

A-level PHYSICS

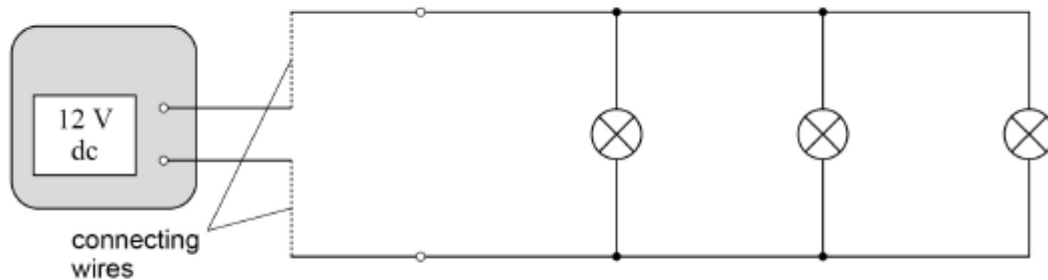
7408 – Waves, Electricity, Fields and their consequences

Total number of marks: 47

0 5

Figure 9 shows some of the apparatus used in a demonstration of electrical power transmission using a dc power supply.

Figure 9



A power supply of emf 12 V and negligible internal resistance is connected to three identical 12 V, 1.5 W lamps in parallel.

0 5 . 1

Show that the resistance of one of the lamps when it is operating at 12 V is about 100 Ω .

$$P = \frac{V^2}{R} \quad 1.5 = \frac{12^2}{R} \quad R = \frac{144}{1.5} = 96 \approx 100 \Omega \quad [1 \text{ mark}]$$

0 5 . 2

Initially the power supply is connected to the lamps using two short copper wires of negligible resistance.

Calculate the current in the power supply.

[2 marks]

$$\frac{1}{R_{\text{Total}}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{1}{16} + \frac{1}{16} + \frac{1}{16}$$

$$= \frac{1}{32}$$

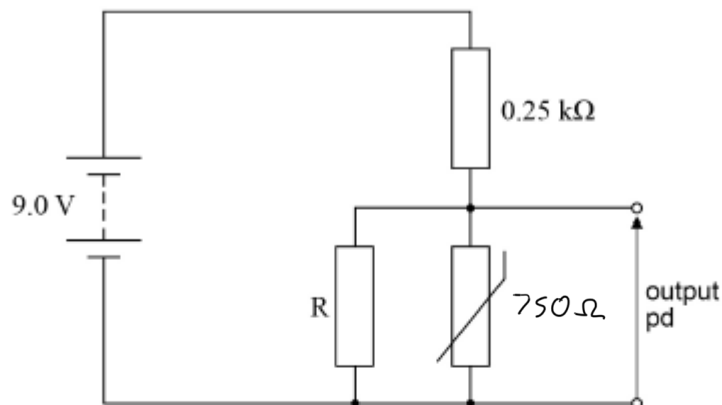
$$R_{\text{Total}} = 32 \quad I = V/R = 12/32 = 3/8$$

current = 0.375 A

0 4

Figure 7 shows a circuit designed by a student to monitor temperature changes.

Figure 7



The supply has negligible internal resistance and the thermistor has a resistance of 750Ω at room temperature. The student wants the output potential difference (pd) at room temperature to be 5.0 V

0 4 . 1

The $0.25 \text{ k}\Omega$ resistor is made of 50 turns of wire that is wound around a non-conducting cylinder of diameter 8.0 mm

$$\text{Resistivity of the wire} = 4.2 \times 10^{-7} \Omega \text{ m}$$

Determine the area of cross-section of the wire that has been used for the resistor.

[3 marks]

$$R = \frac{\rho L}{A} \quad L = 50 \times 2\pi r$$

$$A = \frac{\rho L}{R} \quad L = 50 \times 2\pi \left(\frac{8 \times 10^{-3}}{2}\right)$$

$$L = \frac{2}{5} \pi$$

$$A = \frac{4.2 \times 10^{-7} \times \frac{2}{5} \pi}{0.25 \times 10^3}$$

$$A = 2.1 \times 10^{-9} \text{ m}^2$$

$$\text{area of cross-section} = \underline{2.1 \times 10^{-9}} \text{ m}^2$$

0 4 . 2

The student selects a resistor rated at 0.36 W for the $0.25 \text{ k}\Omega$ resistor in Figure 7.

Determine whether this resistor is suitable.

[2 marks]

$$P.d. \text{ across resistor} \rightarrow 9 - 5 = 4 \text{ V}$$

$$P = \frac{V^2}{R} \rightarrow P = \frac{4^2}{0.25 \times 10^3} = 0.064 \text{ W}$$

$$0.064 < 0.36 \quad \therefore \underline{\text{is suitable}}$$

04.3 Determine the value of R that the student should select.

Give your answer to an appropriate number of significant figures.

[5 marks]

Current leaving supply $\rightarrow I = P/V = \frac{0.064}{4}$

$I = 0.016 \text{ A}$

P.d. across R and thermistor $\rightarrow 5 \text{ V}$

Resistance of R and thermistor $\rightarrow R_T = \frac{V}{I} = \frac{5}{0.016} = 312.5 \Omega$

$\frac{1}{312.5} = \frac{1}{R} + \frac{1}{750}$

$R = \left(\frac{1}{312.5} - \frac{1}{750} \right)^{-1} = 540 \Omega \text{ (2 s.f.)}$

value of R = 540 Ω

03.1 Explain how a stationary wave is produced when a stretched string is plucked.

The wave travels down the string, reflects off the end and inverts, forming a series of nodes & antinodes where destructive & constructive interference occurs. [3 marks]

03.2 The vibrating length of one of the strings of a violin is 0.33 m

When the tension in the string is 25 N, the string vibrates with a first-harmonic frequency of 370 Hz

Show that the mass of a 1.0 m length of the string is about $4 \times 10^{-4} \text{ kg}$

frequency $\rightarrow F = \frac{\sqrt{\frac{T}{\mu}}}{2L}$ $(2FL)^2 = \frac{T}{\mu}$ $m = \frac{TL}{(2FL)^2} = \frac{25 \times 0.33}{(2 \times 370 \times 0.33)^2} = 1.38 \times 10^{-4} \text{ kg}$ [2 marks]
 \rightarrow mass of 0.33 m
 mass of 1m = $1.38 \times 10^{-4} \times 3 = 4.15 \times 10^{-4} \approx 4 \times 10^{-4} \text{ kg}$

03.3 Determine the speed at which waves travel along the string in question 03.2 when it vibrates with a first-harmonic frequency of 370 Hz

[1 mark]

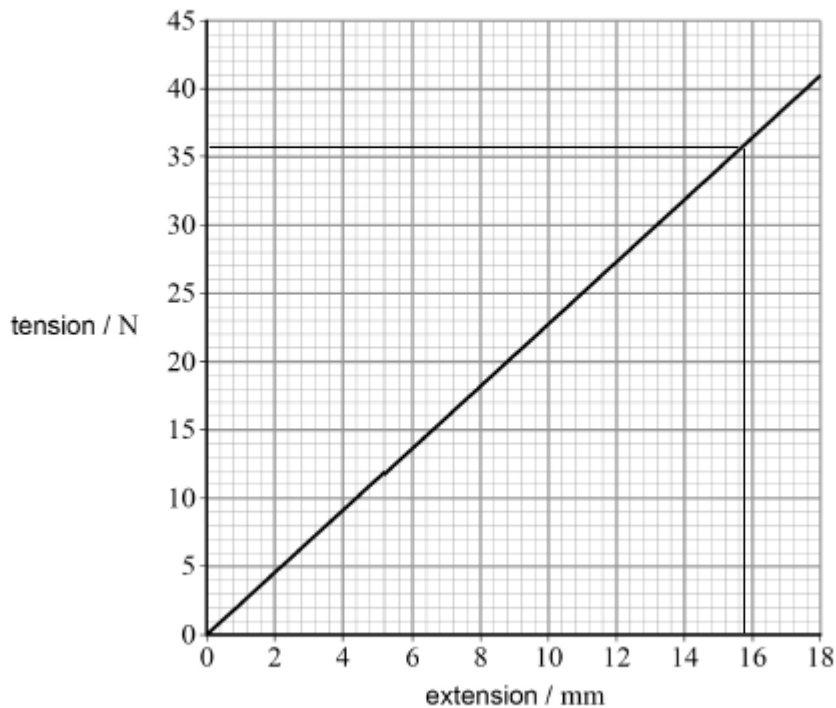
$V = F\lambda$ $\lambda = 2 \times 0.33$
 $= 0.66$

$V = 370 \times 0.66 = 244.2 \approx 240 \text{ m s}^{-1}$

speed of waves = 240 m s^{-1}

03.4 Figure 6 shows how the tension in the string in question 03.2 varies with the extension of the string.

Figure 6



The string with its initial tension of 25 N is vibrating at a frequency of 370 Hz
The diameter of the circular peg is 7.02 mm

Determine the higher frequency that is produced when the string is stretched by rotating the tuning peg through an angle of 75°

Assume that there is no change in the diameter of the string.

[4 marks]

$$| \text{rotation of peg} = 22 \text{ mm} = 7.02 \pi$$

$$22 \times \frac{75}{360} = 4.6 \text{ mm}$$

$$\text{Total extension} = 11 + 4.6 = 15.6 \text{ mm}$$

$$T = 36 \text{ N}$$

$$L = 0.33 + 4.6 \times 10^{-3} = 0.3346$$

$$f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$

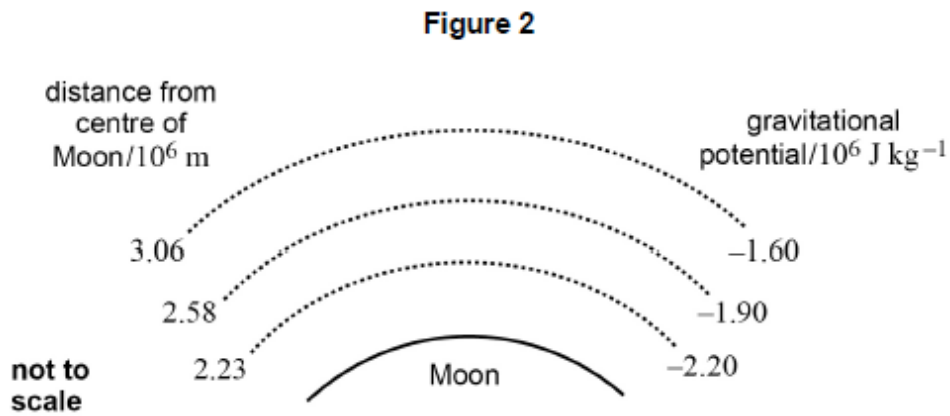
$$f = \frac{1}{2(0.3346)} \sqrt{\frac{36}{4.15 \times 10^{-4}}}$$

$$f = 440 \text{ Hz}$$

frequency = 440 Hz

0 3 . 1 Define gravitational potential at a point.
The work done to bring a unit mass from infinity to that point. [1 mark]

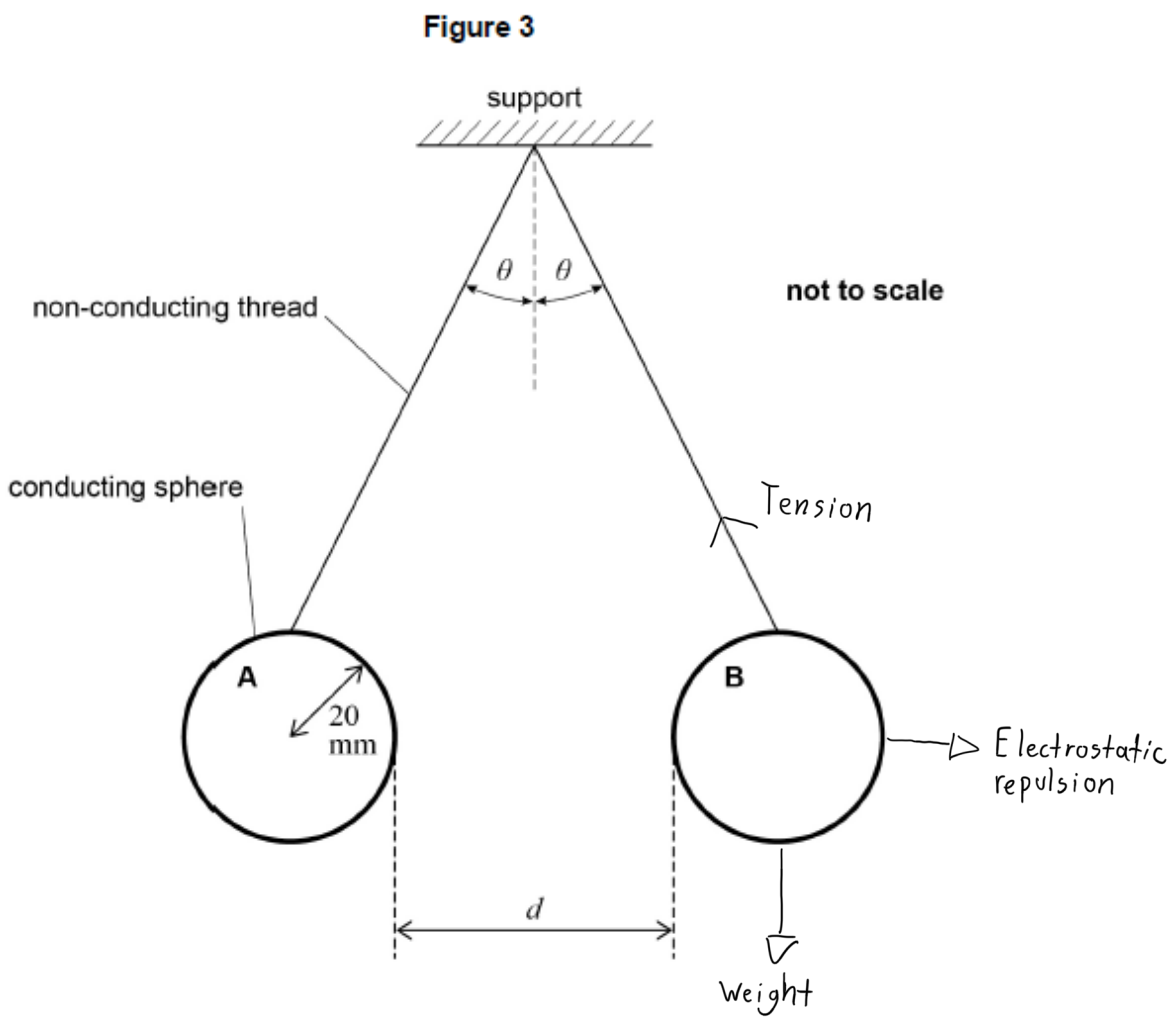
0 3 . 2 Figure 2 shows the positions of equipotential surfaces at different distances from the centre of the Moon.



Explain how the equipotential surfaces in **Figure 2** show that the gravitational field is **not** uniform.

Some of the equipotential lines are closer together than others. [1 mark]

Figure 3 shows an arrangement used to investigate the repulsive forces between two identical charged conducting spheres. The spheres are suspended by non-conducting thread.



Each sphere has a mass of 3.2×10^{-3} kg and a radius of 20 mm. The distance d is 40 mm.

The capacitance of a sphere of radius r is $4\pi\epsilon_0 r$.

Each sphere is charged by connecting it briefly to the positive terminal of a high-voltage supply, the other terminal of which is at 0 V. After this has been done the charge on each sphere is 52 nC.

0 4 . 1 Calculate the potential of one of the spheres.

[3 marks]

$$V = \frac{kQ}{r} = \frac{Q}{4\pi\epsilon_0 r}$$

$$Q = 52 \times 10^{-9} \text{ C}$$

$$V = \frac{52 \times 10^{-9}}{4\pi\epsilon_0 (20 \times 10^{-3})} = 23378.7 \text{ V}$$
$$= 2.3 \times 10^4$$

potential = 2.3 × 10⁴ V

0 4 . 2 The charged spheres in **Figure 3** are at equilibrium.

Draw labelled arrows on **Figure 3** to show the forces on sphere **B**.

[2 marks]

0 4 . 3 Suggest a solution to **one** problem involved in the measurement of d in **Figure 3**.

place the spheres between 2 insulative plates to keep them apart along the same axis. [2 marks]

0 4 . 4 Show that the magnitude of the electrostatic force on each sphere is about $4 \times 10^{-3} \text{ N}$.

[3 marks]

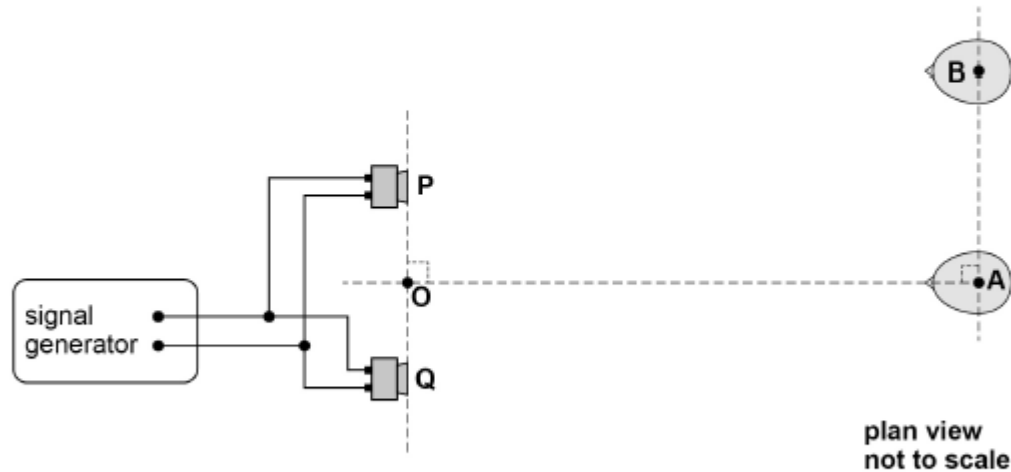
$$F = \frac{Qq}{4\pi\epsilon_0 r^2} = \frac{(52 \times 10^{-9})^2}{4\pi\epsilon_0 (80 \times 10^{-3})^2} = 3.8 \times 10^{-3} \approx 4 \times 10^{-3} \text{ N}$$

0 3

A student investigates the interference of sound waves using two loudspeakers, P and Q, connected to a signal generator (oscillator). Each loudspeaker acts as a point source of sound.

Figure 3 shows the arrangement.

Figure 3



Point O is the midpoint between P and Q.

0 3 . 1

Explain why the two loudspeakers are coherent sources of sound waves.

They produce two sets of waves with the same frequency and constant phase difference.

[2 marks]

0 3 . 2

The student faces the two loudspeakers at point A. Point A is at equal distances from P and Q.

He then moves to point B, at right angles to the line OA, still facing the two loudspeakers.

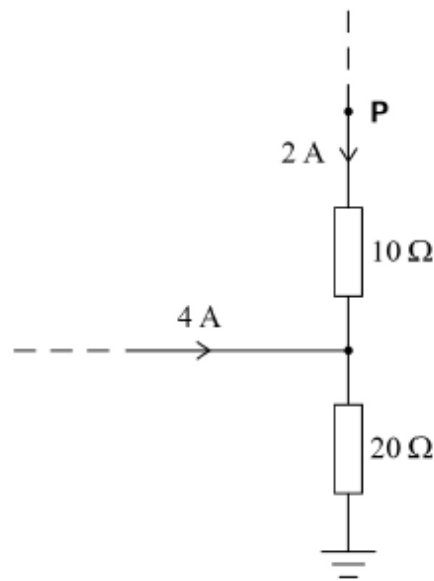
As his head moves from A to B the amplitude of the sound wave he hears decreases and then increases. The amplitude starts to decrease again as he moves beyond B.

Explain why the variation in amplitude occurs as he moves from A to B.

[3 marks]

- Coherent sound waves propagate outwards from the speakers, and interfere and superpose with each other.
- This forms areas of constructive and destructive interference.
- A & B are areas of constructive interference and the point in between them is a point of destructive interference.

2 3 The diagram shows part of a circuit and the currents in the circuit.



$$V = IR$$
$$V = 2 \times 10 = 20V$$

$$V = IR$$
$$V = 6 \times 20 = 120V$$

$$120V + 20V = 140V$$

What is the potential difference between point **P** and earth?

[1 mark]

- A 60 V
- B 100 V
- C 120 V
- D 140 V

1 8 Stationary waves are set up on a rope of length 1.0 m fixed at both ends.

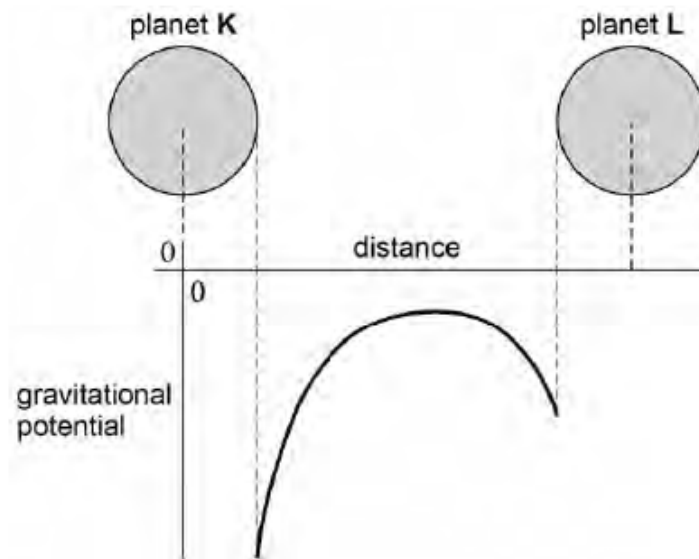
Which statement is **not** correct?

[1 mark]

- A The first harmonic has a wavelength of 2.0 m.
- B The midpoint of the rope is always stationary for even-numbered harmonics.
- C A harmonic of wavelength 0.4 m can be set up on the rope.
- D There are five nodes on the rope for the fifth harmonic.

1 4

The graph shows how the gravitational potential varies with distance between two planets, K and L, that have the same radius.

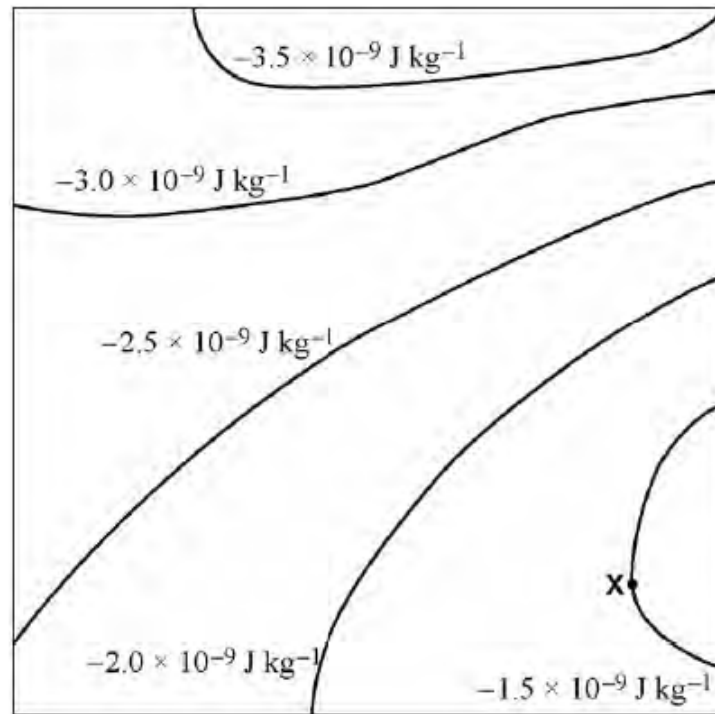


Which statement is correct?

[1 mark]

- A The mass of L is greater than the mass of K.
- B The gravitational field strength at the surface of L is greater than that at the surface of K.
- C The escape velocity from planet L is greater than that from planet K.
- D More work must be done to move a mass of 1 kg from the surface of K to a distant point, than 1 kg from the surface of L.

1 5 The diagram shows equipotential lines near a group of asteroids.



Which arrow shows the direction of the gravitational field at X?

[1 mark]

- A \uparrow
- B \downarrow
- C \leftarrow
- D \rightarrow

1 9 An uncharged capacitor is connected to a power supply which supplies a constant current of $10 \mu\text{A}$.

After 100 ms , the potential difference across the capacitor is 5.0 kV .

What is the capacitance of the capacitor?

[1 mark]

- A $2.0 \times 10^{-10} \text{ F}$
- B $4.0 \times 10^{-10} \text{ F}$
- C $2.5 \times 10^9 \text{ F}$
- D $5.0 \times 10^9 \text{ F}$

$$I = 10 \times 10^{-6}$$

$$t = 100 \times 10^{-3}$$

$$V = 5 \times 10^3$$

$$Q = CV$$

$$Q = It = 10 \times 10^{-6} \times 100 \times 10^{-3} = 1 \times 10^{-6} \text{ C}$$

$$1 \times 10^{-6} = 5 \times 10^3 C$$

$$C = 2 \times 10^{-10}$$

2 0

When a parallel-plate capacitor is connected across a battery, the energy stored in the capacitor is W .

The battery remains connected as the distance between the capacitor plates is halved.

What is the energy now stored in the capacitor?

[1 mark]

A $0.5W$

B W

C $2W$

D $4W$

2 0

A $1.0 \mu\text{F}$ capacitor is charged for 20 s using a constant current of $10 \mu\text{A}$.

What is the energy transferred to the capacitor?

[1 mark]

A $5.0 \times 10^{-3} \text{ J}$

B $1.0 \times 10^{-2} \text{ J}$

C $2.0 \times 10^{-2} \text{ J}$

D $4.0 \times 10^{-2} \text{ J}$

$$C = 1 \times 10^{-6}$$

$$I = 10 \times 10^{-6}$$

$$t = 20 \text{ s}$$

$$Q = It = 10 \times 10^{-6} \times 20$$

$$Q = 2 \times 10^{-4}$$

$$W = \frac{1}{2} \frac{Q^2}{C}$$

$$= \frac{1}{2} \frac{(2 \times 10^{-4})^2}{1 \times 10^{-6}}$$

$$= 0.02$$

$$= 2 \times 10^{-2} \text{ J}$$