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Level 3 Physics, 2019

91524 Demonstrate understanding of mechanical systems

2.00 p.m. Wednesday 20 November 2019
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 2–12 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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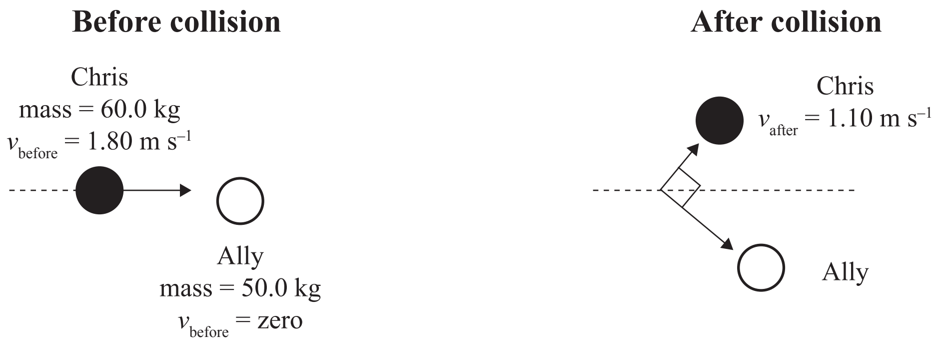
QUESTION ONE: ROLLERBLADING

Ally and Chris are rollerblading. Assuming friction is negligible, the system of Ally and Chris can be considered an isolated system in the horizontal direction.

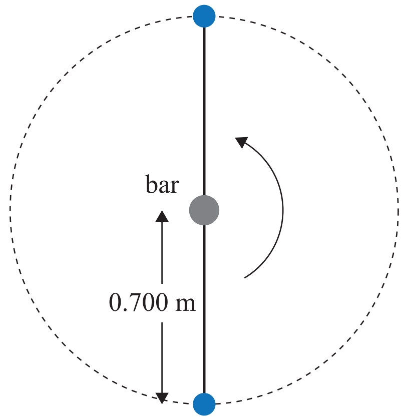
(a) State a relevant physical quantity that is conserved during a collision between Chris and Ally.

(b) At one instant, Ally stops and Chris collides with her. They move off at right angles to each other, as shown in the diagram below.

Show that Ally's speed after the collision is 1.71 m s^{-1}.



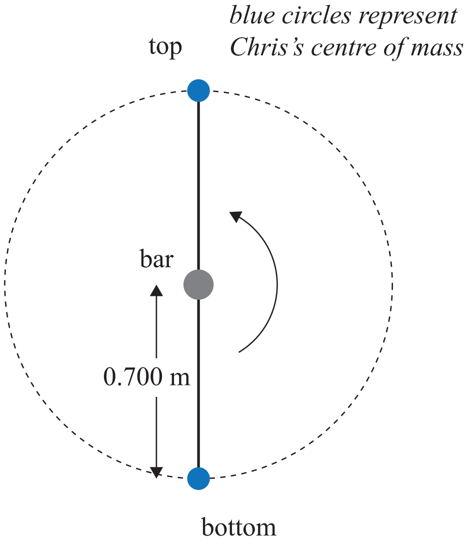
To save himself from falling, Chris sees a horizontal bar and grabs it. He then swings on the bar in a vertical circle. Chris's motion can be simplified by analysing the motion of his centre of mass, which is 0.700 m from the bar. Assume the effects of friction are negligible.



(c) Calculate the minimum speed Chris's centre of mass would need to have at the top of the vertical circle, in order to swing up and over the bar. (Assume he continues in a circular path.)

(d) Describe and explain the size and direction of the tension and weight forces at the bottom and the top positions, assuming Chris swings over the top at minimum speed.

Include force labels on the diagram below to support your answer.



This is a repeat of the diagram on the previous page. If you need to redraw your force labels, use the diagram on page 10.

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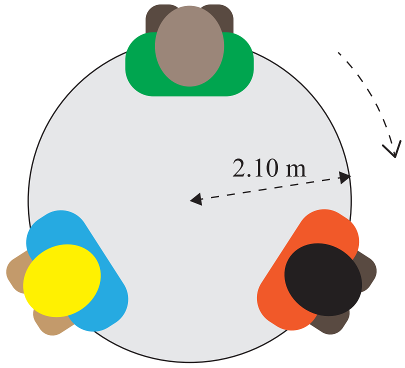
QUESTION TWO: MERRY-GO-ROUND

Three children are playing on a merry-go-round with a rotational inertia of 271 kg m^2. Once the children get the merry-go-round spinning, they stand evenly spaced around the outer edge. Each child has a mass of 28.0 kg, and the merry-go-round has a radius of 2.10 m.



(a) Assuming the rotational inertia of a child's mass on the edge of the disc is given by $I = mr^2$, show that the rotational inertia of the system is 641 kg m^2.

(b) The total energy of the system is 388 J.

Show that:

(i) the angular velocity of the system is 1.10 rad s^{-1}, and

(ii) the linear velocity of one of the children is 2.31 m s^{-1}.

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(c) One child drags her foot on the ground to bring the merry-go-round to a stop in 2.80 s.

Calculate the amount of torque produced by the foot.

(d) The children get the merry-go-round spinning once again at a constant angular speed. Then each child moves inward towards the centre of the merry-go-round.

Using physics principles, explain the effect this has on the rotational energy of the system.

QUESTION THREE: SWING

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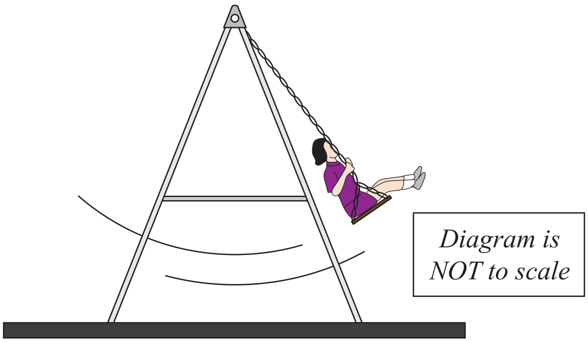
Jay is enjoying a swing at the playground. The period of one oscillation is 2.40 s and Jay maintains a constant amplitude of 0.310 m by swinging her legs back and forth to replace the energy lost due to friction. The mass of the system (Jay and the swing) is 70.0 kg. Jay's motion can be considered simple harmonic motion.



(a) Calculate the maximum velocity of Jay and the swing.

(b) Use a reference circle or other method to determine how much time Jay's displacement is greater than 0.200 m from equilibrium over one period.

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(c) Jay stops swinging her legs when the swing is at its maximum displacement.

On the grid below sketch a graph of her displacement over the next three periods.

Include values for the time and for the initial displacement at t = zero.

If you need to redraw this graph, use the grid on page 10.

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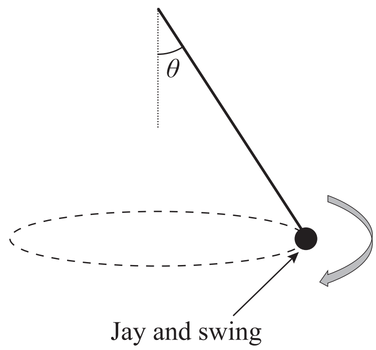
(d) Jay moves to a new swing that is a tyre hanging vertically on a single chain. The system is a conical pendulum. Jay travels at 2.61 m s^{-1} around a circle of radius 0.411 m. The total mass of Jay and the swing is 70.0 kg. Assume friction and the mass of the supporting chain are negligible.



Calculate the tension in the chain supporting the swing and the angle of the chain from vertical.

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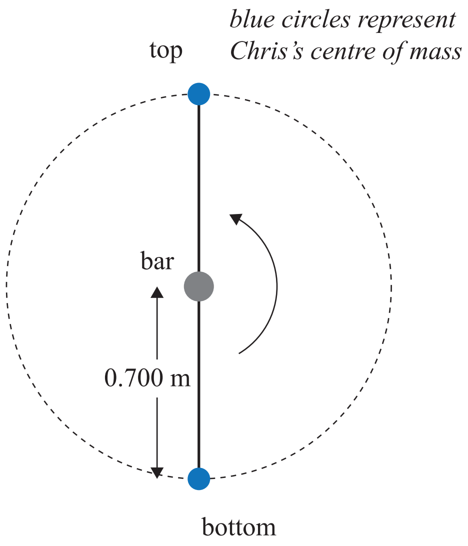
SPARE DIAGRAMS

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



If you need to redraw your graph from Question Three (c), draw it 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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Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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