Selected Questions – Set 4

1.

(a) (i) Name the **two** types of potential energy involved when a mass–spring system performs vertical simple harmonic oscillations.

[1 mark]

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(a) (ii) Describe the energy changes which take place during one complete oscillation of a vertical mass-spring system, starting when the mass is at its lowest point.

[2 marks]

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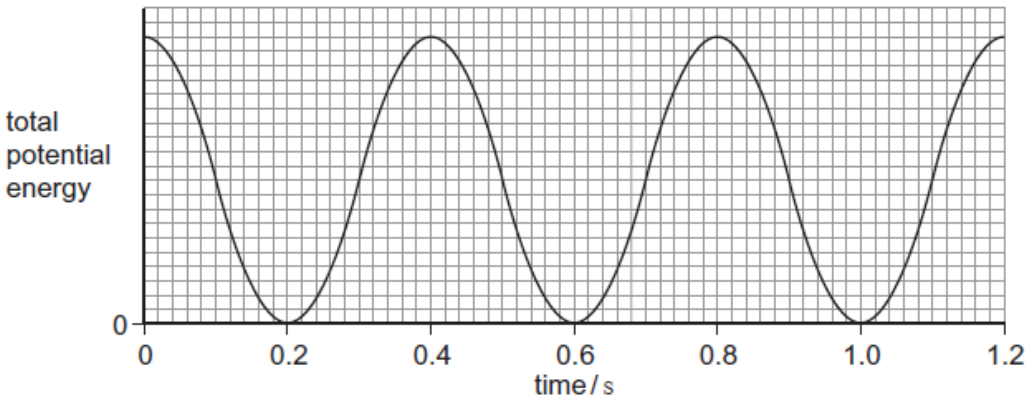
(b) **Figure 3** shows how the **total** potential energy due to the simple harmonic motion varies with time when a mass-spring system oscillates vertically.

Figure 3



(b) (i) State the time period of the simple harmonic oscillations that produces the energy–time graph shown in **Figure 3**, explaining how you arrive at your answer.

[2 marks]

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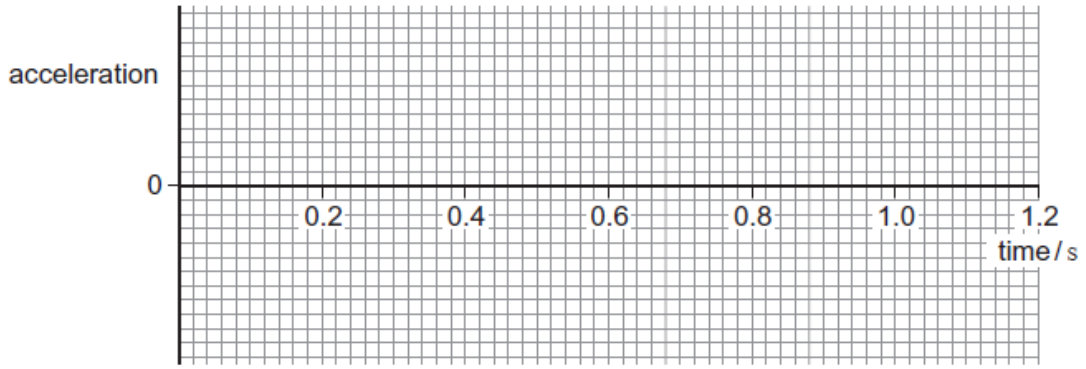
(b) (ii) Sketch a graph on **Figure 4** to show how the acceleration of the mass varies with time over a period of 1.2 s, starting with the mass at the highest point of its oscillations. On your graph, upwards acceleration should be shown as positive and downwards acceleration as negative. Values are not required on the acceleration axis.

[2 marks]

Figure 4



Time period of a mass spring system is given by,

$$T = 2\pi\sqrt{\frac{m}{k}}$$

(c) (i) The mass of the object suspended from the spring in part (b) is 0.35 kg. Calculate the spring constant of the spring used to obtain **Figure 3**. State an appropriate unit for your answer.

[3 marks]

spring constant ..... unit .....

(c) (ii) The maximum kinetic energy of the oscillating object is 2.0×10^{-2} J. Show that the amplitude of the oscillations of the object is about 40 mm.

[4 marks]

2.

A lead ball of mass $0.25\ \text{kg}$ is swung round on the end of a string so that the ball moves in a horizontal circle of radius $1.5\ \text{m}$. The ball travels at a constant speed of $8.6\ \text{m s}^{-1}$.

(a) (i) Calculate the angle, in degrees, through which the string turns in $0.40\ \text{s}$.

[3 marks]

angle ..... degree

(a) (ii) Calculate the tension in the string.
You may assume that the string is horizontal.

[2 marks]

tension ..... N

(b) The string will break when the tension exceeds $60\ \text{N}$.
Calculate the number of revolutions that the ball makes in one second when the tension is $60\ \text{N}$.

[2 marks]

number of revolutions .....

(c) Discuss the motion of the ball in terms of the forces that act on it. In your answer you should:

- explain how Newton's three laws of motion apply to its motion in a circle
- explain why, in practice, the string will not be horizontal.

You may wish to draw a diagram to clarify your answer.

The quality of your written communication will be assessed in your answer.

[6 marks]

3.

A binary star consists of two stars that orbit about their common centre of mass **C**, as shown in Fig. 5.1.

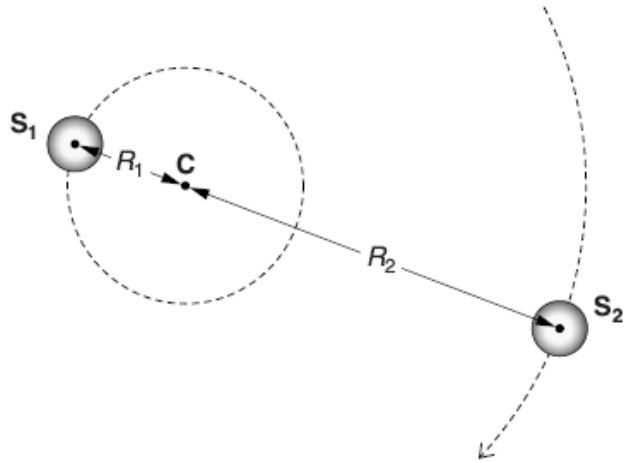


Fig. 5.1

The star $\mathbf{S_1}$ has mass M_1 and orbits in a circle of radius R_1. Star $\mathbf{S_2}$ has mass M_2 and a circular orbit of radius R_2. Both stars have the same orbital period T about **C**.

(a) Using the terms G, M_1, M_2, R_1, R_2 and T write an expression for

(i) the gravitational force F experienced by each star

[1]

(ii) the centripetal force F_1 acting on the star $\mathbf{S}_1$

[1]

(b) Use **(a)(ii)** to show that the ratio of the masses of the stars is given by the expression

$$\frac{M_1}{M_2} = \frac{R_2}{R_1}$$

[2]

(c) The ratio of the masses, M_1/M_2, is equal to 3.0 and the separation between the stars is 4.8×10^{12}m.
Calculate the radii R_1 and R_2.

R_1 = ... m

R_2 = ... m **[3]**

(d) The orbital period T of each star is 4.0 years.
Calculate the orbital speed of $\mathbf{S}_1$.

speed = ... $m s^{-1}$ **[2]**

(e) Calculate the mass of $\mathbf{S_2}$.

mass = ... kg **[3]**

4.

(a) (i) State the relationship between the *gravitational potential energy*, E_p, and the *gravitational potential*, V, for a body of mass m placed in a gravitational field.

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(1 mark)

(a) (ii) What is the effect, if any, on the values of E_p and V if the mass m is doubled?

value of E_p .....

value of V .....

(2 marks)

(b) **Figure 3**

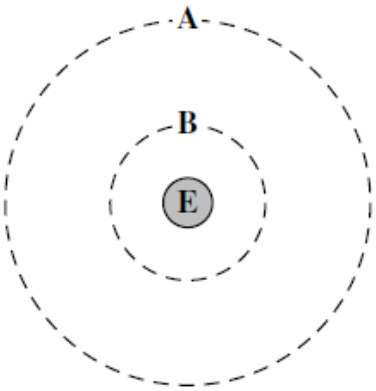

Figure 3 shows two of the orbits, **A** and **B**, that could be occupied by a satellite in circular orbit around the Earth, **E**.
The gravitational potential due to the Earth of each of these orbits is:

orbit **A**	$-12.0\ \text{MJ kg}^{-1}$
orbit **B**	$-36.0\ \text{MJ kg}^{-1}$.

(b) (i) Calculate the radius, from the centre of the Earth, of orbit **A**.

answer = ... m
(2 marks)

(b) (ii) Show that the radius of orbit **B** is approximately 1.1×10^4 km.

(1 mark)

(b) (iii) Calculate the centripetal acceleration of a satellite in orbit **B**.

answer = ... $m\,s^{-2}$

(2 marks)

(b) (iv) Show that the gravitational potential energy of a 330 kg satellite decreases by about 8 GJ when it moves from orbit **A** to orbit **B**.

(1 mark)

(c) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of a satellite as it moves between these orbits.

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(1 mark)

5.

Fig. 4.1 shows a cyclist.

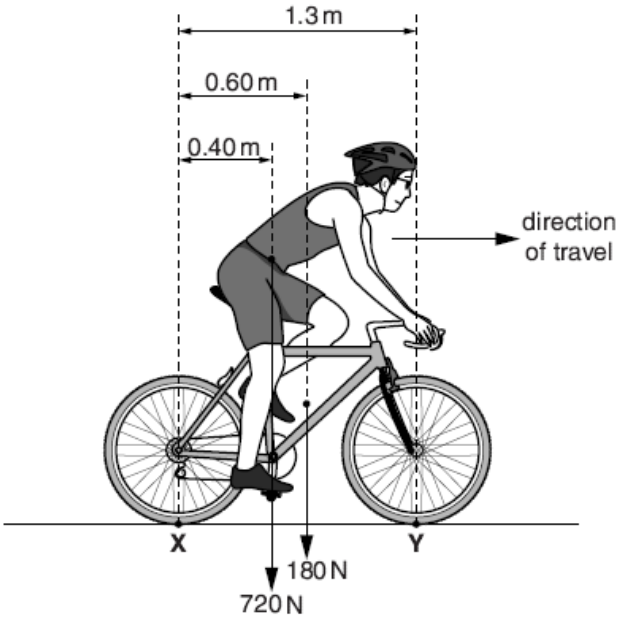

Fig. 4.1

The bicycle tyres are in contact with the road at **X** and **Y**. The cyclist is travelling at **constant** velocity on a level road. The weight of the bicycle is 180 N and the weight of the cyclist is 720 N.

(a) State the magnitude of the resultant force acting on the cyclist. Explain your answer.

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..... **[2]**

(b) Define *moment of a force*.

In your answer, you should use appropriate technical terms, spelled correctly.

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..... **[1]**

(c) Explain why the two vertical forces acting on the tyres at **X** and **Y** do not form a couple.

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..... **[1]**

(d) Take moments about **X** to determine the size of the vertical force *F* acting **on** the tyre at **Y**.

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

(e) The cyclist leans further forward. How does this affect the force on the tyre at **X**? Explain your answer.

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..... **[2]**