Selected Questions – Set 2

1.

(a) Fig. 4.1 shows a section of a uniform string under tension at one instant of time. A progressive wave of wavelength 80 cm is moving along the string from left to right. At the instant shown, the displacement of the string is zero at the point opposite the zero mark on the scale beneath the string.

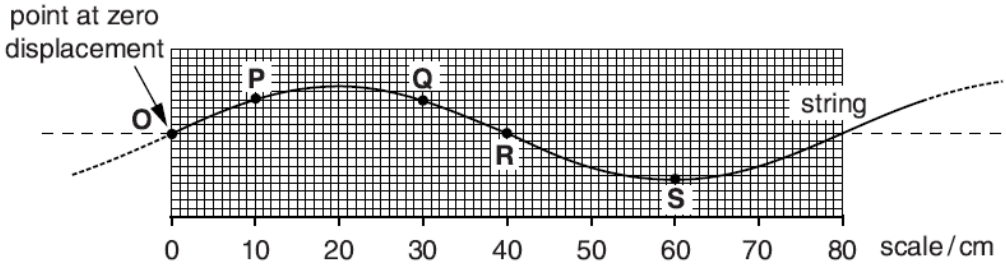

Fig. 4.1

Four points **P**, **Q**, **R** and **S** at 10, 30, 40 and 60 cm respectively, are marked on the string. The oscillatory motion of each point can be described in terms of amplitude, frequency and phase difference from **O**.

(i) State the meaning of each of the terms

1 *amplitude*

....

....

2 *frequency*

....

....

3 *phase difference*.

....

....
[3]

(ii) Describe using these three terms how the motion of points **P**, **Q**, **R** and **S**

1 is similar,

....

....

2 is different.

....

....
[2]

(b) Fig. 4.2 shows the same section of string now held under tension between a clamp and a pulley, 80 cm apart. A mechanical oscillator is attached to the string close to the clamped end. The frequency of the mechanical oscillator is varied until the stationary wave shown is set up between the clamp and the pulley. The same four points as in Fig. 4.1 are marked on the string.

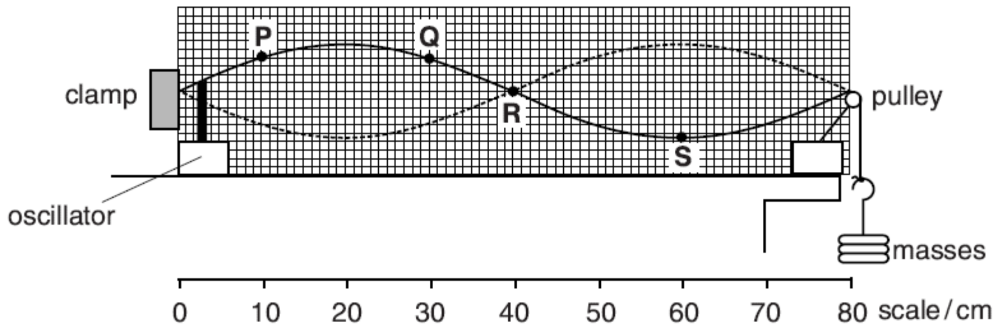

Fig. 4.2

(i) Describe how a stationary wave is different from a progressive wave.

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.... **[2]**

(ii) Explain how the stationary wave is formed on this string.

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....

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....

....

.... **[3]**

(iii) Describe, using the terms amplitude, frequency and phase difference, how the motions of the points **P**, **Q** and **S**

1 are similar,

....

....

2 are different.

....

....

[3]

(iv) In Fig. 4.2 the frequency of oscillation is 30 Hz. State, with a reason, the lowest frequency of oscillation of the string at which the motions of all of the points **P**, **Q**, **R** and **S** are

1 in phase,

....

....

2 all at rest.

....

....

[4]

2.

Fig. 5.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of frequency 10 GHz, of equal amplitude and in phase. A microwave detector is placed at **O** a distance of 4.0 m from **AB**.

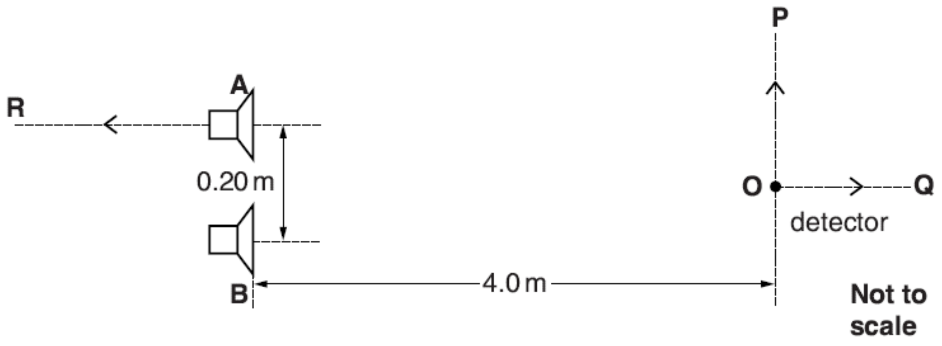

Fig. 5.1

(a) Interference of the waves from the two transmitters is detected only when the transmitters are coherent. Explain the meaning of

(i) *interference*

....

....

.... **[2]**

(ii) *coherent.*

....

.... **[1]**

(b) The length of the detector aerial is half a wavelength. Calculate the length of the aerial.

Show your working.

aerial length = ... m **[2]**

(c) (i) 1 Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OP**.

....

....

....

.... **[2]**

2 Calculate the distance between adjacent **maximum** and **minimum** signals.

distance = ... m **[2]**

(ii) Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OQ**.

....

....

....

.... **[2]**

(iii) Explain why the amplitude of the detected signal decreases to a minimum before increasing again as transmitter **A** is moved a small distance in the direction **AR** with the detector fixed at **O**. Calculate the distance **A** is moved to cause this minimum signal at **O**.

....

....

....

....

....

....

distance = ... m **[2]**

(d) State, with a reason, the effect on the intensity of the signal detected at **O** when each of the following changes is made.

(i) The amplitude of the waves emitted from **A** and **B** is doubled.

....

....

.... **[2]**

(ii) The detector **O** is rotated 90° about the axis through **OQ**.

....

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....

....

.... **[3]**

3.

In an experiment it is observed that when blue light is shone on a clean metal surface electrons are emitted, but with red light there is no electron emission.

(a) State the name of the effect observed in this experiment.

.... **[1]**

(b) Describe Einstein's theory to explain these observations.

In your answer you should include technical terms to explain how the physics of quantum behaviour is used to explain the observations.

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.... **[4]**

(c) The longest wavelength of light incident on the metal surface which causes electrons to be emitted is 480 nm.

(i) Show that the work function of the metal is about 4×10^{-19} J.

[3]

(ii) Calculate the maximum speed of an emitted electron when a photon of energy 5.2×10^{-19} J is incident on the metal surface.

speed = ... $m\,s^{-1}$ **[3]**

(d) **(i)** Describe briefly one piece of evidence for believing that electrons sometimes behave like waves.

....

....

....

.... **[2]**

(ii) Calculate the de Broglie wavelength of an electron moving at $500\,km\,s^{-1}$.

wavelength = ... m **[3]**

4.

This question is about the radioisotope americium-241 used in smoke detectors. Fig. 6.1 shows a cross-section through a simplified smoke detector mounted on the ceiling.

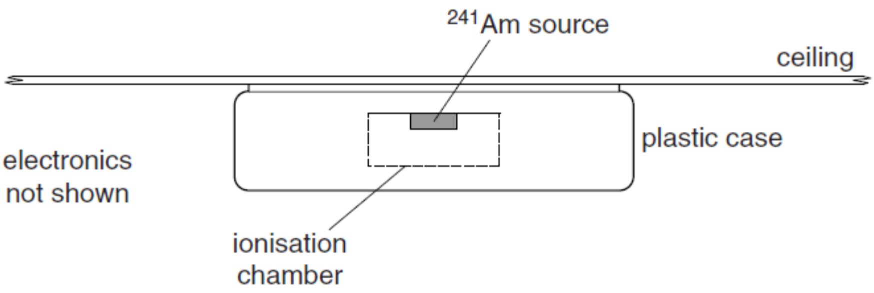

Fig. 6.1

The alpha particles emitted by the americium ionise the air inside the ionisation chamber maintaining a small current in a circuit including the ionisation chamber in series. When smoke enters the chamber the ions are absorbed and the current falls, causing the alarm to sound.

(a) Americium-241 occurs naturally from the decay of plutonium-241 by beta minus emission, or is made artificially by the bombardment of plutonium-240 inside a nuclear reactor. The nuclear equations for each of these processes are shown below with letters substituted for some of the symbols.

$$^{241}_{Z}\text{Pu} \rightarrow {}^{241}_{95}\text{Am} + \beta^-$$

$$^{240}_{Z}\text{Pu} + \text{X} \rightarrow {}^{241}_{95}\text{Am} + \beta^-$$

Write down

(i) the numerical value of the letter Z .... **[1]**

(ii) what Z represents .... **[1]**

(iii) the correct name of particle X. .... **[1]**

(b) A typical smoke detector contains 2.5×10^{-10} kg of americium-241.

(i) Show that the source contains about 6×10^{14} nuclei of americium-241.

[2]

(ii) The half-life of americium-241 is 480 years. Show that its decay constant is about $4.6 \times 10^{-11}\,s^{-1}$.

1 year = 3.15×10^{7} s

[1]

(iii) Calculate the activity of the americium-241 in the smoke detector. Give a suitable unit with your answer.

activity = ... unit .... **[3]**

(iv) Estimate the time it takes for the activity to fall by one percent.

time = ... s **[3]**

(c) Nuclei of americium-241 decay by alpha particle emission. Suggest

(i) why the americium is not a hazard when it is inside the detector

....

.... **[1]**

(ii) how a small speck of the source could be hazardous if it came out of the plastic case.

....

....

.... **[2]**

5.

A spark plug is the device in a petrol engine which ignites the fuel-air mixture, causing an explosion in the cylinder.

(a) A potential difference of 40 kV is needed across a gap of 0.60 mm to produce the spark which ignites the fuel vapour. Calculate the magnitude of the electric field strength in the spark gap just before the spark.

electric field strength = ... unit .... [3]

(b) The electrical supply in a motor car is 12 V. To achieve 40 kV, two coils are wound on the same iron core, shown schematically in Fig. 5.1. The secondary coil is in series with the spark gap. The primary coil is in series with the battery and a switch.

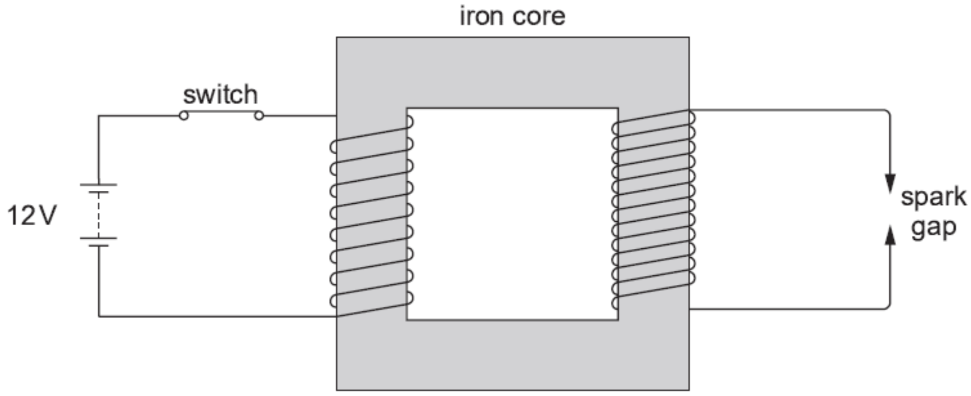

Fig. 5.1

(i) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) The magnetic flux through both coils is the same but the magnetic flux linkage is not. Explain why.

....

....

....

....[2]

(iii) Explain why a potential difference is produced across the spark gap as the switch is opened.

....

....[1]

(iv) Explain how each of the following factors influences the size of the potential difference across the spark gap:

1 the rate of collapse of the magnetic flux

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....

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....[2]

2 the ratio of the number of turns between the primary and secondary coils.

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....[2]

6.

Fig. 4.1 shows a football balanced above a metal bench on a length of plastic drain pipe. The surface of the ball is coated with a smooth layer of an electrically conducting paint. The pipe insulates the ball from the bench.

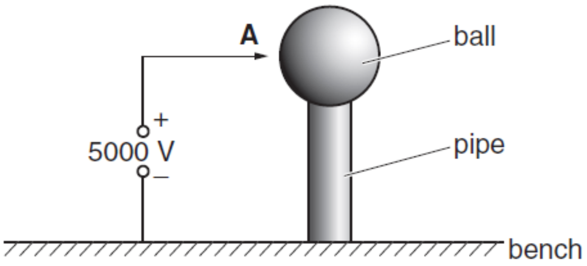

Fig. 4.1

(a) The ball is charged by touching it momentarily with a wire **A** connected to the positive terminal of a 5000 V power supply. The capacitance C of the ball is 1.2×10^{-11} F. Calculate the charge Q_o on the ball. Give a suitable unit for your answer.

Q_o = ……………unit ……..[3]

(b) The charge on the ball leaks slowly to the bench through the plastic pipe, which has a resistance R of $1.2 \times 10^{15}\ \Omega$.

(i) Show that the time constant for the ball to discharge through the pipe is about 1.5×10^4 s.

[1]

(ii) Show that the initial value of the leakage current is about 4×10^{-12} A.

[1]

(iii) Suppose that the ball continues to discharge at the constant rate calculated in **(ii)**. Show that the charge Q_o would leak away in a time equal to the time constant.

[2]

(iv) Using the equation for the charge Q at time t

$$Q = Q_o e^{-t/RC}$$

show that, in practice, the ball only loses about 2/3 of its charge in a time equal to one time constant.

[2]

(c) The ball is recharged to 5000 V by touching it momentarily with wire **A**. The ball is now connected in parallel via wire **B** to an uncharged capacitor of capacitance 1.2×10^{-8} F and a voltmeter as shown in Fig. 4.2.

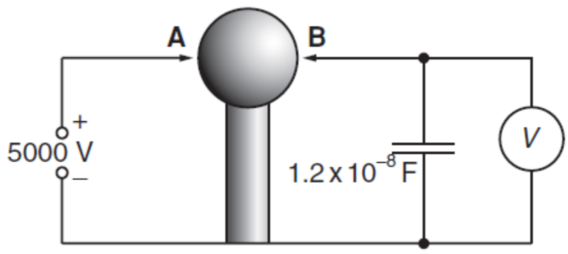

Fig. 4.2

(i) The ball and the uncharged capacitor act as two capacitors in parallel. The total charge Q_o is shared instantly between the two capacitors. Explain why the charge left on the ball is $Q_o/1000$.

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....

....[3]

(ii) Hence or otherwise calculate the initial reading V on the voltmeter.

V = ... V [2]