



Centre Number

71	
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Candidate Number

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ADVANCED  
General Certificate of Education  
2014

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## Physics

Assessment Unit A2 2  
*assessing*  
Fields and their Applications

[AY221]

MONDAY 9 JUNE, MORNING

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MV18

### TIME

1 hour 30 minutes, plus your additional time allowance.

### INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this question paper.

## INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **4(c)(ii)**.

Figures in brackets printed at the end of each question indicate the marks awarded to each question.

Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.

You may use an electronic calculator.

Question 7 contributes to the synoptic assessment required of the specification. Candidates should allow approximately 15 minutes to complete this question. This may be longer if you have an additional time allowance.

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**(Questions start overleaf)**

1 (a) Define gravitational field strength. [1 mark]

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(b) (i) The Moon has a radius of  $1.74 \times 10^6$  m and a mass of  $7.35 \times 10^{22}$  kg. Calculate the gravitational field strength on the surface of the Moon. [3 marks]

Gravitational field strength = \_\_\_\_\_ N kg<sup>-1</sup>

(ii) The Moon moves in a circular orbit of mean radius of  $3.84 \times 10^8$  m around the Earth. The mass of the Earth is  $5.98 \times 10^{24}$  kg. Show that the force on the Moon due to the Earth is  $1.99 \times 10^{20}$  N. [3 marks]

(iii) Calculate the period of the Moon's orbit around the Earth in days. [3 marks]

Period = \_\_\_\_\_ days

(c) The Earth has many artificial satellites with geostationary orbits. Explain fully what the term "geostationary" means. [2 marks]

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- 2 (a) (i) State one similarity and one difference **in the force** produced by electric and gravitational fields. [2 marks]

Similarity \_\_\_\_\_

\_\_\_\_\_

Difference \_\_\_\_\_

\_\_\_\_\_

- (ii) Write down the equation used to calculate the magnitude of the force that exists between two point charges. Identify all the symbols used and state the name of the law that this equation represents. [3 marks]

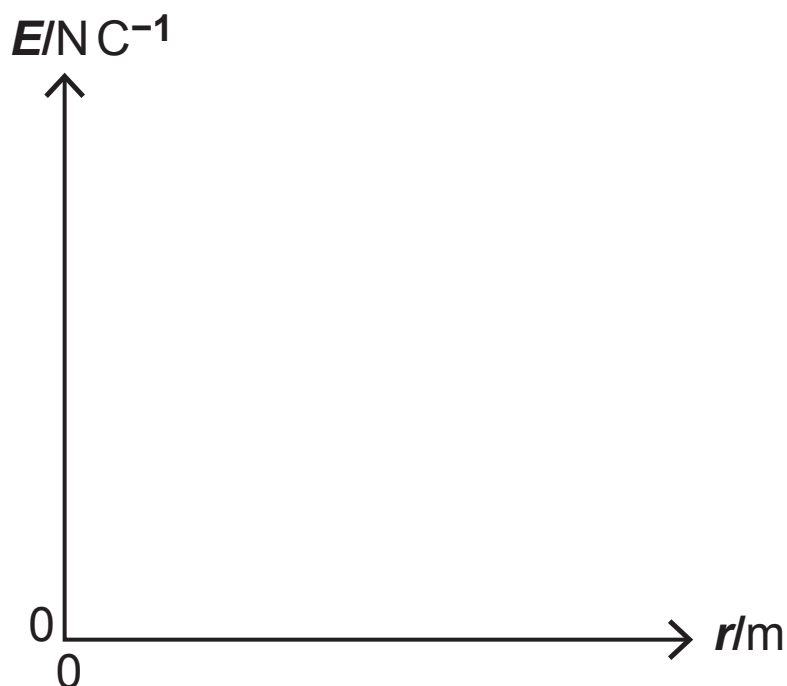
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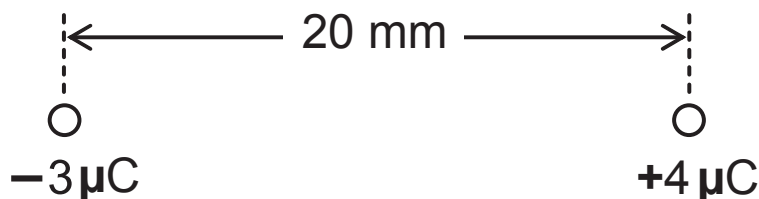
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- (b) (i) On **Fig. 2.1**, sketch a graph showing how the electric field strength  $E$  due to a point charge varies with the distance  $r$  from the charge. [1 mark]



**Fig. 2.1**

A point charge of  $-3\mu\text{C}$  is placed 20 mm from a point charge of  $+4\mu\text{C}$ , see **Fig. 2.2**.



**Fig. 2.2**

- (ii) Calculate the magnitude and direction of the resultant electric field strength at point A midway between the two charges.

Electric field strength = \_\_\_\_\_  $\text{NC}^{-1}$  [3 marks]

Direction = \_\_\_\_\_ [1 mark]



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**(Questions continue overleaf)**

3 (a) A capacitor of capacitance  $330\ \mu\text{F}$  is charged from a  $40\text{ V}$  power supply.

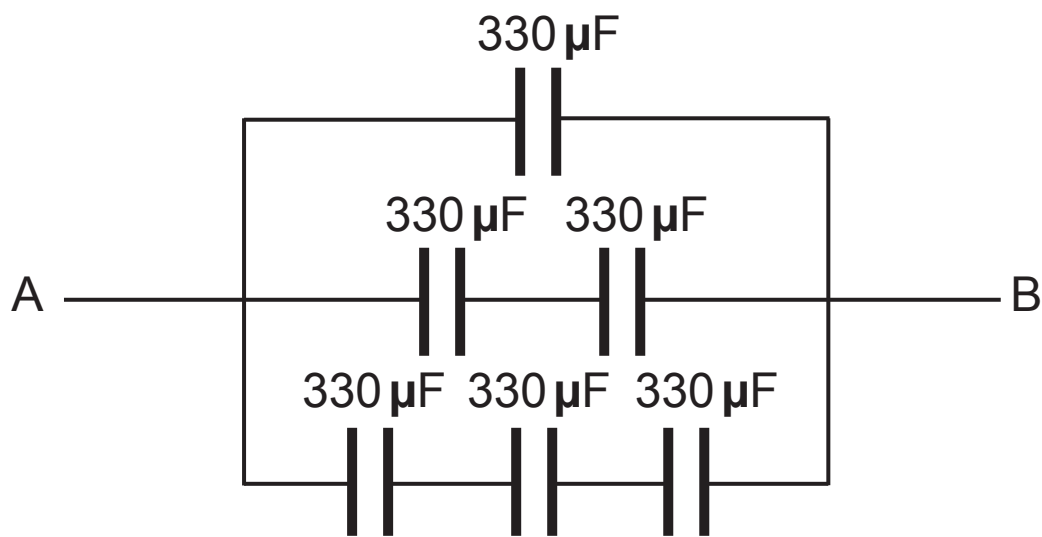
(i) How much charge is stored by the capacitor?  
[2 marks]

Charge = \_\_\_\_\_ C

(ii) What would be the maximum energy stored by this capacitor? [2 marks]

Energy = \_\_\_\_\_ J

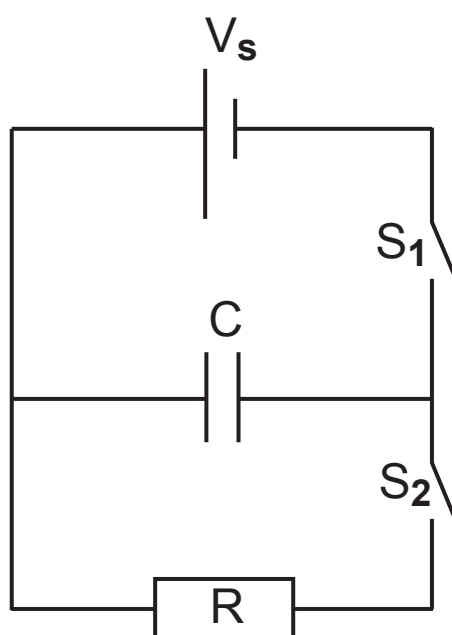
- (b) **Fig. 3.1** shows a network of capacitors each of capacitance  $330\ \mu\text{F}$ . Calculate the capacitance between A and B. [2 marks]



**Fig. 3.1**

Capacitance = \_\_\_\_\_  $\mu\text{F}$

- (c) **Fig. 3.2** shows a circuit containing a capacitor of capacitance  $C$ , a resistor of resistance  $R$ , a supply voltage  $V_s$  and two switches  $S_1$  and  $S_2$ .



**Fig. 3.2**

When switch  $S_1$  is closed the capacitor is charged by the battery.

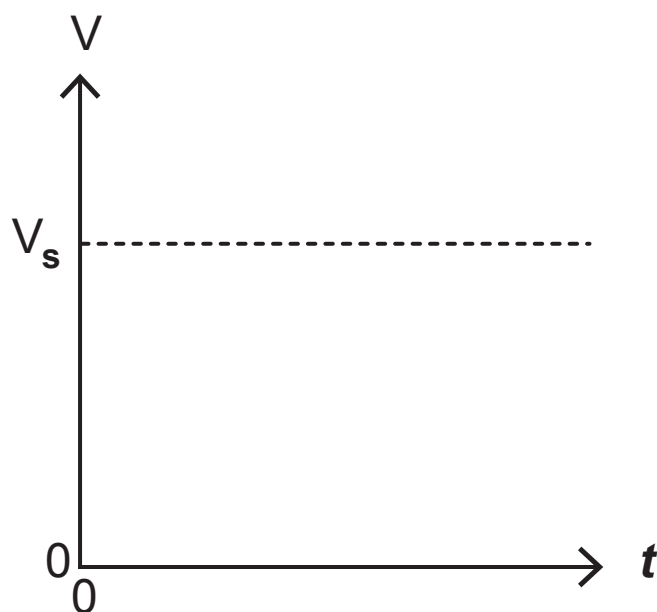
- (i) Explain how the capacitor is charged in terms of the movement of charge. [3 marks]

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- (ii) On **Fig. 3.3** sketch a graph to show how the potential difference  $V$  across the capacitor plates varies with time  $t$  during the charging process. Switch  $S_1$  is closed at time  $t = 0$ . [1 mark]



**Fig. 3.3**

The capacitor is charged to a maximum potential difference and switch  $S_1$  is then opened. When switch  $S_2$  is closed the capacitor discharges through the resistor  $R$  and the potential difference  $V_C$  across the capacitor  $C$  decreases with time  $t$ .

(iii) What effect does the resistor have on the discharge of the capacitor? [1 mark]

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(iv) Define the time constant  $\tau$  of the circuit in terms of the variation of the potential difference across the capacitor with time as it discharges. [1 mark]

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- (d) A  $470\ \mu\text{F}$  capacitor is charged to a potential difference of  $200\ \text{V}$ . The capacitor is discharged through a resistor  $R$ . After  $12\ \text{s}$ , the potential difference across the capacitor has fallen to  $74\ \text{V}$ . Calculate the resistance of resistor  $R$  in  $\text{k}\Omega$ . [3 marks]

Resistance = \_\_\_\_\_  $\text{k}\Omega$

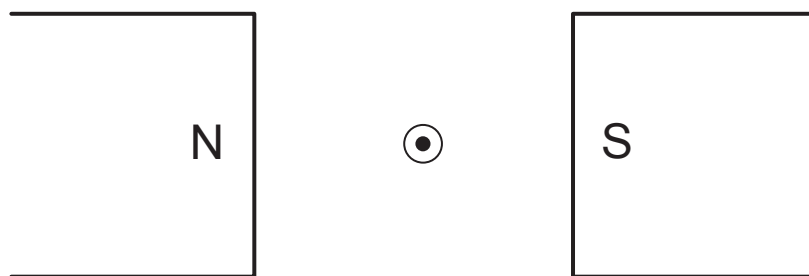
- 4 Your answer to part (c)(ii) of this question should be in continuous prose. You will be assessed on the quality of your written communication.

(a) Define the weber. [2 marks]

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- (b) Fig. 4.1 shows a current carrying wire between two magnetic poles. The direction of the current in the wire is out of the page.



**Fig. 4.1**

- (i) State the direction of the force on the current carrying wire. [1 mark]

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- (ii) The wire carries a current of 3.0A. The length of the wire in the field is 5.0 cm and it experiences a force of 0.03 N. Calculate the strength of the magnetic field in millitesla. [3 marks]

Magnetic field strength = \_\_\_\_\_mT

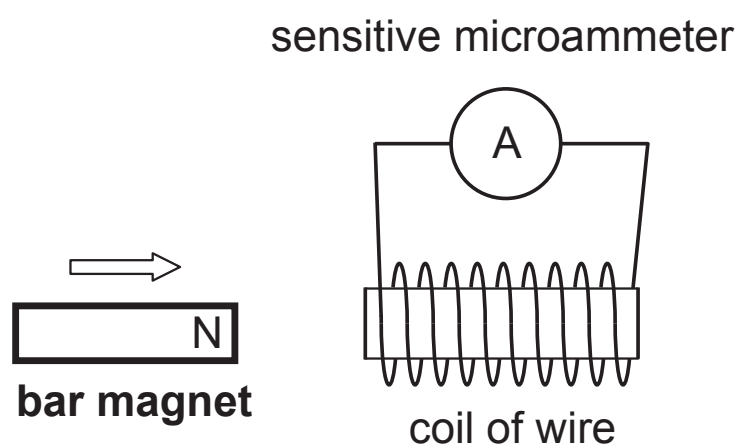
- (c) (i) State Lenz's Law of electromagnetic induction.  
[1 mark]

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- (ii) State what happens as the N pole of the bar magnet approaches the coil, as shown in **Fig. 4.2** and explain how this is consistent with Lenz's Law. [3 marks]



**Fig. 4.2**

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Quality of written communication [2 marks]

(d) A flat circular multi-turn coil with a total resistance of  $20\ \Omega$  has 50 turns and an area of  $80\text{ cm}^2$ . The coil is placed perpendicular to a uniform magnetic field of  $0.3\text{ T}$ .

(i) Calculate the **total** flux linkage through the multi-turn coil. [3 marks]

Flux linkage = \_\_\_\_\_ Wb

(ii) Calculate the induced e.m.f. if the magnetic field is reduced to zero in  $50\text{ ms}$ . [2 marks]

Induced e.m.f. = \_\_\_\_\_ V

(iii) Calculate the induced current. [1 mark]

Induced current = \_\_\_\_\_ A

- 5 (a)** A cathode ray oscilloscope (CRO) is used extensively by physicists to display electrical signals. Outline the basic structure of the CRO. [4 marks]

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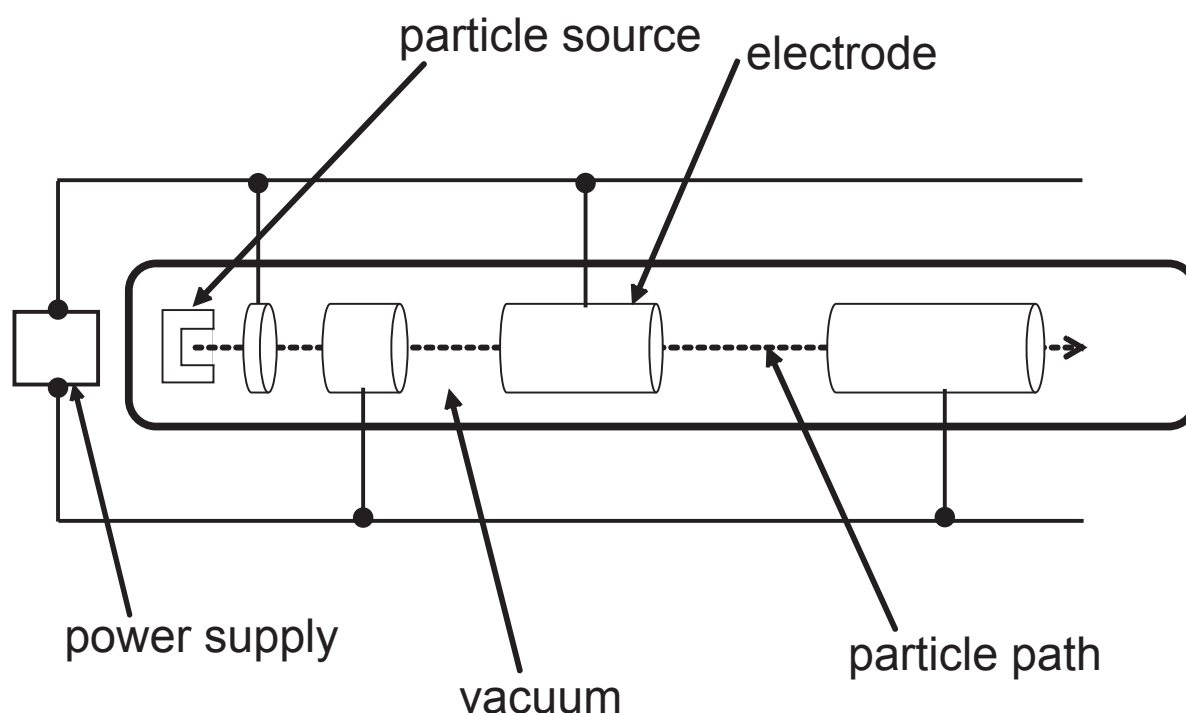
- (b)** A beam of electrons in an evacuated tube enters the uniform electric field provided by a potential difference of 600 V applied across two parallel plates 50 mm apart. The beam is deflected by the electric field until a uniform magnetic field of 0.72 mT perpendicular to the beam is applied to cancel the deflection and straighten the beam. Calculate the speed of the beam in the field. [5 marks]

Velocity of beam of electrons = \_\_\_\_\_  $\text{ms}^{-1}$

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**(Questions continue overleaf)**

- 6 A linear particle accelerator is a type of particle accelerator that increases the speed of subatomic particles. **Fig. 6.1** illustrates the main features of a linear accelerator.



**Fig. 6.1**

- (a) Why is it necessary for the chamber to be a vacuum?  
[1 mark]

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- (b)** Describe and explain how the speed of a subatomic particle is increased by a linear particle accelerator.  
[5 marks]

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- (c)** Leptons and hadrons are two groups of subatomic particles.

- (i)** State two differences between leptons and hadrons.  
[2 marks]

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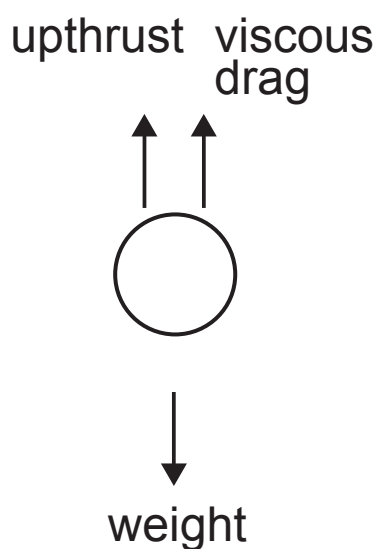
- (ii)** Hadrons can be subdivided into two types. Name the two types of hadrons and give a specific example of each type. [2 marks]

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- 7 (a) Stokes' Law is used in the study of the velocity of an object falling through a fluid. When a small, spherical ball bearing is released in glycerol it accelerates at first but its velocity soon reaches a steady value, known as the terminal velocity. **Fig. 7.1** shows the forces acting on the ball bearing as it falls. Viscous drag is the name given to the frictional force that exists between an object and the fluid through which it moves.



**Fig. 7.1**

- (i) When the ball bearing drops at a constant speed, state the relationship between the three forces labelled in **Fig. 7.1**. [1 mark]

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- (ii) Stokes showed that the viscous drag  $F_v$  acting on a sphere of radius  $r$ , dropped through a fluid of viscosity  $\eta$  and moving with velocity  $v$  is given by **Equation 7.1**. Viscosity is the property of a fluid that measures how much it opposes the motion of an object through it.

$$F_v = 6\pi r \eta v \quad \text{Equation 7.1}$$

Determine the base unit of viscosity  $\eta$ . [2 marks]

Base unit of  $\eta$  = \_\_\_\_\_

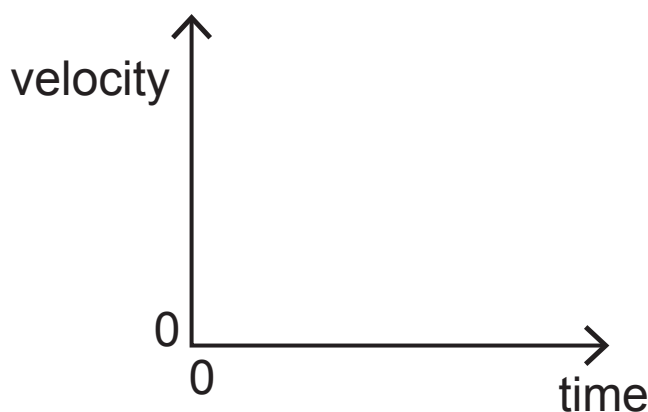
(iii) The upthrust  $F_U$  is equivalent to the **weight** of fluid displaced by the ball bearing as it falls. Derive an expression for the upthrust force experienced by the ball bearing in terms of the density of the fluid  $\rho_f$  through which the ball bearing moves, the radius  $r$  of the ball bearing and such physical constants as are required.

N.B. The volume of a sphere  $V = 4\pi r^3/3$  [2 marks]

$$F_U = \underline{\hspace{2cm}}$$

(iv) On the axes of **Fig. 7.2**, sketch two graphs:

- one to show how the velocity of an object falling from rest in a vacuum varies with time. Label this graph V.
- a second to show how the velocity of an object falling from rest in a fluid varies with time. Label this graph F. [2 marks]



**Fig. 7.2**

- (v) Calculate the terminal velocity of a steel ball bearing of radius 3.0 mm falling through glycerol. The density of steel is  $8000 \text{ kg m}^{-3}$  and the density of glycerol is  $1300 \text{ kg m}^{-3}$ . The viscosity of glycerol at room temperature is 1.5 S.I. units. The upthrust experienced by the ball bearing at terminal velocity is 1.44 mN. [3 marks]

Terminal velocity = \_\_\_\_\_  $\text{m s}^{-1}$

- (b) A very small steel ball bearing of radius 1.2 mm and mass  $5.79 \times 10^{-5} \text{ kg}$  attains a terminal velocity of  $1400 \text{ m s}^{-1}$  in air.

- (i) Calculate the wavelength associated with the ball bearing moving at terminal velocity through the air. [2 marks]

Wavelength = \_\_\_\_\_ m

- (ii) Discuss the usefulness of using the wave model to explain the motion of the ball bearing as it falls.  
[1 mark]

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- (iii) Use Einstein's mass–energy equivalency principle to calculate the difference between the ball bearing's mass when stationary and its mass when moving at terminal velocity and indicate whether it becomes heavier or lighter by ticking the appropriate box in the answer line. [3 marks]

Mass difference = \_\_\_\_\_ kg

Heavier ☐ Lighter ☐

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**THIS IS THE END OF THE QUESTION PAPER**

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Question Number	Marks
1	
2	
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Total Marks	

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# GCE Physics

## Data and Formulae Sheet for A2 1 and A2 2

### Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permittivity of a vacuum	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\left( \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ F}^{-1} \text{ m} \right)$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
(unified) atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

The following equations may be useful in answering some of the questions in the examination:

## Mechanics

Conservation of energy  $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$

for a constant force

Hooke's Law  $F = kx$  (spring constant  $k$ )

## Simple harmonic motion

Displacement  $x = A \cos \omega t$

## Sound

Sound intensity level/dB  $= 10 \lg_{10} \frac{I}{I_0}$

## Waves

Two-source interference  $\lambda = \frac{ay}{d}$

## Thermal physics

Average kinetic energy of a molecule  $\frac{1}{2}m \langle c^2 \rangle = \frac{3}{2}kT$

Kinetic theory  $pV = \frac{1}{3}Nm \langle c^2 \rangle$

Thermal energy  $Q = mc\Delta\theta$

## Capacitors

Capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Capacitors in parallel

$$C = C_1 + C_2 + C_3$$

Time constant

$$\tau = RC$$

## Light

Lens formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Magnification

$$m = \frac{v}{u}$$

## Electricity

Terminal potential difference

$$V = E - Ir \quad (\text{e.m.f. } E; \text{ Internal Resistance } r)$$

Potential divider

$$V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$$

## Particles and photons

Radioactive decay

$$A = \lambda N$$

$$A = A_0 e^{-\lambda t}$$

Half-life

$$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

de Broglie equation

$$\lambda = \frac{h}{p}$$

## The nucleus

Nuclear radius

$$r = r_0 A^{\frac{1}{3}}$$

