Selected Questions – Set 3

1.

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.

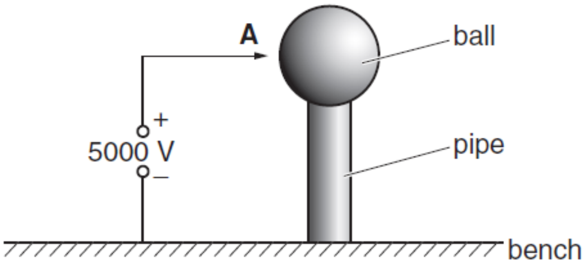

Fig. 4.1

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

Q_o = ……………unit …….

(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 ab 1.5×10^4 s.

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

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

(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 5000V 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.

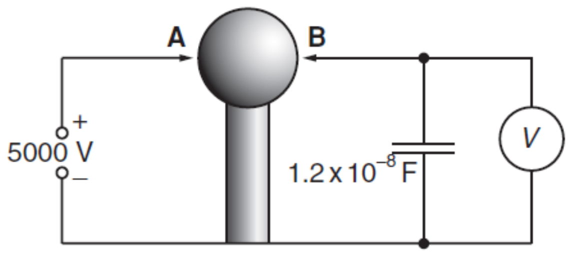

Fig. 4.2

(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]

2.

This question is about the discharge of combinations of capacitors.

In Figs. 4.1 and 4.2, the capacitors are charged through a 10 kΩ resistor from a 10 V d.c. supply when the switch **S** is connected to **X**. They discharge when the switch is moved to **Y**. The ammeters A_1, A_2, A_3 and A_4 monitor the currents in the circuits. Initially, the switch is connected to **X** and the capacitors are fully charged.

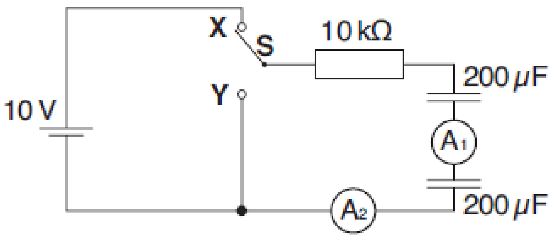

Fig. 4.1

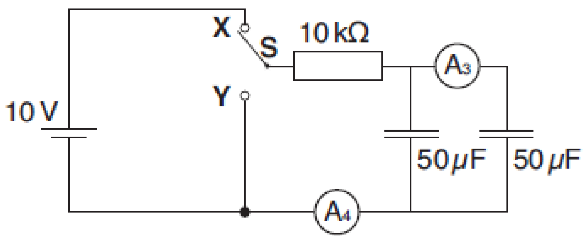

Fig. 4.2

(a) State

(i) the voltage across each capacitor in Fig. 4.1 .... V [1]

(ii) the voltage across each capacitor in Fig. 4.2 .... V [1]

(b) **(i)** Calculate the total charge stored in the circuit of Fig. 4.2.

charge = ... C [2]

(ii) Explain why the total charge stored in the circuit of Fig. 4.1 is the same as in the circuit of Fig. 4.2.

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....[2]

(c) Fig. 4.3 shows how the reading I on ammeter A_2 in the circuit of Fig. 4.1 varies with time t as the capacitors discharge, after the switch is moved from **X** to **Y** at $t = 0$.

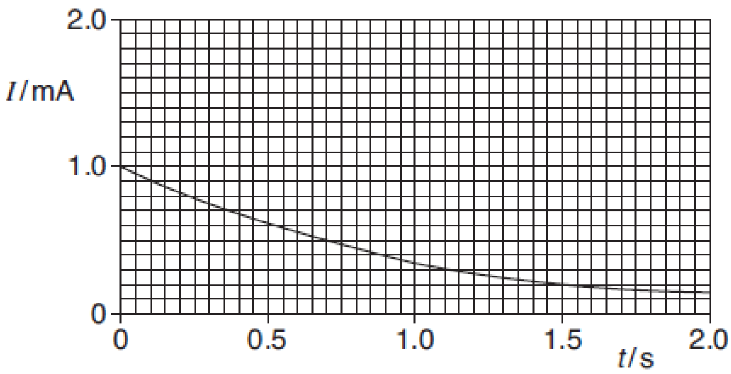

Fig. 4.3

(i) Describe how and explain why the reading on ammeter A_1 varies, if at all, over the same time interval.

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....[2]

(ii) Sketch curves on Fig. 4.3 to show how you expect the readings on ammeters A_3 and A_4 to vary with time from $t = 0$, when the switch is moved from **X** to **Y** in Fig. 4.2. Label your curves $\mathbf{A_3}$ and $\mathbf{A_4}$ respectively. [3]

3.

(a) An object is oscillating with simple harmonic motion. Place a tick (✓) in the box against each true statement that applies to the acceleration of the object.

The acceleration …

… is in the opposite direction to the displacement. ☐

… is directly proportional to the amplitude squared. ☐

… increases as the displacement decreases. ☐

… increases as the speed of the object decreases. ☐

[2]

(b) The graph in Fig. 3.1 shows the variation of the velocity *v* of the object with time *t*.

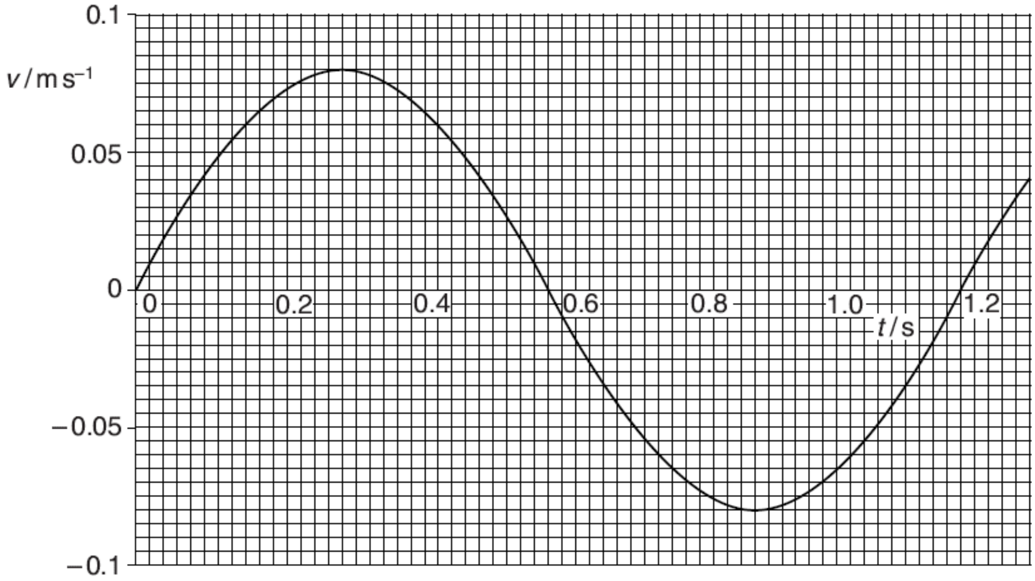

Fig. 3.1

Using the graph, determine

(i) the frequency of the motion

frequency = ... Hz **[1]**

(ii) the amplitude of the motion

amplitude = ... m **[2]**

(iii) the maximum acceleration of the object.

acceleration = ... $m s^{-2}$ **[2]**

(c) (i) With the help of a suitably labelled graph, explain what is meant by *resonance* of a mechanical system.

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.... **[4]**

(ii) State and explain an everyday example of resonance.

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.... **[2]**

4.

(a) Fig. 3.1 shows a car of mass 800 kg travelling at a constant speed of $15\,m\,s^{-1}$ around a bend on a level road following a curve of radius 30 m.

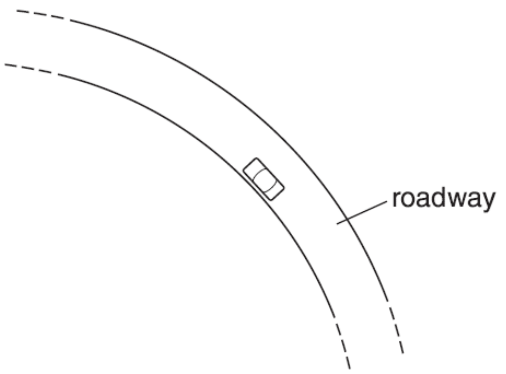

Fig. 3.1

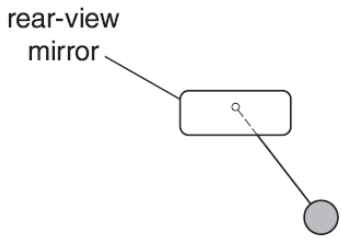

Fig. 3.2

(i) Draw an arrow on Fig. 3.1 to indicate the direction of the resultant horizontal force on the car at the position shown. **[1]**

(ii) Calculate the magnitude *F* of this force.

F = ... N **[3]**

(iii) A medallion hangs on a string from the shaft of the rear view mirror in the car.

Fig. 3.2 shows its position in the vertical plane, perpendicular to the direction of travel in Fig. 3.1.

1 Draw and label arrows on Fig. 3.2 to indicate the forces acting on the medallion. **[2]**

2 On another occasion the car travels around the bend at $25\,m\,s^{-1}$. The angle of the string to the vertical is different. Explain how and why this is so. You may find it useful to sketch a vector diagram to aid your explanation.

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.... **[3]**

(b) Each wheel assembly of the car is mounted on a suspension spring. In a garage test, one wheel assembly is suspended off the ground by its spring with the damper disconnected. Fig. 3.3 shows a graph of the vertical motion of the wheel assembly against time when it is given a small displacement and released.

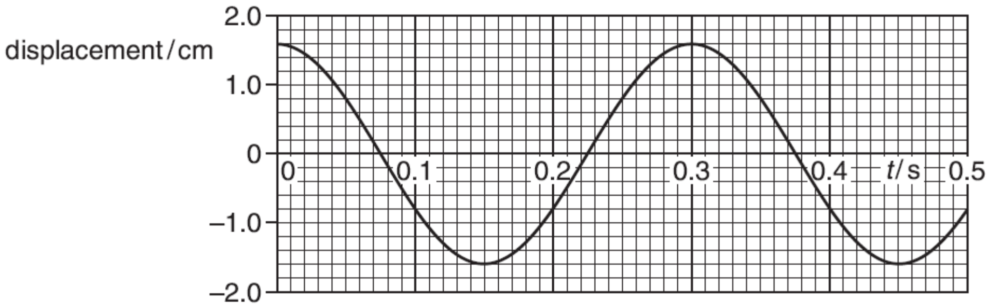

Fig. 3.3

(i) Use the graph to find the natural frequency f_0 of oscillation of the wheel.

f_0 = ... Hz **[2]**

(ii) When the car is travelling along a ridged concrete road at a speed of $20\,m\,s^{-1}$ the driver notices that the car bounces significantly. The ridges in the road are equally spaced 6.2 m apart.

1 Calculate the frequency f of the bounce.

f = ... Hz **[1]**

2 State and explain the phenomenon which is occurring.

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.... **[3]**