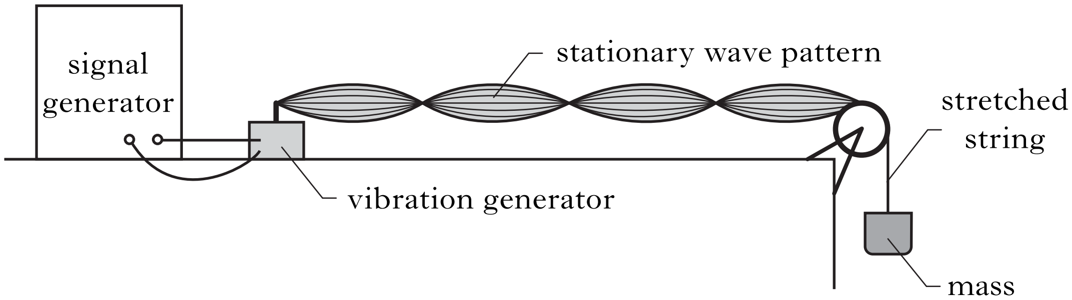

Figure 17

The following data are obtained.

Distance between adjacent nodes = $(0{\cdot}150 \pm 0{\cdot}005)$ m
Frequency of signal generator = (250 ± 10) Hz

(*a*) Show that the wave speed is $75\,\mathrm{m\,s^{-1}}$. **2**

(*b*) Calculate the absolute uncertainty in this value for the wave speed. Express your answer in the form $(75 \pm \quad)\,\mathrm{m\,s^{-1}}$. **3**

(*c*) (i) In an attempt to reduce the absolute uncertainty, the frequency of the signal generator is increased to (500 ± 10) Hz. Explain why this will **not** result in a reduced absolute uncertainty. **1**

(ii) State how the absolute uncertainty in wave speed could be reduced. **1**

(7)

[*END OF QUESTION PAPER*]

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