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NZQA

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Level 3 Physics, 2017

91524 Demonstrate understanding of mechanical systems

2.00 p.m. Monday 20 November 2017
Credits: Six

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of mechanical systems.	Demonstrate in-depth understanding of mechanical systems.	Demonstrate comprehensive understanding of mechanical systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Booklet L3–PHYSR.

In your answers use clear numerical working, words, and / or diagrams as required.

Numerical answers should be given with an SI unit, to an appropriate number of significant figures.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–11 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

TOTAL

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QUESTION ONE

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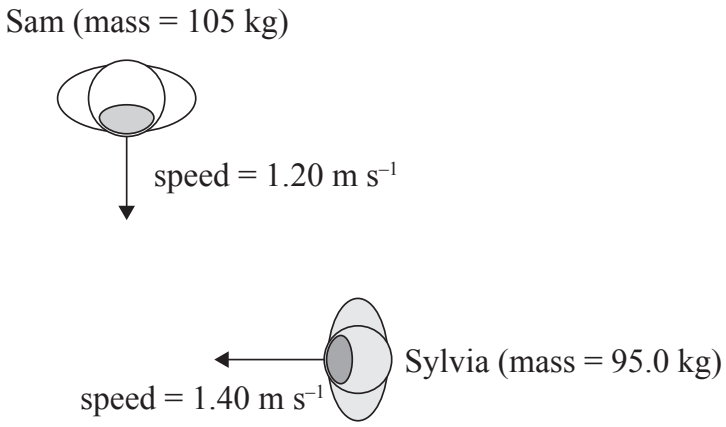
Two astronauts, Sylvia and Sam, are on a mission to another planet. During their journey they are doing a "space walk" outside their spaceship.

At one time they are moving freely as shown in the diagram below. They collide and stick together.



(a) Calculate the distance between Sam and the centre of mass of the system when he and Sylvia are 4.80 m apart.

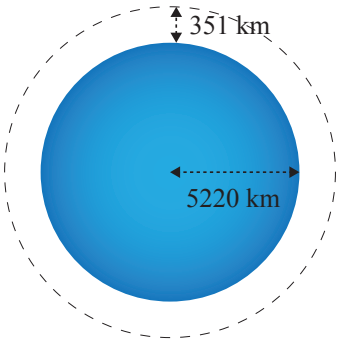
(b) Describe what happens to the centre of mass of the system as the astronauts move closer together and then collide.

(c) Calculate the astronauts' combined speed after they collide.

(d) When the spaceship reaches the planet, the spaceship goes into orbit around the planet with a period of 5.46×10^3 s, and at a height of 351 km above the surface.

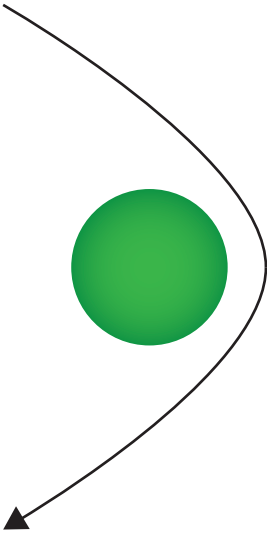
Assume the orbit is circular.

The planet has a radius of 5220 km.



(i) Calculate the mass of the planet.

(ii) On the return journey to Earth, the spaceship goes past a different planet. The spaceship's path is shown in the diagram.



Explain how the spaceship's speed changes as it gets closer to the planet.

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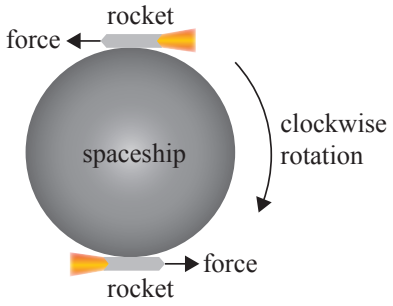
QUESTION TWO



Sylvia and Sam's spaceship spins clockwise on its axis as it is moving through space. The astronauts can change the angular velocity of the spaceship by firing two small rockets that are mounted tangentially as shown. The rockets produce an anticlockwise torque. The rotational inertia of the spaceship is 5.80×10^4 kg m^2.

(a) Calculate the size of the torque required from each rocket to cause an angular acceleration of 2.00×10^{-2} rad s^{-2}.

(b) The spaceship is rotating clockwise at 0.580 rad s^{-1} when the rockets are fired.

Calculate the angular speed of the spaceship after one rotation.

(c) Assume that the torque produced by the rockets is constant.

Explain what happens to the size of the angular acceleration as the rockets gradually emit burnt fuel.

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(d) Some time later, the spaceship is rotating freely at 0.450 rad s^{-1} with the rockets turned off, as shown in Diagram 1. The spaceship's photo-voltaic cells are then extended out from the spaceship, causing the rotational inertia to increase by 2.74×10^3 kg m^2.

Diagram 1

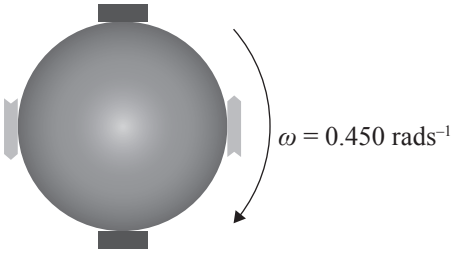
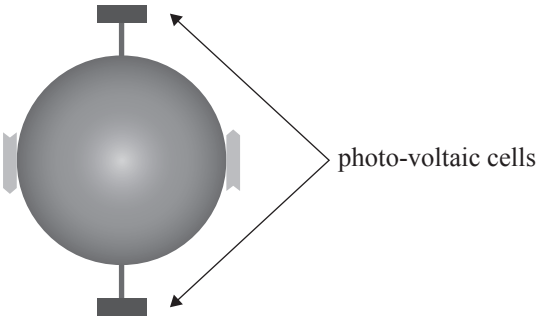


Diagram 2



(i) Explain why the period of rotation changes as the photo-voltaic cells are extended (Diagram 2).

(ii) Calculate the period of rotation when the photo-voltaic cells are fully extended.

QUESTION THREE

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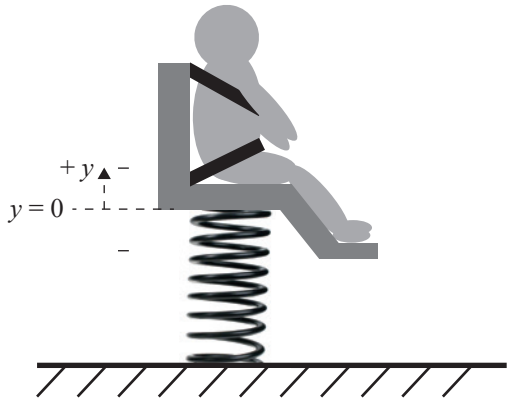
Astronauts need to be able to measure their mass regularly so that they can monitor their health. They can do this by being strapped on to a lightweight seat that is attached to a spring as shown in the diagram below.

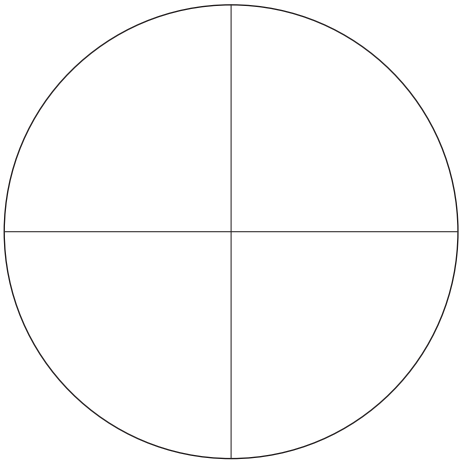


When Sylvia is displaced from equilibrium, she oscillates in simple harmonic motion with a period of 8.00 s. You may assume her motion is linear.

(a) Describe any changes in the size or direction of the restoring force as Sylvia moves away from equilibrium in the $+y$ direction.

(b) The amplitude of Sylvia's oscillation is 0.120 m.

Use a reference circle or other method to calculate the shortest time it takes for Sylvia to move up 0.080 m from her equilibrium position.



If you need to redraw your response, use the diagram on page 8.

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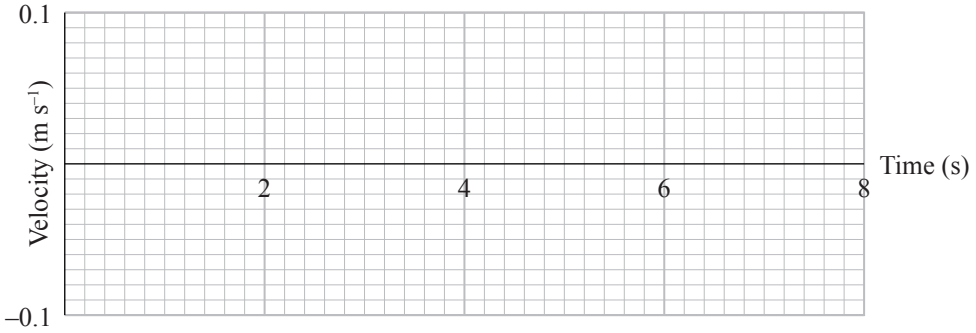
(c) On the axis below, draw a graph showing Sylvia's velocity vs time, starting when she is closest to the floor.

Include the value of the maximum velocity.



If you need to redraw your response, use the grid on page 8.

(d) To start the oscillation, Sam applies a vertical force of 4.40 N to Sylvia. This force causes Sylvia to move a distance of 0.120 m.

- Calculate Sylvia's mass.
- Describe any assumptions you have made to simplify your calculation.

SPARE DIAGRAMS

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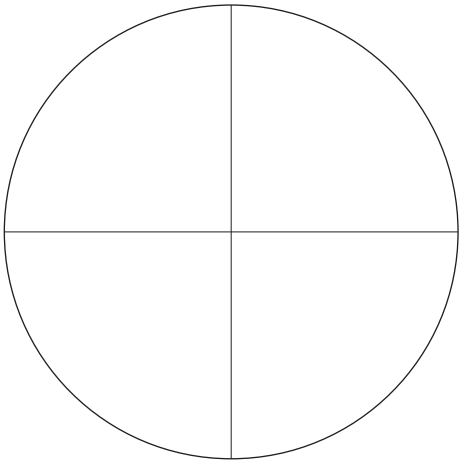
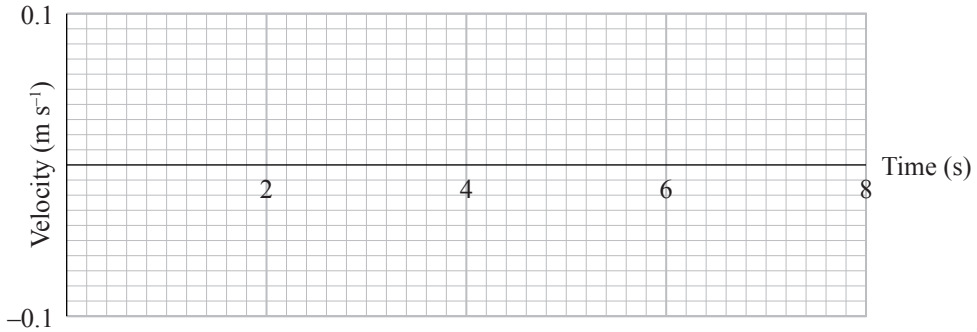
If you need to redraw your response to Question Three (b), draw it on the diagram below. Make sure it is clear which answer you want marked.



If you need to redraw your response to Question Three (c), draw it on the grid below. Make sure it is clear which answer you want marked.



Extra paper if required.
Write the question number(s) if applicable.

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