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Level 3 Physics 2020

91524 Demonstrate understanding of mechanical systems

2.00 p.m. Wednesday 2 December 2020
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 2–8 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: TOM'S PLANE

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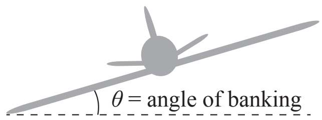
Tom flies a Boeing 737-800, which is an averaged-sized plane with a take-off mass of 7.50×10^4 kg. There are times when he flies it horizontally in a straight line, and there are times when he has to take a circular path such that the plane is banked at an angle to the horizontal.

The diagrams below represent these two situations.

(a) Draw the force due to gravity and the lift force on the plane in the two situations below.



If you need to redraw your response, use the diagram on page 7.

(b) Compare the size of the force due to gravity and lift force on the plane when Tom flies it horizontally in a straight line, and when he flies it in a horizontal circle banked at an angle.

Give reasons why they are similar or different in each situation.

Numerical working is not necessary.

(c) On one occasion Tom flies the plane of mass 7.50×10^4 kg in a circular path, with a speed of 54.0 m s^{-1}, banked at an angle of 35.0° to the horizontal.

Calculate the radius of the circle that the plane describes.

Explain your working for calculating the radius of the circular path the plane describes.

A diagram may assist your explanation.

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(d) Tom then flies his plane at a height of 1.28×10^4 m above the surface of the Earth.

Calculate the gravitational field strength at the height Tom flies the plane.

Mass of Earth $= 5.98 \times 10^{24}$ kg

Radius of Earth $= 6.37 \times 10^6$ m

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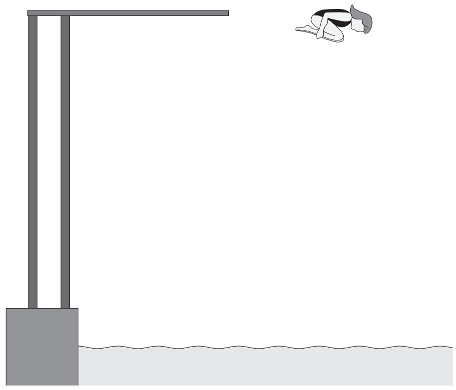
QUESTION TWO: SOMERSAULTS WHILE DIVING

Sandra dives from a diving board that is 10.0 m high. She finds she can do somersaults (rotations) by tucking her body in. In the tucked position, her body can be modelled as a sphere of mass 60.0 kg and radius 0.200 m.

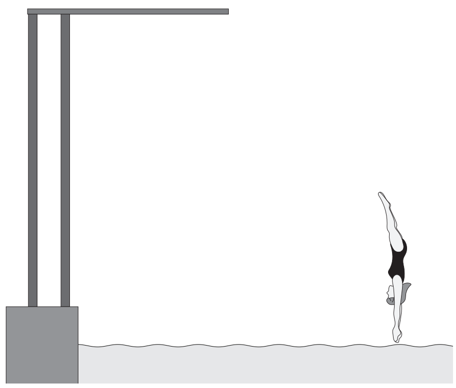
The rotational inertia of a sphere is given by $I = \frac{2}{5}mr^2$.



(a) While in the tucked position, she dives (rotates) with a constant angular velocity of 9.56 $rads^{-1}$.

Show that her angular momentum is 9.18 kg m^2 s^{-1}.

(b) Just before entering the water, she straightens her body, thereby changing her rotational inertia.



Explain what effect this will have on her rotational motion.

Comment on her:

- angular velocity
- rotational kinetic energy.

You may ignore effects of friction while she is in the air.

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(c) It takes Sandra 0.280 s to straighten her body just before entering the water. Her rotational inertia becomes 4.80 kg m^2.

Calculate her angular deceleration during this time.

(d) One day, Sandra observes Tapu practising somersaults from the diving board. Tapu does 2.00 complete somersaults in 1.25 seconds.

Calculate Tapu's average angular velocity while executing the somersaults.

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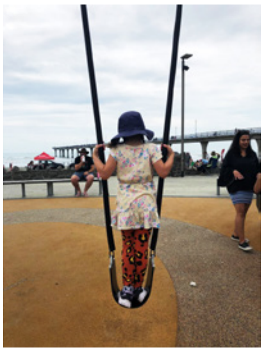
QUESTION THREE: IN THE PLAYGROUND

(a) Serena sits on a rigid swing that is 3.00 m long.

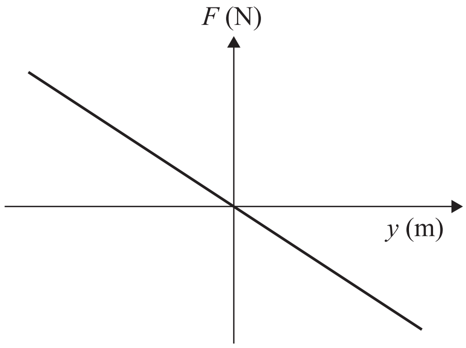
Show that the period of the swing is 3.50 s.

(b) Explain, giving reasons, how the period of the swing will be affected if Serena stands up on the swing while it is swinging freely.



(c) The graph below is that of the restoring force, F, on Serena, against y, which is the horizontal displacement of Serena from her equilibrium position.

Explain how the information in the graph below shows that the swing is an example of SHM.



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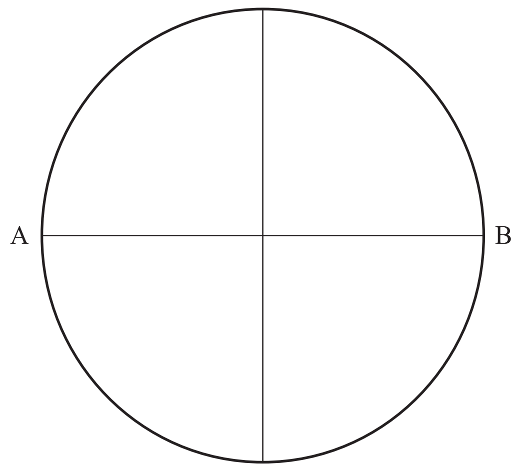
(d) Serena swings from end A to end B with an amplitude of 1.50 m and a period of 3.50 s.

Using the reference circles below or otherwise, calculate the velocity of Serena and the swing when she is 0.500 m from end B.



SPARE DIAGRAM

If you need to redraw your force labels from Question One (a), draw them below. Make sure it is clear which answer you want marked.

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

QUESTION NUMBER

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