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General Certificate of Education
2016

Physics

Assessment Unit A2 2
assessing
Fields and their Applications

MV18

[AY221]
THURSDAY 9 JUNE, AFTERNOON

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.
You must answer the questions in the spaces provided.
Complete in blue or black ink only.
Answer **all nine** questions.

Information for Candidates

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **7(b)**.
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.

1 A satellite, of mass **m**, moves in a circular orbit of radius **d** around a planet of mass **M**, as illustrated in **Fig. 1.1**. The periodic time of the orbit is **T**.
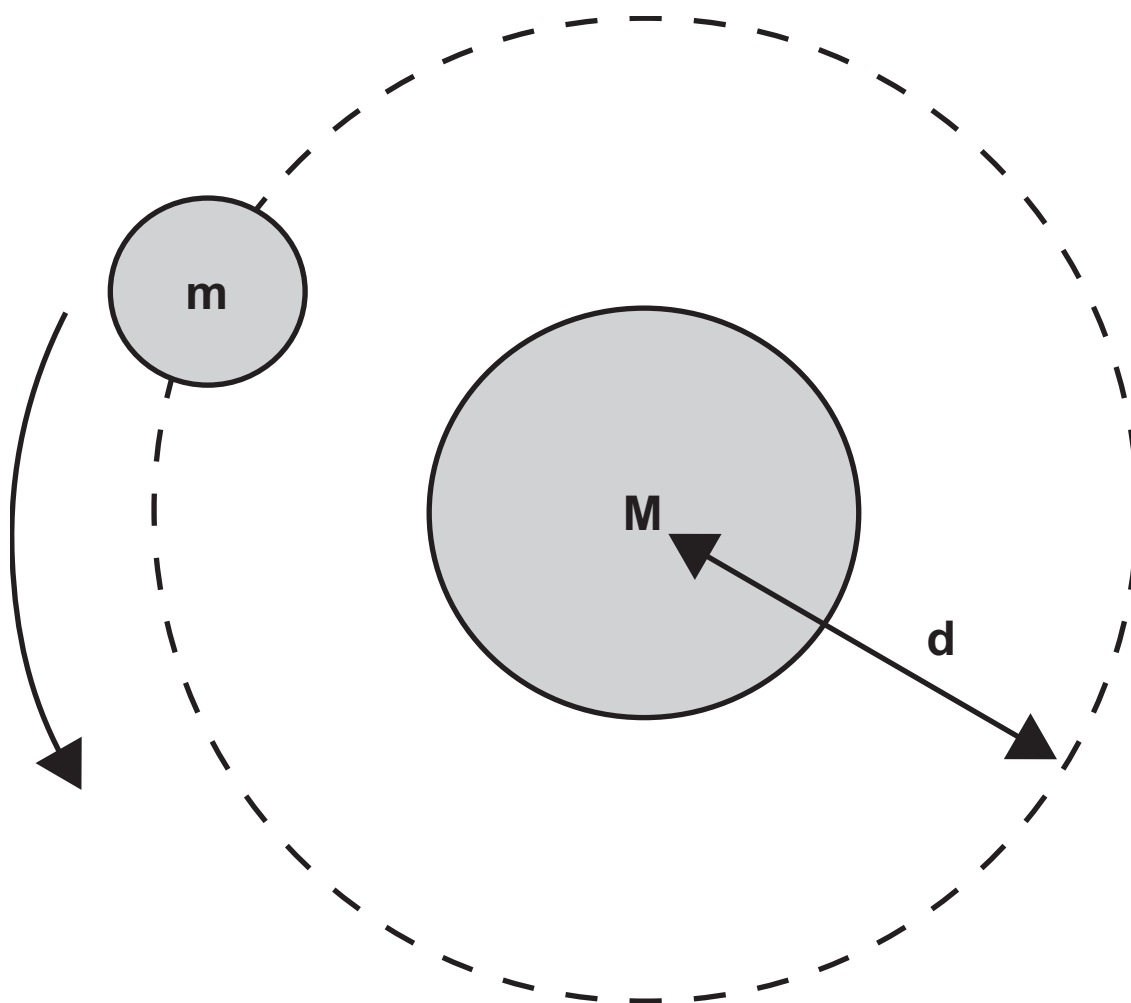

Fig. 1.1

(a) (i) State Newton's law of universal gravitation in words. [3 marks]

_____

_____

_____

(ii) Use Newton's law of universal gravitation to show that the constant of proportionality in Kepler's 3rd law $(T^2 \propto d^3)$ is $\frac{4\pi^2}{GM}$.   [3 marks]

(b) Rhea is the second largest satellite of Saturn.
Table 1.1 provides data on Saturn and Rhea.

Table 1.1

	Saturn	Rhea
Mass/kg	5.68×10^{26}	2.31×10^{21}
Radius/km	5.82×10^{4}	7.64×10^{2}

(i) Calculate the orbital period of Rhea, in days, given that it orbits Saturn with their centres of mass at an average distance of 5.27×10^{5} km.   [3 marks]

Orbital period = _____ days

(ii) Determine the gravitational field strength, **g**, on the surface of Rhea.   [3 marks]

$g =$ _____ N kg^{-1}

2 **(a)** Determine the electric field strength in a vacuum 5.0 cm from a +40 μC point charge.   [3 marks]

Field strength = _____ N C^{-1}

(b) A –60 μC point charge is positioned 5.0 cm from the +40 μC point charge. Determine the magnitude and direction of the force on the –60 μC charge.   [3 marks]

Force = _____ N

Direction = _____

3 **Fig. 3.1** shows the variation in the voltage across a capacitor with time as the capacitor discharges through a fixed resistance. The capacitor is fully charged at time = 0 seconds.
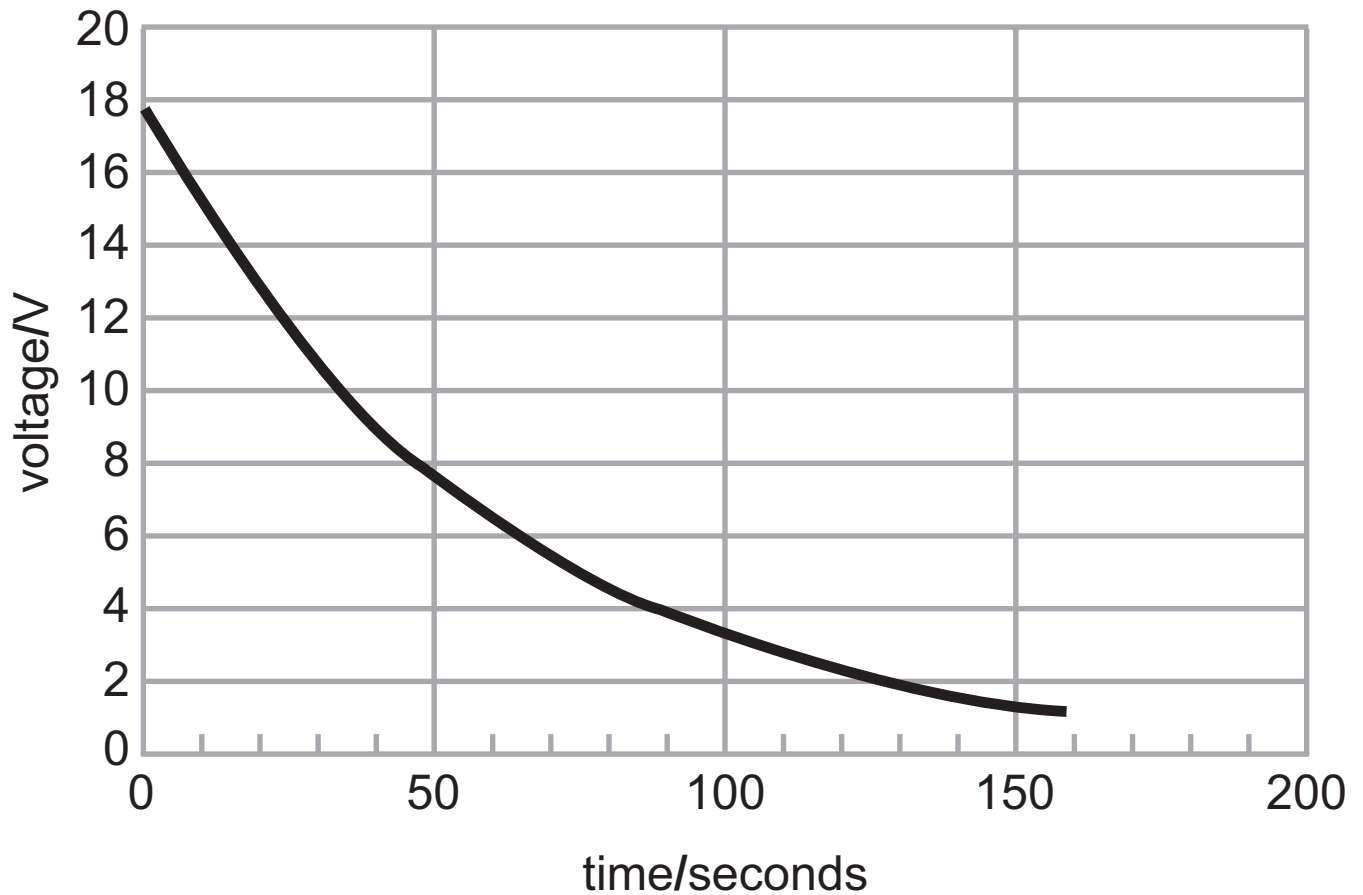

Fig. 3.1

(a) (i) Draw a circuit diagram to show how the capacitor may be charged quickly and discharged slowly.
[3 marks]

(ii) Using your circuit in **(i)**, describe a procedure that would enable someone to record the data required to plot the graph in **Fig. 3.1**.   [2 marks]

_____

_____

_____

_____

(b) (i) Deduce the time constant for the capacitor–resistor circuit from **Fig. 3.1**. [2 marks]

Time constant = _____ s

(ii) If the fixed resistor has a value of 123 kΩ and the capacitor is made up of **three** equal valued capacitors in series, determine the capacitance of each capacitor. [2 marks]

Capacitance = _____ F

4 Wedding corsages, lapel badges, photographs etc. may be secured in position using thin permanent magnets.

Table 4.1 provides manufacturer's information on how the magnetic flux density and magnet strength vary with distance from a magnet. The data is for a neodymium disc magnet of diameter 10 mm and thickness 1 mm.

Table 4.1

Distance/mm	0	0.1	1	10	100
Magnetic flux density/mT	129	128	115	10	0
Pull force/N	5.7	5.6	4.5	0.0	0.0

(a) Determine the magnetic flux at the face of a neodymium disc magnet of diameter 10 mm and thickness 1 mm.
[3 marks]

Magnetic flux = _____ Wb

(b) When a copper rod is placed 1 cm from the circular pole of the neodymium disc magnet only 1.3 cm of the length of the rod is within the magnetic field, see **Fig. 4.1**.
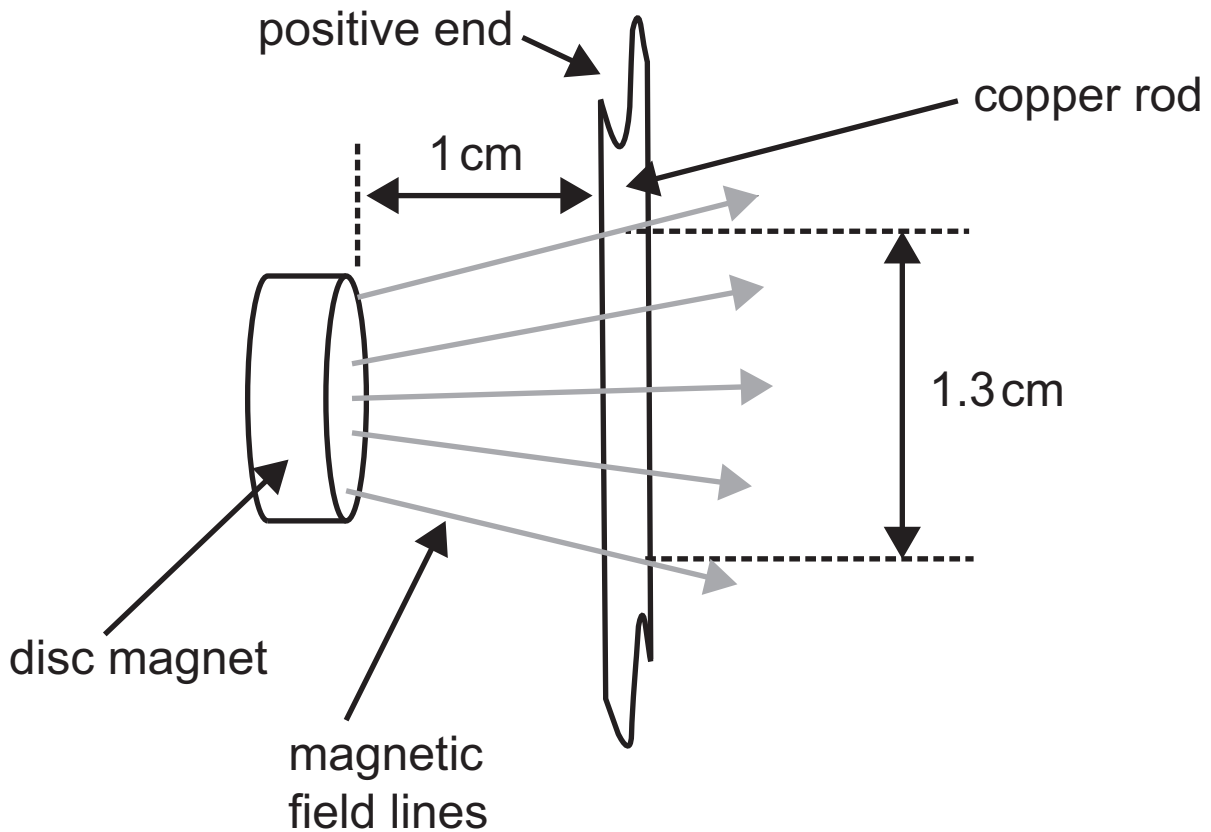

Fig. 4.1

(i) Use the information in both **Table 4.1** and **Fig. 4.1** to calculate the force experienced by the copper rod when a potential difference of 15 V is momentarily applied between its ends. The rod has a resistance of $2.4 \times 10^{-4}\,\Omega$. [3 marks]

Force = _____ N

(ii) In what direction will the force experienced by the copper rod act if the top of the copper rod was connected to the positive terminal of the 15 V supply? See **Fig. 4.1**. Explain your answer. [3 marks]

_____

_____

_____

5 Electromagnetic tethers are a method by which electricity can be generated in space. Essentially a satellite or spacecraft allows a long conducting wire, the tether, to extend from it as it orbits. The tether tends to hang in the vertical position and, as the satellite orbits, sweeps through an effective area of the magnetic field.

(a) Calculate the electromotive force (e.m.f.) induced across the ends of a 25.0 km long tether orbiting with a velocity 8.21×10^3 m s^{-1} where the horizontal component of the Earth's magnetic field is 4.01×10^{-6} T.   [3 marks]

e.m.f. = _____ V

(b) A certain mobile phone charger steps down the mains voltage from 230 V using a transformer which has a primary coil with 1104 turns and a secondary coil with 24 turns.

(i) Assuming the transformer is 100**%** efficient, calculate the output voltage across the secondary coil.
[2 marks]

Voltage = _____ V

(ii) Transformers operate with a high efficiency but there is still some energy loss. For this mobile phone charger the voltage across the secondary coil is actually 4.6 V and the current transformed from 0.026 A to 1.1 A. What is the efficiency of the transformer?   [2 marks]

Efficiency = _____

6 **Fig. 6.1** is a simplified diagram of the inside of a cathode ray oscilloscope (CRO). The dashed black line represents the electron beam.
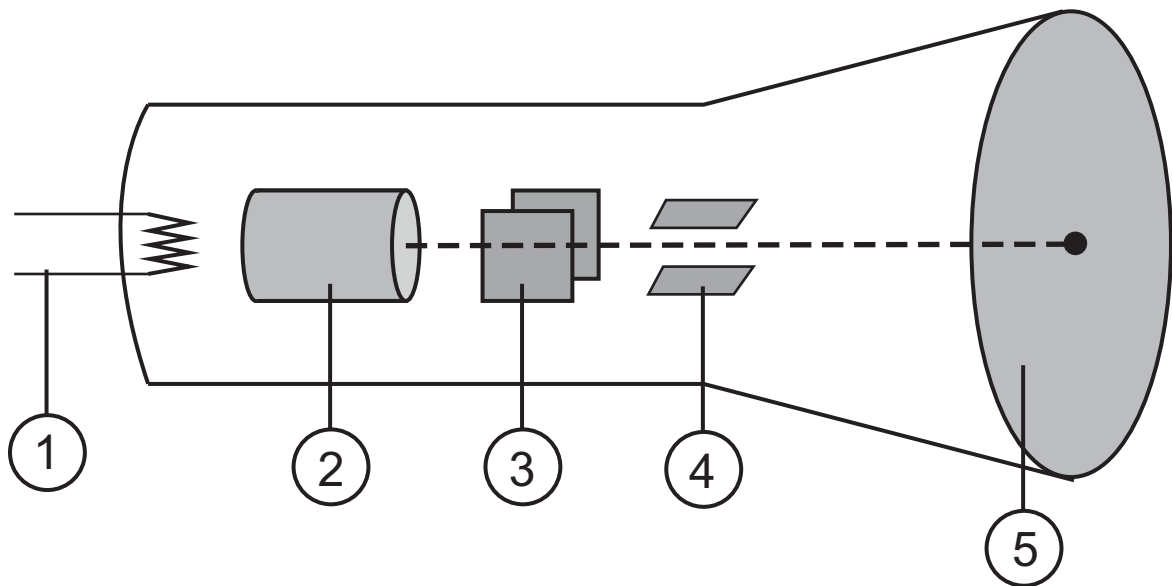

Fig. 6.1

(a) (i) Complete **Table 6.1** by naming each of the components identified in **Fig. 6.1**.   [2 marks]

Table 6.1

Components	Name
1	
2	
3	
4	
5	

(ii) Explain how the CRO can be used as a measuring instrument for voltage.   [2 marks]

_____

_____

_____

_____

_____

(b) In a CRO the moving electrons are deflected by electric fields. Consider the situation illustrated in **Fig. 6.2** where an electron enters a uniform electric field horizontally at the mid-point between two parallel plates, 80 mm apart, with a velocity of 5.6×10^7 m s^{-1}. The top plate is at a potential of +2.5 kV relative to the bottom plate.

120 mm

electron
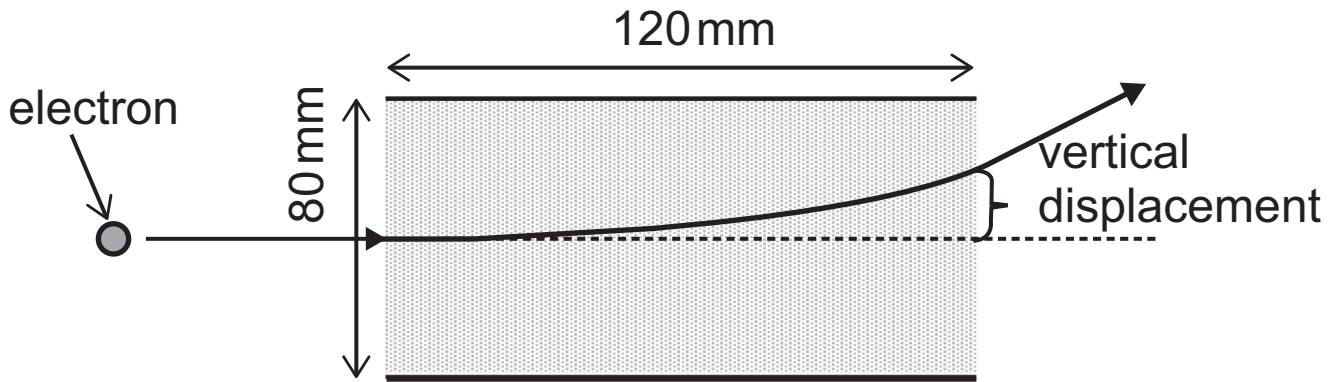
80 mm

vertical displacement

Fig. 6.2

Calculate the vertical displacement (see **Fig. 6.2**) of an electron at the end of the plates.   [5 marks]

Vertical displacement = _____ m

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

7 The concept of antimatter first arose through the theoretical work of Paul Dirac on the energy states of electrons. To explain a mathematical result in his theory he introduced the anti-electron (positron).

(a) Compare the electron and positron by completing **Table 7.1**. [2 marks]

Table 7.1

Particle	Mass/u	Charge/C	Lepton number	Baryon number
Electron				
Positron				

Positron emission tomography (PET) scanning is a relatively common medical procedure. Many hospitals have a **cyclotron** particle accelerator to accelerate protons, which are fired into an atomic nucleus to create isotopes, which decay by emitting a positron.

(b) Describe the basic operating principles of a cyclotron.
[5 marks]

_____

_____

_____

_____

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Quality of written communication   [2 marks]

(c) (i) The isotopes produced by the cyclotron are ingested by the patient. The positrons emitted during the scan combine with electrons to produce pairs of gamma photons from which the image can be produced. Explain why gamma photons are produced and why always in pairs.   [2 marks]

_____

_____

_____

(ii) Calculate the energy of a gamma photon produced by the annihilation of an electron and positron. Give the value in keV.   [4 marks]

Energy = _____ keV

8 Beta-minus, β–, decay is described in **Equation 8.1**.

$$n \rightarrow p + e + \bar{\nu}_e \qquad \textbf{Equation 8.1}$$

(a) (i) Show that the β– decay reaction conserves charge.
[1 mark]

(ii) Show that the β– decay reaction conserves lepton number.   [1 mark]

(b) Some of the particles involved in the β− decay reaction are classified as leptons. To what group of particles do the non-leptons belong? State the difference between the lepton group and the other group.   [2 marks]

_____

_____

_____

(c) (i) Name the force responsible for the β− decay reaction and identify the gauge boson that is emitted in this process.   [2 marks]

_____

_____

(ii) The gauge boson in **(c)(i)** has a half-life of approximately 3×10^{-25} seconds. What happens to it when it decays?   [1 mark]

_____

_____

9 Some features of a petrol engine lawnmower are identified in **Fig. 9.1**.

speed
control

tensioned
pull string

petrol
combustion
engine

Fig. 9.1

(a) The vibration of the engine causes the tensioned pull string to vibrate. A standing wave is set up on the tensioned pull string (see **Fig. 9.1**) when the speed control is in a specific position. **Fig. 9.2** shows the standing wave produced.
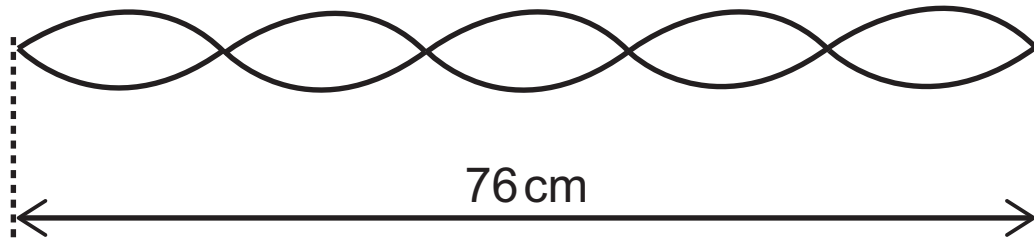

Fig. 9.2

(i) Show that the engine is rotating at 3.6×10^3 revolutions per minute (RPM) when the standing wave shown in **Fig. 9.2** is produced and the speed of the wave on the tensioned pull string is $18.3\,\text{m s}^{-1}$. Assume the engine RPM numerically equals the frequency of vibration of the progressive waves that set up the standing wave on the tensioned pull string.   [3 marks]

(ii) In the engine the piston moves in simple harmonic motion within its cylinder. Estimate the maximum force acting on a piston of mass 120 g that moves a maximum distance of 86 mm from its equilibrium position when the engine rotates at 3600 RPM. See **Fig. 9.3**.   [4 marks]
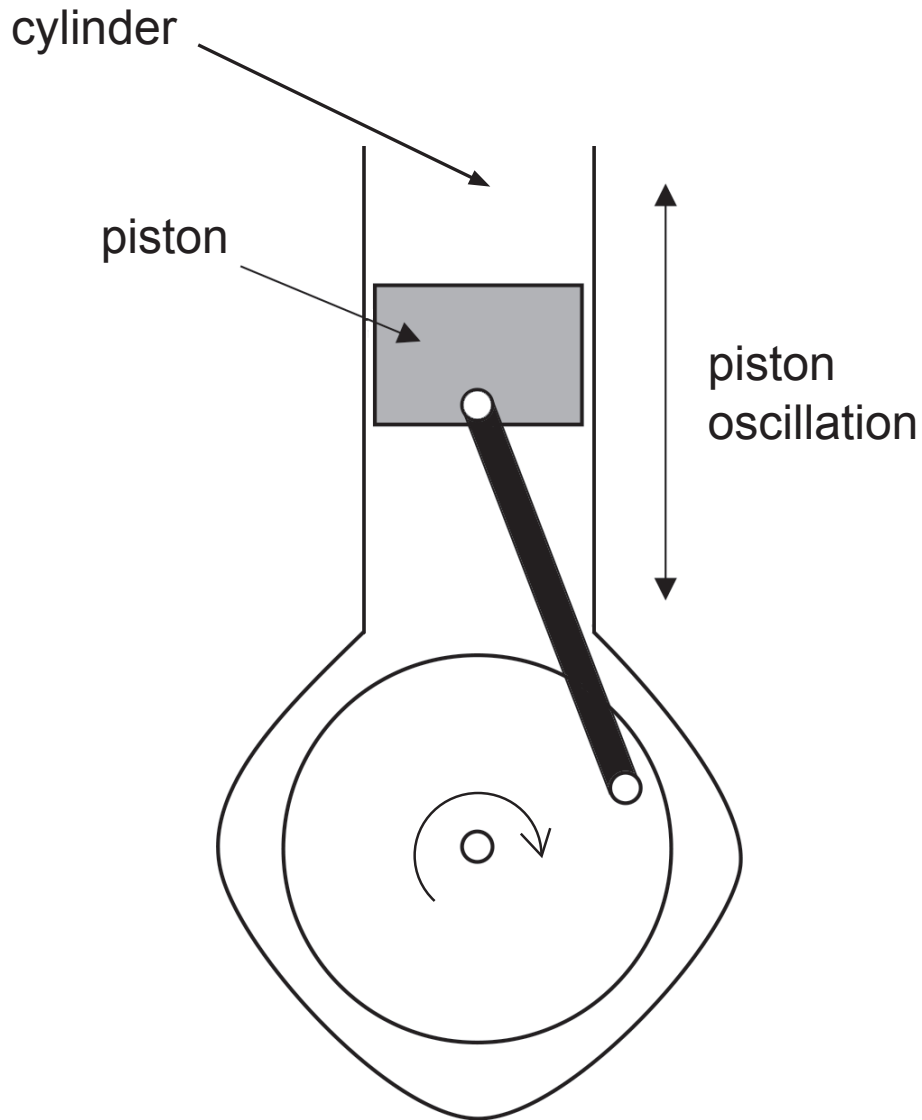
cylinder

piston

piston oscillation

Fig. 9.3

Force = _____ N

(b) The spark produced by a spark plug is used to cause the fuel-air mixture in the lawnmower engine to combust. This produces the force that moves the piston. A typical spark plug (shown in **Fig. 9.4**) produces a current of 13.6 mA through a 0.8 mm spark gap and converts 0.03 J of energy in a 1.20 ms time duration.

spark gap

Fig. 9.4

(i) Calculate the potential difference (p.d.) across the spark gap.   [3 marks]

p.d. = _____ V

(ii) How many electrons will reach the positive terminal of the spark plug in the 1.20 ms that the spark lasts?
[3 marks]

Number of electrons = _____

(c) A petrol lawnmower emits a sound that has an intensity level of 92 dB at a distance of 0.10 m from the engine. Calculate the sound intensity level experienced by someone using the lawnmower if their ears are 2.0 m from the engine where the intensity is $\frac{1}{400}$ the size it was 0.1 m from the engine.   [3 marks]

The threshold of hearing is 1×10^{-12} W m^{-2}.

Sound intensity level = _____ dB

THIS IS THE END OF THE QUESTION PAPER

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GCE (AS) Physics

Data and Formulae Sheet

Values of constants

speed of light in a vacuum $c = 3.00 \times 10^8$ m s^{-1}

elementary charge $e = 1.60 \times 10^{-19}$ C

the Planck constant $h = 6.63 \times 10^{-34}$ J s

mass of electron $m_e = 9.11 \times 10^{-31}$ kg

mass of proton $m_p = 1.67 \times 10^{-27}$ kg

acceleration of free fall
on the Earth's surface $g = 9.81$ m s^{-2}

electron volt $1 \text{ eV} = 1.60 \times 10^{-19}$ J

Useful formulae

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)

Sound

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

Waves

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

Light

Lens formula $\qquad\qquad\qquad \dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

Magnification $\qquad\qquad\quad\ m = \dfrac{v}{u}$

Electricity

Terminal potential difference $\quad V = E - Ir$ (e.m.f. E; Internal Resistance r)

Potential divider $\qquad\qquad V_{out} = \dfrac{R_1 V_{in}}{R_1 + R_2}$

Particles and photons

de Broglie equation $\qquad\qquad \lambda = \dfrac{h}{p}$