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Draw a cross through the box (☒) if you have NOT written in this booklet

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NZQA | Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Physics 2026

91524 Demonstrate understanding of mechanical systems

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 appropriate SI unit.

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.

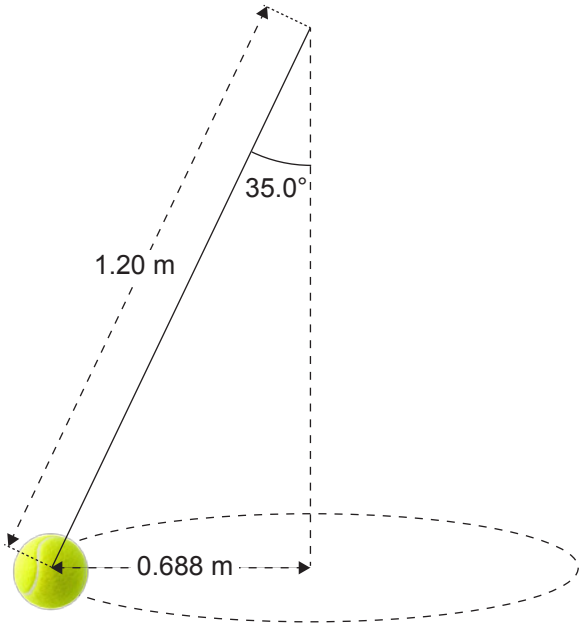
Do not write in the margins (////). This area will be cut off when the booklet is marked.

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

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QUESTION ONE: CIRCULAR AND TRANSLATIONAL MOTION

A tennis ball of mass 58.5 g is tied to a string of negligible mass. The ball is swung in a conical motion so the string makes an angle of 35.0° with the vertical. The length of the string is 1.20 m, and the radius of the circle formed is 0.688 m.



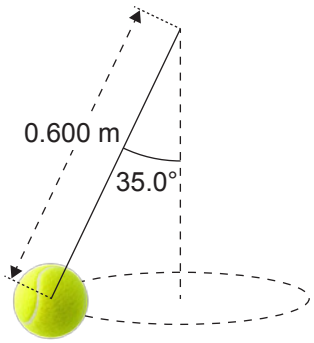
(a) Draw a free body diagram to show all forces acting on the ball at this point.

If you need to redraw your response, use the box on page 10.

(b) Calculate the speed of the tennis ball.

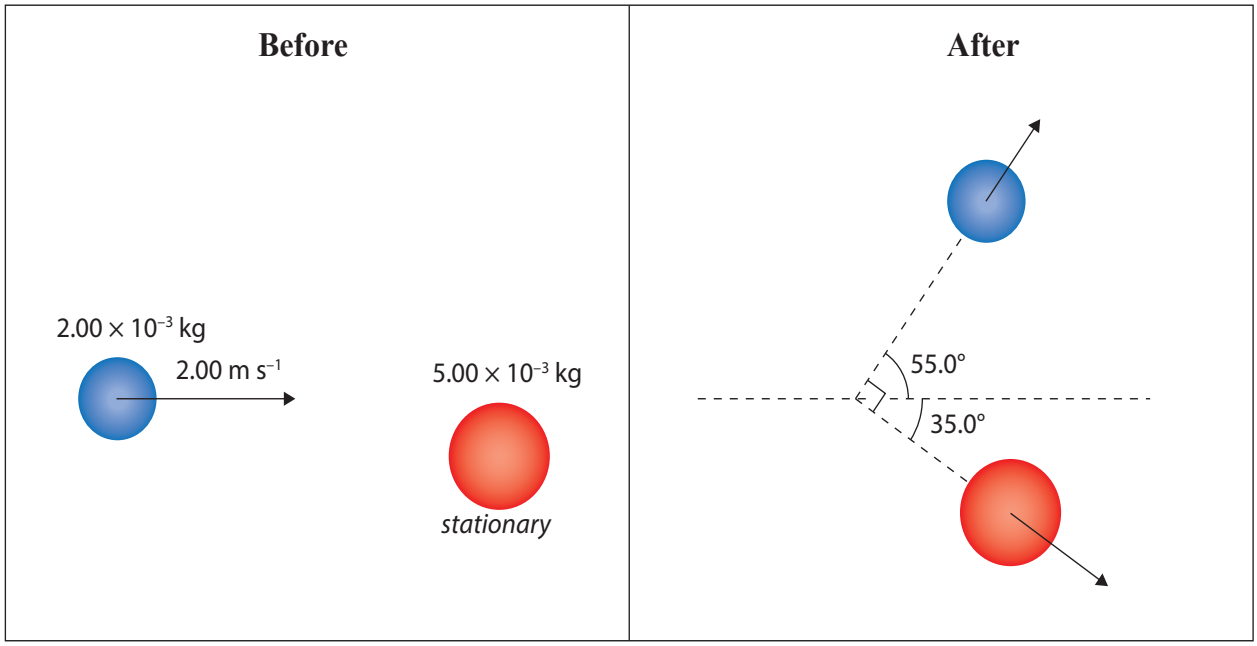
(c) The string is shortened to half its length. The ball is swung, keeping the angle the same as before.

Describe and explain how halving the length of the string will affect the centripetal force and the speed of the ball.



(d) A game of marbles is being played. A small blue marble (2.00×10^{-3} kg) with initial velocity of 2.00 m s^{-1} collides with a stationary large red marble (5.00×10^{-3} kg), and they move off as shown. The blue marble moves off at an angle of 55.0° and the red marble moves off at an angle of 35.0°.

Assume no net external force acts on the system.



Calculate the final speeds of both marbles.

You may wish to draw a vector diagram in the space below.

QUESTION TWO: ROTATIONAL MOTION

Matt and Prapthi are investigating motion. A solid ball is placed at the top of a slope and released. The ball rolls without slipping. When the ball reaches the bottom, it has angular velocity of 22.1 rad s^{-1}. The ball has a mass of 50.0 g, a radius of 5.35 cm, and a rotational inertia of 5.72×10^{-5} kg m^2.



(a) Calculate the linear velocity of the ball at the bottom of the slope.

(b) The ball takes 0.507 s to travel to the bottom of the slope.

Calculate the length of the slope.

(c) Matt is sitting on a bar stool that can rotate about a vertical axis through its centre with negligible friction. He holds a 2.00 kg mass in each outstretched hand.

The rotational inertias of Matt, the stool, and masses together at two different arm positions are given in the table below.

Arm position	Rotational inertia
Arms extended	4.80 kg m^2
Arms pulled in	1.60 kg m^2

(i) Matt starts at rest, with his arms extended. Prapthi applies a constant torque of 14.0 N m for a duration of 0.350 s, then lets go.

Show that Matt's angular velocity immediately after the torque is removed is 1.02 rad s^{-1}.

(ii) Matt then pulls his arms in.

Find his new angular velocity.

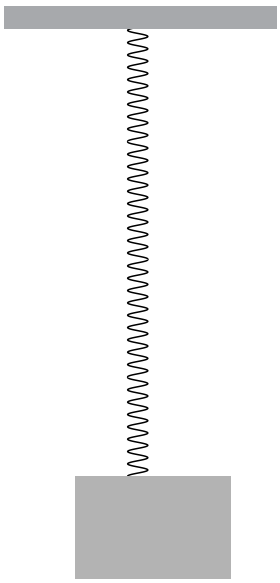
(d) Once spinning, bringing his arms in results in a change to Matt's angular velocity and the rotational inertia of the system.

Explain, fully, the energy changes that occur during this process.

You should include relevant calculations in your answer.

QUESTION THREE: SIMPLE HARMONIC MOTION

A 0.250 kg soft toy is attached to a spring with a spring constant of 3.00 N m^{-1}. It is raised 0.120 m above its equilibrium position and then released, bouncing up and down in simple harmonic motion (SHM) with a period of 1.81 s.



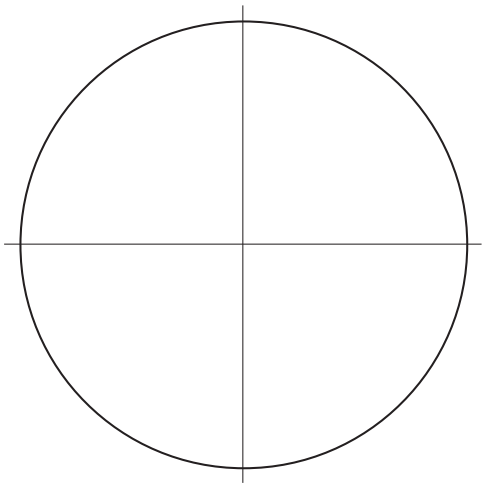
Adapted from: https://shop.shorebirds.org.nz/shop/softtoysoundsmall/

(a) Show that the angular frequency of the SHM is 3.47 rad s^{-1}.

(b) Calculate the maximum velocity of the toy, and state the position of the toy at this point.

(c) By using a reference circle or any other method, calculate the velocity of the toy when it first reaches a displacement of 0.0450 m below the equilibrium position.

If you need to redraw your response, use the grid on page 10.



(d) The toy bounces up and down, and eventually comes to rest.

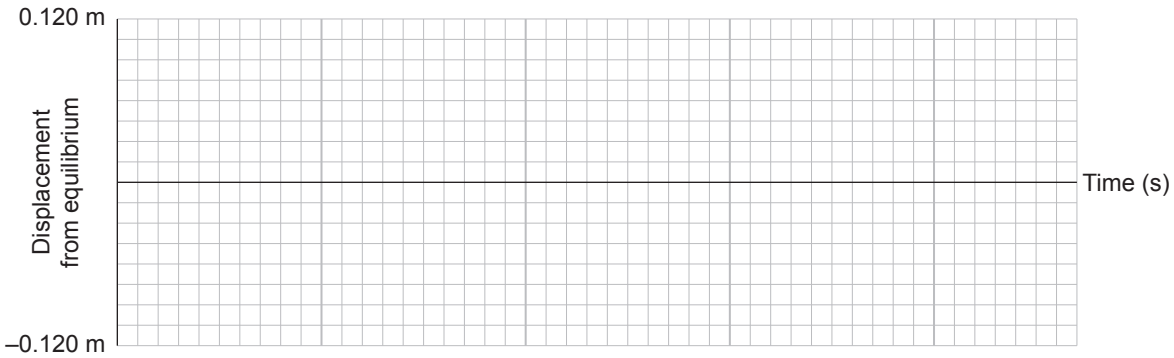
(i) Name this phenomenon and explain why the toy eventually comes to rest.

Include the effect, if any, on the period and amplitude of the system.

(ii) The soft toy was initially 0.120 m above its equilibrium position.

Draw a graph of the displacement against time to show how the displacement changes over three oscillations.

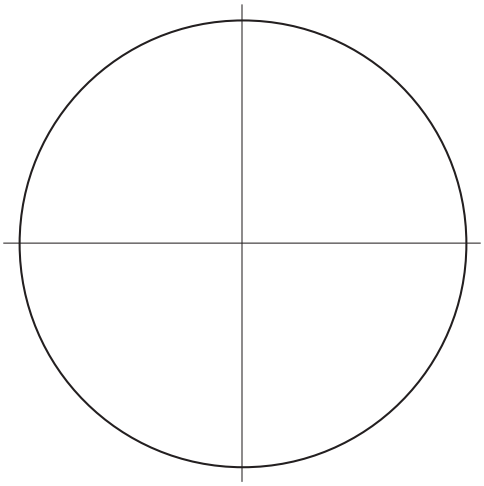
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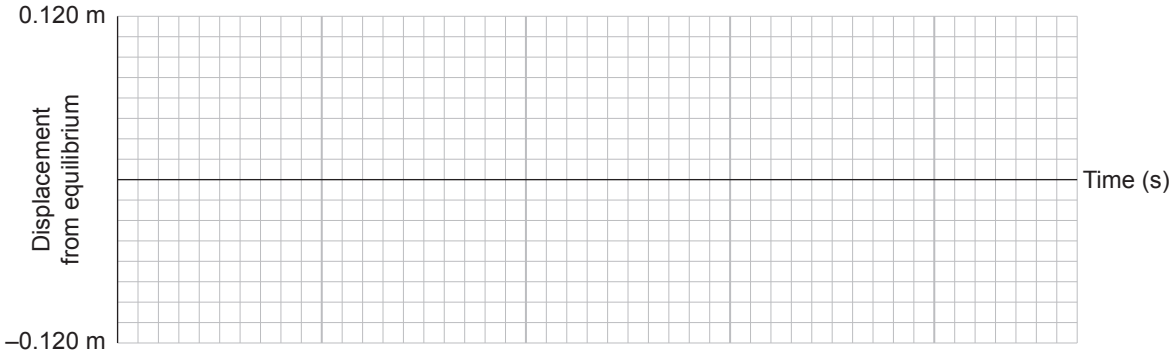
SPARE DIAGRAMS

If you need to redraw your response to Question One (a), use the box below. Make sure it is clear which answer you want marked.

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



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



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

QUESTION NUMBER

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

QUESTION NUMBER