SUPERVISOR'S USE ONLY

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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 2024

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.

QUESTION ONE: CIRCULAR AND ROTATIONAL MOTION

A solid steel ball bearing with a radius of 7.00 mm and a mass of 11.2 g is released from different heights on a steel track. It rolls down and then travels over a series of bumps. Each bump and dip has a radius of 35.0 mm.

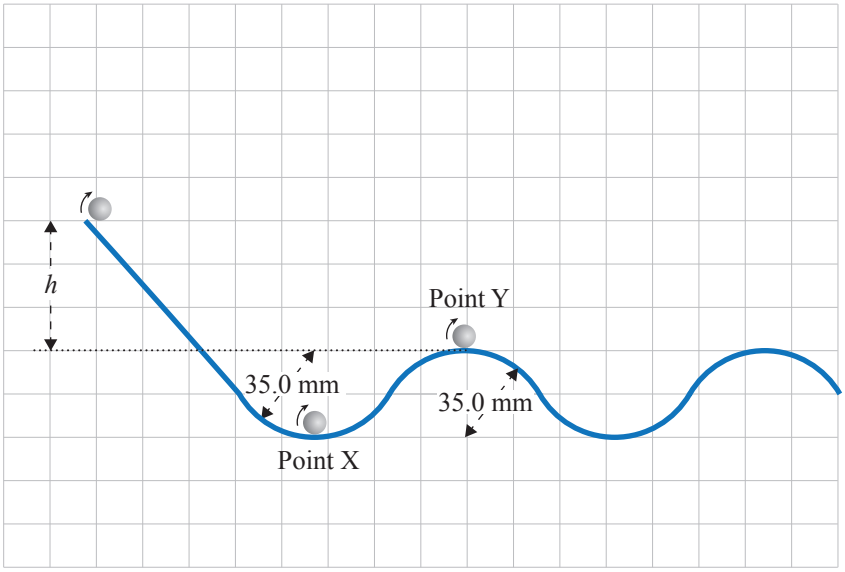


Diagram is NOT to scale

(a) In one trial, the ball bearing reaches the bottom of the first dip with a velocity of 0.850 m s^{-1}.

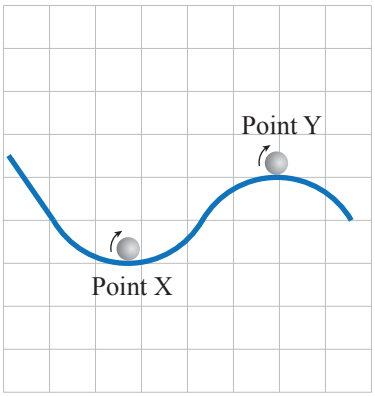
Calculate the angular velocity of the ball bearing when it is at the bottom of the first dip (Point X).

(b) Show that the maximum speed is 0.586 m s^{-1} in order for the ball bearing to remain in contact with the track while going over the bump, at Point Y.

The bump has a radius of 35.0 mm.

(c) Compare the forces acting at the top (Point Y) and bottom (Point X) of each bump, and hence explain how the net force varies in these positions.

Labelled force diagrams will be useful in supporting your answer.

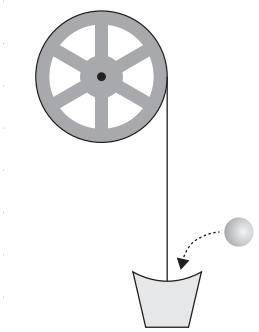


If you need to redraw your response, use the diagram on page 8.

(d) By considering energy changes, calculate the maximum height, h, above the top of the first bump (Point Y) that the ball bearing can be initially released from if it is to remain in contact with the track as it travels over the bumps.

The ball bearing is a solid sphere, and has rotational inertia given by $I = \frac{2}{5}mr^2$.

QUESTION TWO: ROTATIONAL MOTION

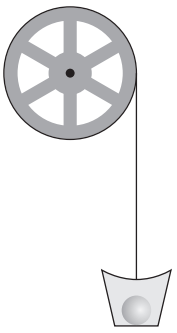


A golf ball of mass 0.0460 kg is placed into a light cup that is attached to a flywheel, diameter 0.220 m, and begins to accelerate downwards at a constant rate of 1.83 m s^{-2}.

(a) Show that the angular acceleration of the flywheel is 16.6 rad s^{-2}.

(b) If the ball and cup start from rest and fall through a distance of 0.750 m, calculate the final angular velocity of the flywheel.

(c) Calculate the rotational inertia of the flywheel.



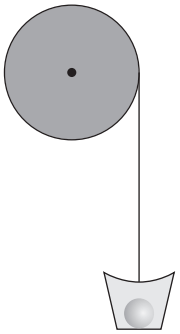
Begin your answer by calculating the force that is causing the flywheel to accelerate.

A free-body force diagram may assist you in calculating the tension in the string.

free-body force diagram

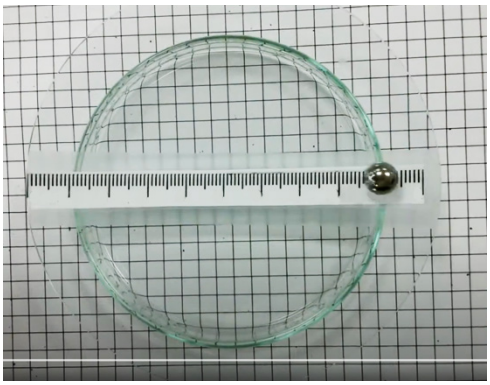
If you need to redraw your response, use the diagram on page 8.

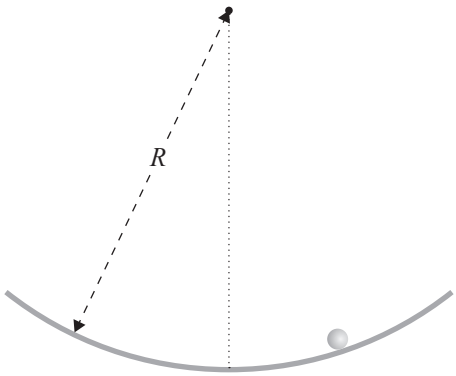
(d) Explain what will happen to the final velocity of the ball and cup if the flywheel is replaced with a solid disc of the same radius and mass as that of the flywheel.



QUESTION THREE: SIMPLE HARMONIC MOTION

A ball bearing is released on a watch glass, and rolls back and forth with simple harmonic motion. The watch glass is a shallow, semi-circular glass bowl with a radius of curvature, R.

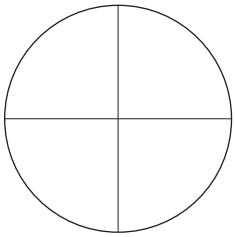




(a) State the two conditions necessary for the ball bearing to be considered to be moving with simple harmonic motion.

(b) The ball bearing is released 0.0400 m from the right of the equilibrium position, and oscillates with a time period of 0.882 s.

Using reference circles or otherwise, calculate the displacement of the ball bearing after 1.20 seconds.

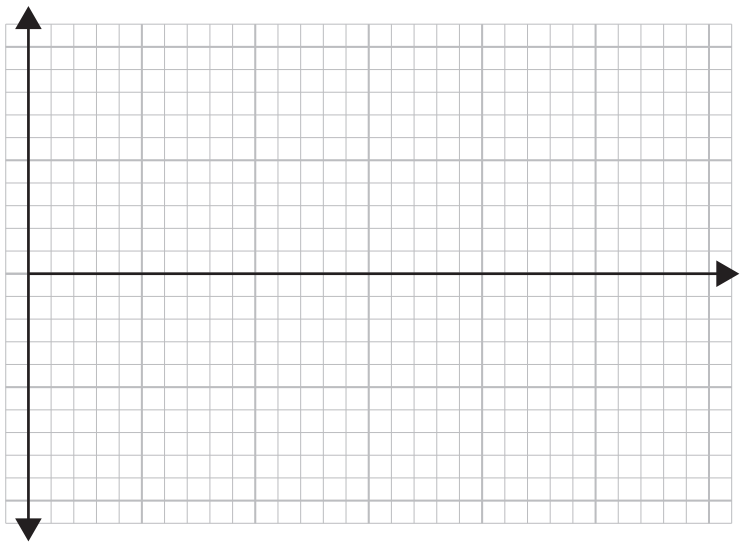


If you need to redraw your response, use the diagram on page 8.

(c) Eventually, the ball bearing comes to rest.

Using the axes provided, draw a labelled graph of the displacement vs time for five complete oscillations.

Include values for displacement and time.



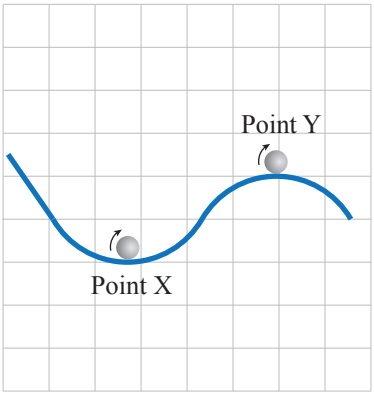
If you need to redraw your response, use the diagram on page 9.

(d) Name this phenomenon, and explain in detail why the ball bearing eventually comes to rest.

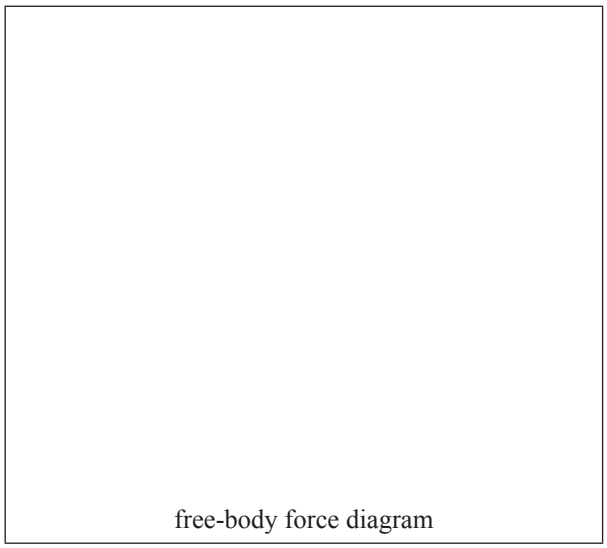
Support your answer with any relevant formulae.

SPARE DIAGRAMS

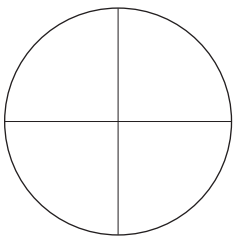
If you need to redraw your response to Question One (c), use the diagram below. Make sure it is clear which answer you want marked.



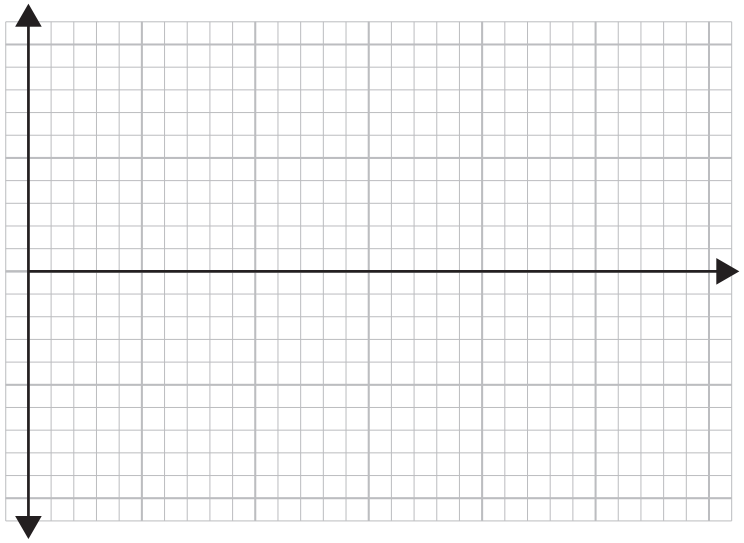
If you need to redraw your response to Question Two (c), use the space below. Make sure it is clear which answer you want marked.



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



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



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