Cambridge Assessment International Education

Cambridge International AS & A Level

7: Further mechanics – Topic questions

The questions in this document have been compiled from a number of past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
1	2017	June	41
2	2017	June	41
1	2017	March	42

The mark scheme for each question is provided at the end of the document.

1 **(a)** Explain how a satellite may be in a circular orbit around a planet.

....

....

....[2]

(b) The Earth and the Moon may be considered to be uniform spheres that are isolated in space. The Earth has radius R and mean density ρ. The Moon, mass m, is in a circular orbit about the Earth with radius nR, as illustrated in Fig. 1.1.

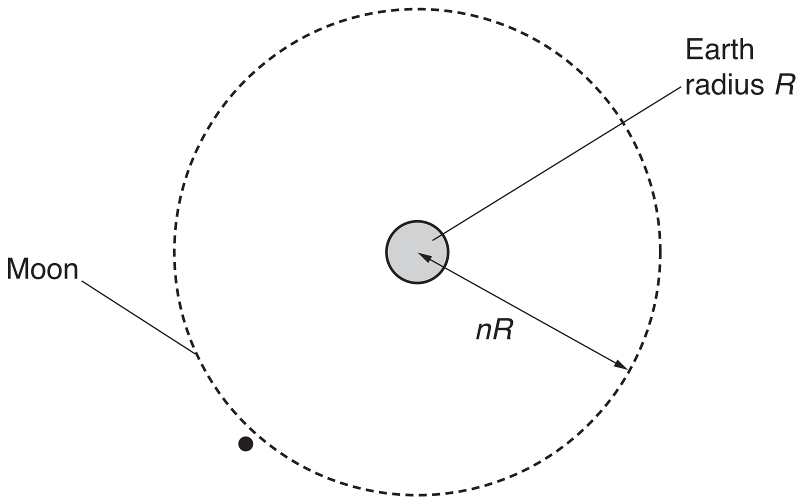

Fig. 1.1

The Moon makes one complete orbit of the Earth in time T.
Show that the mean density ρ of the Earth is given by the expression

$$\rho = \frac{3\pi n^3}{GT^2}.$$

[4]

(c) The radius R of the Earth is 6.38×10^3 km and the distance between the centre of the Earth and the centre of the Moon is 3.84×10^5 km.
The period T of the orbit of the Moon about the Earth is 27.3 days.
Use the expression in **(b)** to calculate ρ.

ρ = ... $kg\,m^{-3}$ [3]

[Total: 9]

2 A bar magnet of mass 180 g is suspended from the free end of a spring, as illustrated in Fig. 2.1.

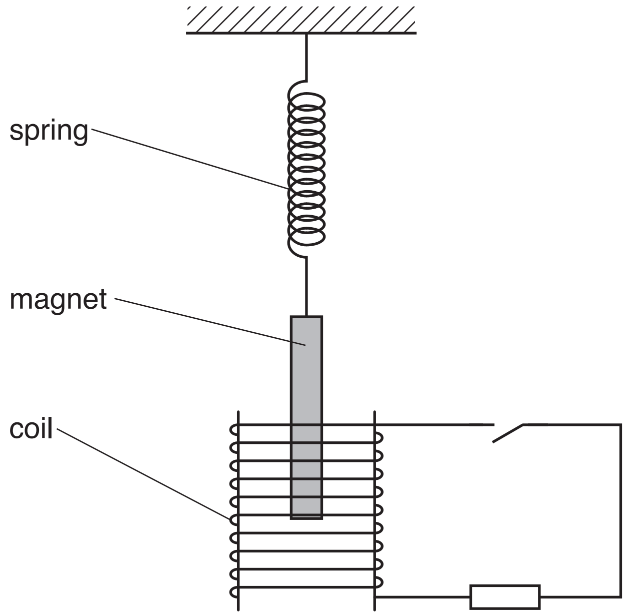

Fig. 2.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 3.0$ s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 2.2.

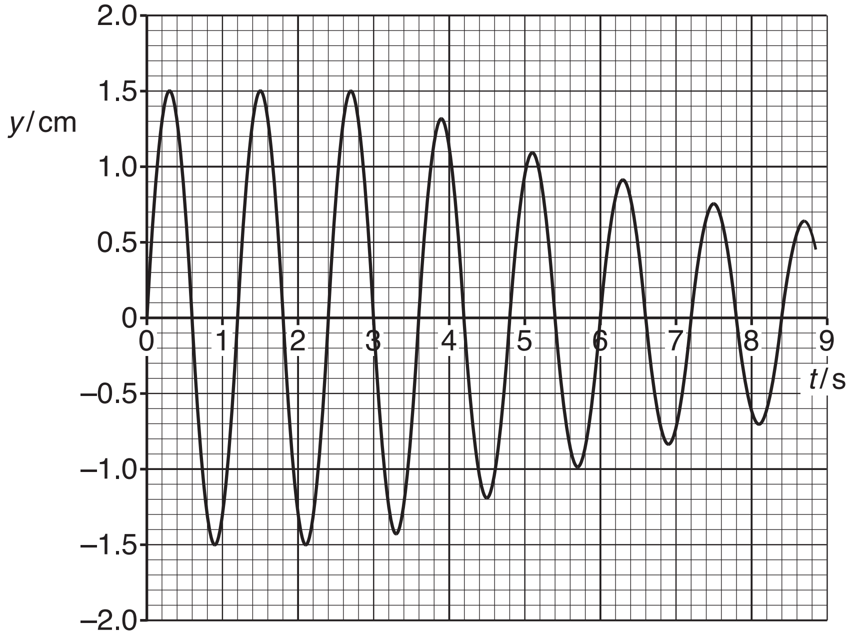

Fig. 2.2

(a) Determine, to two significant figures, the frequency of oscillation of the magnet.

frequency = ... Hz [2]

(b) State whether the closing of the switch gives rise to light, heavy or critical damping.

....[1]

(c) Calculate the change in the energy ΔE of oscillation of the magnet between time $t = 2.7$ s and time $t = 7.5$ s. Explain your working.

ΔE = ... J [6]

[Total: 9]

1 **(a)** Define *gravitational potential* at a point.

....

....

....[2]

(b) A rocket is launched from the surface of a planet and moves along a radial path, as shown in Fig. 1.1.

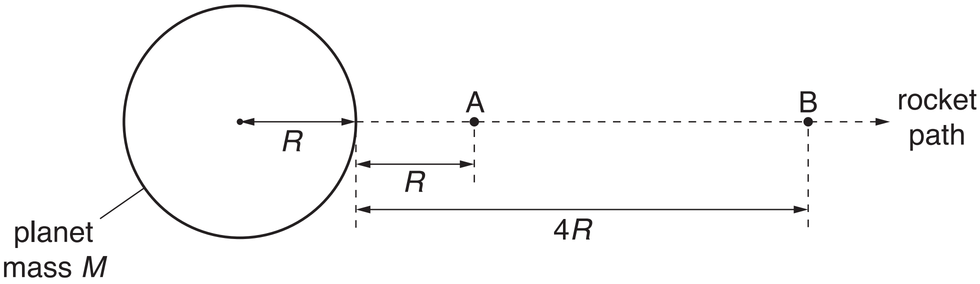

Fig. 1.1

The planet may be considered to be an isolated sphere of radius R with all of its mass M concentrated at its centre. Point A is a distance R from the surface of the planet. Point B is a distance $4R$ from the surface.

(i) Show that the difference in gravitational potential $\Delta\phi$ between points A and B is given by the expression

$$\Delta\phi = \frac{3GM}{10R}$$

where G is the gravitational constant.

[1]

(ii) The rocket motor is switched off at point A. During the journey from A to B, the rocket has a constant mass of 4.7×10^4 kg and its kinetic energy changes from 1.70 TJ to 0.88 TJ.

For the planet, the product *GM* is $4.0 \times 10^{14}\,N\,m^2\,kg^{-1}$. It may be assumed that resistive forces to the motion of the rocket are negligible.

Use the expression in **(b)(i)** to determine the distance from A to B.

distance = ...m [3]

[Total: 6]

Question	Answer	Marks
1 (a)	gravitational force (of attraction between satellite and planet)	**1**
	provides / is centripetal force (on satellite about the planet)	**1**
1 (b)	$M = (4/3) \times \pi R3\rho$	**1**
	$\omega = 2\pi / T$ **or** $v = 2\pi nR / T$	**1**
	$GM / (nR)^2 = nR\omega^2$ **or** v^2 / nR	**1**
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	**1**
1 (c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	**1**
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	**1**
	$\rho = 5.54 \times 10^3$ kg m^{-3}	**1**
		Total: 9
2 (a)	e.g. period = 3 / 2.5	**1**
	frequency = 0.83 Hz	**1**
2 (b)	light (damping)	**1**
2 (c)	at 2.7 s, $A0 = 1.5$ (cm)	**1**
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	**1**
	$= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	**1**
	at 7.5 s, $A_0 = 0.75$ (cm)	**1**
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ **or** energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	**1**
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	**1**
		Total: 9
1 (a)	work done per unit mass	**1**
	bringing (small test) mass from infinity (qto the point)	**1**
1 (b) (i)	$\Delta\phi = (GM / 2R) - (GM / 5R) = 3GM / 10R$	**1**
1 (b) (ii)	change in GPE = $(3 \times 4.0 \times 10^{14} / 10\,R) \times 4.7 \times 10^4$	**1**
	$(3 \times 4.0 \times 10^{14} / 10\,R) \times 4.7 \times 10^4 = (1.70 - 0.88) \times 10^{12}$ $R = 6.88 \times 10^6$	**1**
	distance = $3 \times 6.88 \times 10^6$ $= 2.1 \times 10^7$ m	**1**
		Total: 6

Notes about the mark scheme are available separately.