3

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NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2013

91524 Demonstrate understanding of mechanical systems

2.00 pm Monday 25 November 2013
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.

Excellence

TOTAL 21

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You are advised to spend 60 minutes answering the questions in this booklet.

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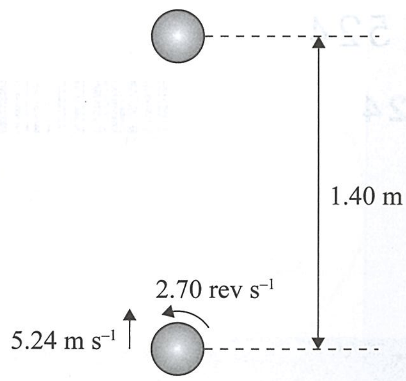
QUESTION ONE: TOSSING BALLS

A hollow ball has a mass of 0.310 kg and radius 0.0340 m. The ball is thrown vertically upwards from rest. It rises through a height of 1.40 m then drops down again. When it is released, it is moving upwards at 5.24 m s^{-1} and rotating at 2.70 revolutions per second.

During the throwing action, a tangential force of 0.480 N is applied to the surface of the ball for a period of 0.250 s.



(a) Show that the angular speed of the ball when it is released is 17.0 rad s^{-1}.

$\omega = 2\pi(2.7) = 16.96 \text{ rad s}^{-1} = 17.0 \text{ rad s}^{-1}$

A

Correct working shown.

(b) Show that the average angular acceleration of the ball before it is released is 67.9 rad s^{-2}.

$\alpha = \frac{\Delta\omega}{t} \quad \alpha = \frac{17.0 - 0}{0.25} = 67.86 \text{ rads}^{-2} = 67.9 \text{ rad s}^{-2}$

A

Correct working shown.

(c) Calculate the rotational inertia of the ball.

$\tau = I\alpha$

$I = \frac{0.480 \times 0.0340}{67.9}$

$= 2.41 \times 10^{-4} \text{ kg m}^2$

M

Shows correct answer and unit. Could gain an E for this part if full working was shown by adding the torque equation.

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(d) For the following two situations, explain whether the height to which the ball rises will be less than, greater than, or the same as 1.40 m.

Ignore the effects of air resistance.

(i) The ball is **not** rotating, but is given the **same** linear speed when it is released.

Energy is conserved so rotational kinetic energy + linear kinetic energy = Energy$_{maximum}$ of the system. Since, the ball is not rotating unlike the 1st example, at the top' the ball ~~of the~~ only has gravitational potential energy. Since this energy is more than that in the 1st example, the height to which the ball rises will be greater than 1.40 m.

~~Pg 8~~

A

Does not understand that only the linear kinetic energy turns into gravitational potential energy, so gets the height incorrect. Incorrect height is justified with reasonable energy idea.

(ii) The ball is **solid** instead of hollow, but has the **same** mass and radius. The same amount of total work is done to give the ball its linear and rotational motion, and it has the same angular speed.

The ball has less rotational inertia because more of the mass is concentrated at a closer distance to the spin axis for a solid ball, compared to the hollow ~~ball~~ ball that has more mass concentrated further from the spin axis, and they have the same mass and radius. Same amount of total work and same angular speed, at the top energy$_{max}$ = gravitational potential energy + rotational kinetic energy. ~~Rot~~ Rotational kinetic energy $= \frac{1}{2} I \omega^2$, since I is less, so it has (Conservation of energy) less rotational kinetic energy and more gravitational potential energy. Therefore the height to which the ball rises will be greater than 1.40 m.

~~Pg 8~~

M

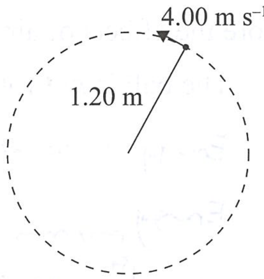
M

Correctly explains how the rotational inertia changes well, and explains how this affects the rotational kinetic energy. Would have gained an E for this section if they had noted that there was more linear kinetic energy, which changes into more gravitational potential energy, and therefore rises to a greater height.

M6

QUESTION TWO: SWINGING BALLS

A ball on the end of a cord of length 1.20 m is swung in a vertical circle. The mass of the ball is 0.250 kg. When the ball is in the position shown in the diagram, its speed is 4.00 m s^{-1}.



Acceleration due to gravity on Earth = 9.81 m s^{-2}

(a) Calculate the size of the centripetal force acting on the ball at the instant shown in the diagram.

$F = m\left(\frac{v^2}{r}\right) = \frac{0.250 \times 4^2}{1.20} = 3.33\text{ N}$

A

Correct answer.

(b) Explain why the ball moves fastest at the bottom of the circle.

At the top of the circle, the ball has more gravitational potential energy and less kinetic energy than at the bottom because energy of a closed system is conserved. Since the ball has more kinetic energy at the bottom, it has more speed. Any other point in the circle has more gravitational potential energy so the bottom must be the fastest.

M

Links conservation of energy to more kinetic energy at the bottom, therefore higher speed.

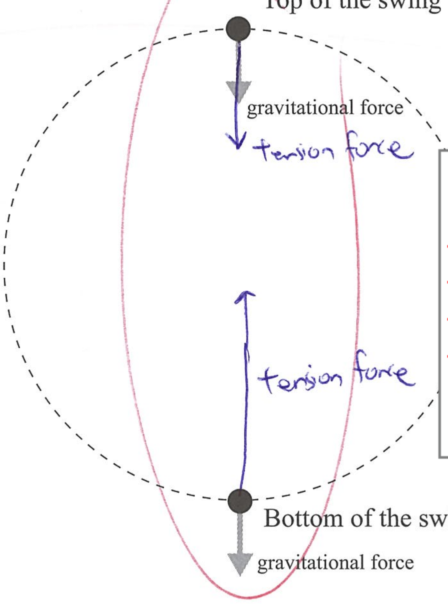
91524

(c) (i) Diagram 1 shows the gravitational force acting on the ball at the top and bottom of the swing.

Assuming the tension force is non-zero at all points, draw vectors to show the relative sizes of tension forces at the top and bottom.

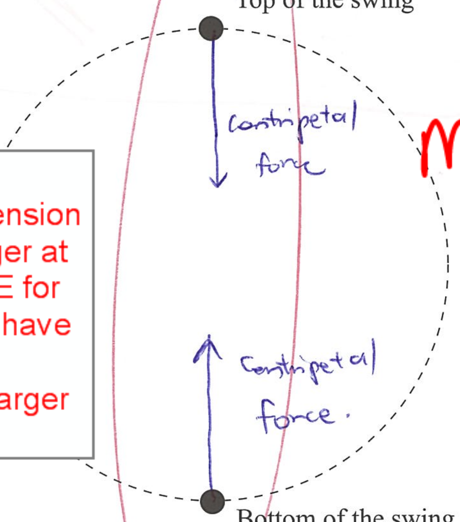
(ii) Using the same scale, draw the **centripetal force**, on Diagram 2, at these two positions.

Diagram 1



Arrows have correct directions, and the tension force is correctly larger at the bottom. To gain E for this part, they would have to have shown the centripetal force as larger at the bottom.

Diagram 2



M

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(d) Show that the minimum speed the ball must have during its circular motion is 3.43 m s^{-1} at the top.

Explain your answer.

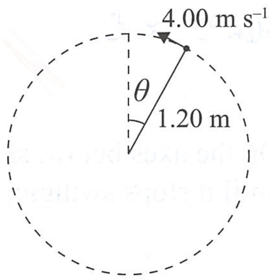
$F_{resultant} = F_g + F_T$, for speed to be at a minimum, $F_T = 0$ so $F_{resultant} = F_g$. $F_{resultant}$ in this case is $F_{centripetal}$. $\therefore F_{centripetal} = F_g$

$\frac{\cancel{m} v^2}{r} = \cancel{m} g$ $\quad v = \sqrt{9.81 \times 1.2} = 3.43 \text{ m s}^{-1}$. If speed goes below that, the centripetal force required to stay in that circle is smaller, so the "remaining" F_g will pull the ball and disrupt the circle pattern.

E

Explains why Fg=Fc by saying tension is zero.
Then shows some working and solves for v.

(e) The ball drops to its minimum speed of 3.43 m s^{-1} at the top of the circle.



Using conservation of energy, show that the angle at which the tangential speed of the ball is 4.00 m s^{-1}, is $\theta = 34.9°$.

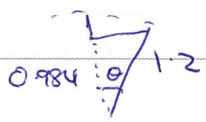
$\frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2$

Assuming the level that passes through the centre of the circle, $h = 0$ m,

$\frac{1}{2}(3.43)^2 + (9.81)(1.2) = \frac{1}{2}(4^2) + 9.81 h_2$

$h_2 = 0.984$ m

From the diagram,



$\cos\theta = \frac{0.984}{1.2}$

$\theta = 34.9°$

E

Uses conservation of energy and trigonometery correctly to get the angle.

E8

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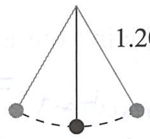
QUESTION THREE: OSCILLATING BALLS

A ball, attached to a cord of length 1.20 m, is set in motion so that it is swinging backwards and forwards like a pendulum.



(a) Show that the period of a pendulum of length 1.20 m that is oscillating in simple harmonic motion is 2.20 s.

$T = 2\pi\sqrt{\frac{l}{g}} = 2\pi\sqrt{\frac{1.2}{9.81}} = 2.1975\,s = 2.20\,s$

A

Correct working.

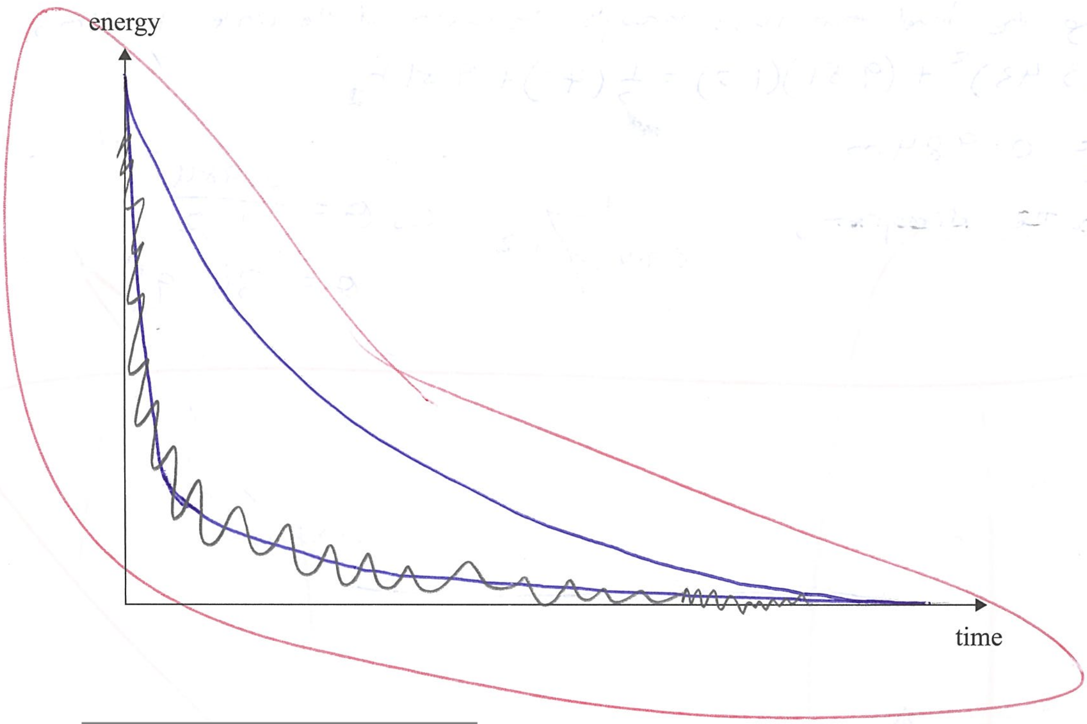
(b) Explain what must be done to ensure that the motion of the ball approximates simple harmonic motion.

The angular displacement of the pendulum must be small enough so that the pendulum bob travels an approximate straight line and that both $\sin\theta$ and $\tan\theta \approx \theta$.

M

States that angle must be small, and states one requirement for SHM (straight line motion).

(c) On the axes below, sketch a graph to show what happens to the ball's **total** energy over time until it stops swinging.



M

Graph slopes down in a correct exponential decay shape.

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(d) It is possible to get the ball swinging by holding the top end of the cord and gently shaking it backwards and forwards.

Explain how shaking the top end of the cord can make the ball on the bottom of the cord oscillate in simple harmonic motion.

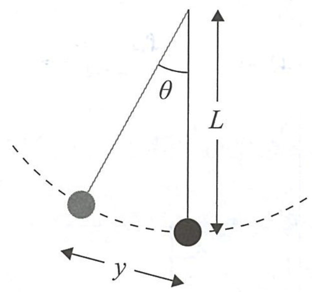
In your answer, you should consider resonance and energy transfer.

As long as the energy input has a driving force that has a frequency that matches the natural frequency of the pendulum, the pendulum will resonate and oscillate at its largest amplitude. As long as the acceleration and driving force is directly proportional to the displacement of the bob towards the centre (equilibrium position), the ball on the bottom of the cord will oscillate in simple harmonic motion.

M

States that shaking must be at natural frequency to get a large amplitude. To get E they could add that energy is transferred from hand to kinetic and gravitational potential energy of ball.

(e) Simple harmonic motion requires a restoring force that changes in proportion to the size of the displacement.

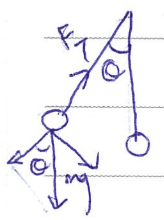


Discuss what provides the restoring force when the ball is swinging in simple harmonic motion.

In your answer, you should:

- describe what forces act on the ball
- explain how these forces change as the ball swings
- draw vectors to show how a restoring force is produced.

Forces that act on the ball are gravity force and tension force. ~~The ball has to travel in a straight line to be considered a simple harmonic motion. So only~~ the tension force can be resolved horizontally to provide the restoring force ($F_T \sin\theta$). For the gravity force to ~~act on~~ provide the restoring force,



from diagram, $mg\sin\theta$ component can be resolved to get a force acting on the horizontal ($mg\sin\theta\cos\theta$). So total restoring force at maximum amplitude $= F_T\sin\theta + mg\sin\theta\cos\theta$ Pg 8

E

Shows correct force diagram with tension and gravity. Gets the idea that the restoring force is a component of the gravitational force or tension force, but there is some contradiction. Explains that vertical component of tension balances gravitational force, and therefore as the angle gets larger the tension force gets larger.

E7

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

QUESTION NUMBER

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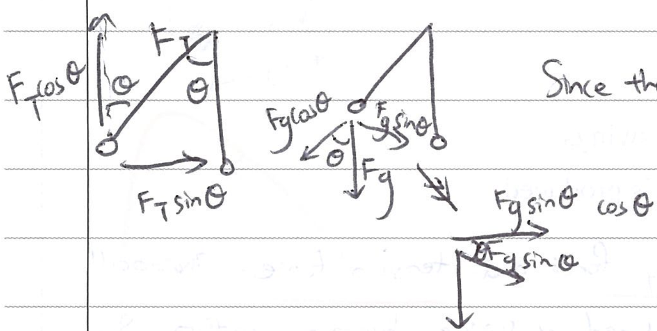
~~1)d)i) $E_{max} = E_{K(LIN)} + E_{K(ROT)}$ At the top, energy is conserved since no external energy input. $E_{max} = E$~~

e) As the ball swings, the weight does not change. (m and g are constant). However, the component of mg that assists in the restoring force changes. At the edge of each swing, this component is at its maximum, while at the equilibrium position, ~~the~~ mg does not have a component in that direction.

The tension force changes from maximum at the edge to minimum in the middle. At the edges, the vertically resolved component has to equal the (mg)., So does the "vertically" resolved component of mg has to equal the tension force. ~~So the~~ At the middle $F_T = F_g$. So at the edge, F_T has to be the biggest to ~~neutralise the~~ resolve forces which equals the F_g.



Since there is no force acting at equilibrium, it matches the motion of a simple harmonic motion.

Based on the nature of sin and cos graphs, the magnitude of the force is directly proportional to the distance from the equilibrium and always act towards the equilibrium based on the vector diagrams.

91524