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QUALIFY FOR THE FUTURE WORLD
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Level 3 Physics, 2016

91524 Demonstrate understanding of mechanical systems

2.00 p.m. Tuesday 15 November 2016
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.

Merit

TOTAL 16

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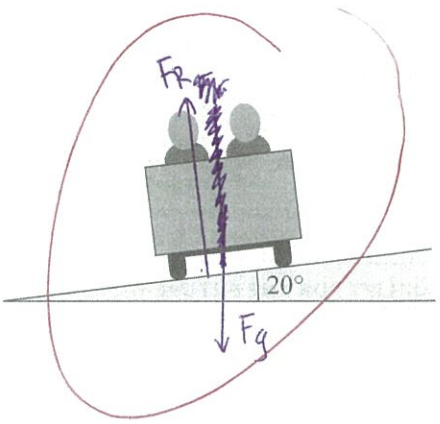
QUESTION ONE: CIRCULAR MOTION

Alice is in a car on a ride at a theme park. The car travels along a circular track that is banked, as shown in the diagram below.

The candidate correctly draws and labels two force vectors.

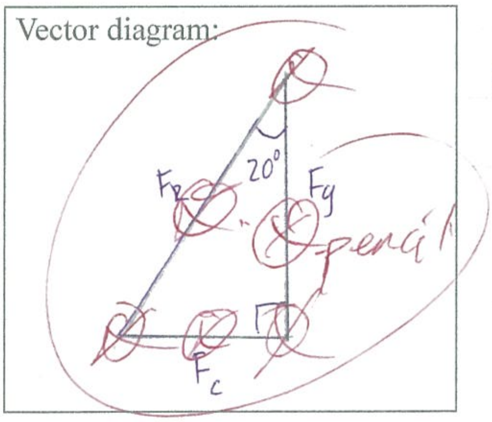


(a) On the diagram above, draw labelled vectors showing the two forces acting on the car.

You may assume that friction is negligible.

(b) The mass of the car and passengers is 9.60×10^2 kg. The track is banked at an angle of 20°.

Use a vector diagram to calculate the size of the centripetal force on the car.



$\tan\theta = \frac{o}{a}$

$\tan 20° = \frac{F_c}{F_g}$

$F_g = mg$

$= 9.6 \times 10^2 (9.81)$

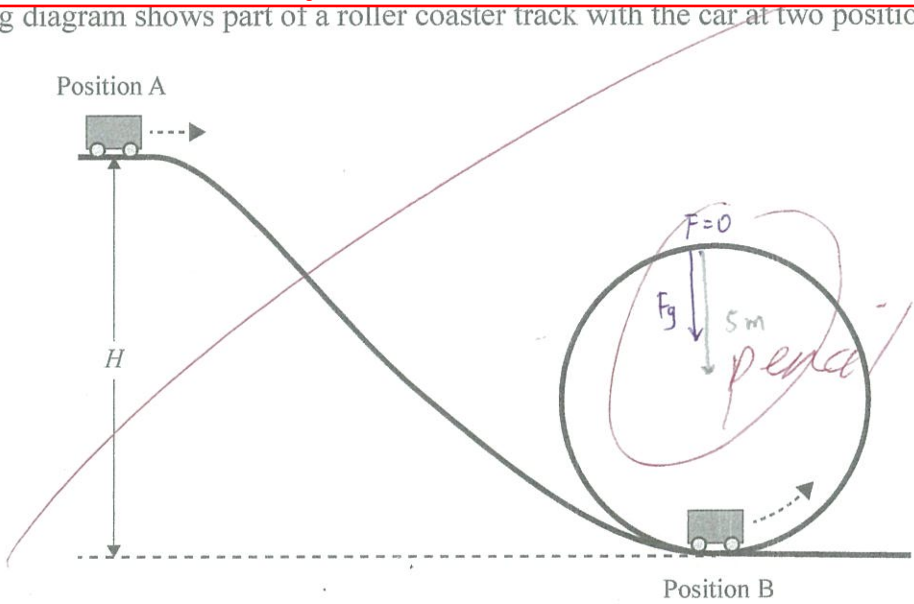
$F_g = 9420\text{N}$

$F_c = \tan 20°(9420)$

$F_c = 3427.7\text{ N} = 3430\text{N}$ (3s.f.)

For an Achieved, the candidate correctly calculates the size of the centripetal force of the car. To get a Merit, the candidate also needs to draw a correct vector diagram..

The following diagram shows part of a roller coaster track with the car at two positions.



(c) Compare the force that the track exerts on the car when the car is at the top of the hill (Position A), with the force that the track exerts on the car when the car is at the bottom of the hill, entering the loop (Position B).

Explain your answer.

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At position A, the force that the ~~car~~ track exerts on the car is the reaction force which is acting upwards and is balanced by the force of gravity. However, at position B, the force that the track exerts onto the car is the centripedal force which allows the car at position B to be in circular motion. The centripedal force is as a result of the ~~vertical component of~~ friction force of the track onto the car. ~~which is~~ The centripedal force at position B is acting towards the centre.

The candidate correctly explains that at position A the force from the track equals the gravity force .To get a Merit, the candidate needs to give the complete answer for both positions with links between concepts.

(d) At the top of the circular loop the force that the track exerts on the car is zero.

Using energy considerations, calculate the height H, of the hill if the radius of the loop is 5.00 m.

You may assume that friction is negligible.

$F_c = F_g$

$\frac{mv^2}{r} = mg$

$v = \sqrt{gr}$

pencil

$F_c = F_g$

$F_c = mg = 9.60\times10^2\,(9.81)$

$F_c = 9420\,N$

$F_c = \frac{mv^2}{r} \qquad 9420 = \frac{(9.60\times10^2)\,v^2}{5} \qquad v = \sqrt{\frac{9420\times5}{960\times10^2}} \qquad v = 7.00\,ms^{-1}$

$E_p = E_K$

$mgh = \frac{1}{2}mv^2$

$(9.81)\,h = \frac{1}{2}(7)^2$

~~h = 2.8m~~ $h = 2.50\,m$

The candidate correctly calculates the speed of the car on top of the loop. For Excellence, the candidate needs to show correct calculation and correct answer for the height H.

M5

QUESTION TWO: ROTATIONAL MOTION

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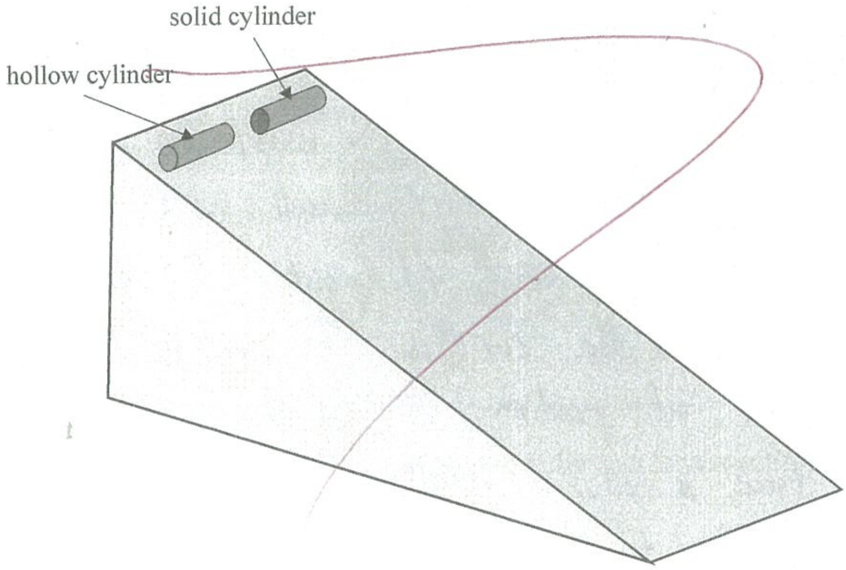
A solid cylinder and a hollow cylinder of the same shape and mass are rolled down a slope.



(a) State the energy changes that take place as the cylinders roll down the slope.

You may assume that there is negligible heat and sound energy produced.

To get an Achieved, the candidate needs to state that gravitational potential energy changes to both linear and rotational kinetic energy.

At the top, the total energy of the cylinders will be $E_T = E_p$. As the cylinders roll down the slope, gravitational potential energy will convert into kinetic energy and rotational kinetic energy.

(b) The hollow cylinder has a radius of 0.058 m. It rolls down the slope, and reaches a speed of 0.250 m s^{-1} at the bottom.

The rotational inertia of the hollow cylinder is 0.140 kg m^2.

Calculate the rotational kinetic energy of the hollow cylinder at the bottom of the slope.

$v = r\omega$ $\quad 0.250 = 0.058\,\omega$, $\quad \omega = \frac{0.250}{0.058}$, $\quad \omega = 4.31$ rads^{-1} (3 s.f.)

$E_{K(ROT)} = \frac{1}{2} I \omega^2$

$E_{K(ROT)} = \frac{1}{2}(0.140)(4.31)^2$

$E_{K(ROT)} = 1.30$ J (3s.f.)

Correct equation and evidence for calculating the rotational kinetic energy.

(c) The hollow cylinder starts from rest and has an angular acceleration of 1.72 rad s^{-2}.

Calculate the time taken to complete the first full rotation.

For an Achieved, the candidate uses the correct formula to calculate the time taken to complete the first full rotation but substituting incorrect final angular velocity.

$\alpha = 1.72 \text{ rad s}^{-2}$

$w_i = 0$

$w_f = 4.31 \text{ rad s}^{-1}$

$W_f = w_i + \alpha t$

$4.31 = 0 + 1.72 t$

$t = \frac{4.31}{1.72}$

$t = 2.46 \text{ s}$

$\cancel{W = 2\pi f}$, $\cancel{f = \frac{1}{T}}$

$\cancel{w = \frac{2\pi}{T}}$ $\cancel{4.31 = \frac{2\pi}{T}}$ $\cancel{T = \frac{2\pi}{4.31}}$ $\cancel{F = 1.4576}$

$\cancel{T = 1.465 \text{ (3s.f.)}}$

(d) The solid and the hollow cylinders are both released at the same time from the top of the slope.

Explain why the solid cylinder reaches the bottom of the slope first.

The solid cylinder and hollow cylinder have the same mass and radius, however, as the solid cylinder has its mass concentrated closer to its center of mass, as $I \propto r^2$, it will have a smaller inertia compared to the hollow ball which has its mass concentrated further from the centre of mass thus it has a larger inertia. As the solid cylinder has a smaller inertia, $E_{K(ROT)} \propto I$ provided w is constant thus a ~~smaller inertia will~~ mean less E_p at the top will convert into $E_{K(ROT)}$ for the solid cylinder. As a result, more E_p will convert into E_K (linear) for the solid ~~cylinder thus as~~ E_K ~~is greater~~, $E_K \propto v$ (m is constant) thus it will travel with a greater velocity and thus reach the bottom of the slope first.

peace!

The candidate correctly links two ideas by stating that solid cylinder has less rotational inertia since it has all its mass closer to the centre and then correctly links two ideas to conservation of energy.

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M6

QUESTION THREE: SIMPLE HARMONIC MOTION

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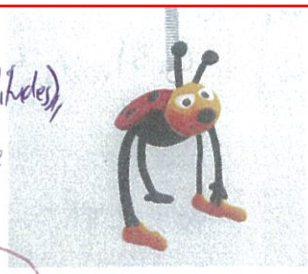
A toy bumble bee hangs on a spring suspended from the ceiling in the laboratory. Tom pulls the bumble bee down 10.0 cm below equilibrium and releases it. The bumble bee moves in simple harmonic motion.

To get an Achieved, the candidate needs to state that the acceleration(or restoring force) is proportional to displacement and acts in the opposite direction to displacement.

$A = 0.1$ m pencil



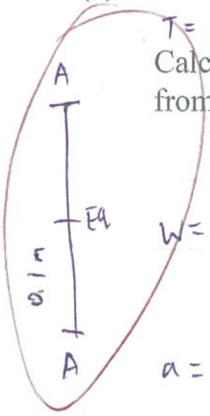
(a) State the two conditions necessary for simple harmonic motion.

- The spring must travel between two extreme ends (amplitudes) in a linear motion. There must be a restoring force acting in the opposite direction to ~~displacement, towards equilibrium~~ to bring the spring back to equilibrium.

(b) The bumble bee's oscillation has a period of 1.57 s.

$T = 1.57$ s

Calculate the bumble bee's acceleration at time $t = 0.25$ s after Tom releases the bumble bee from the lowest point.



$w = \frac{2\pi}{T} = 4.00 \text{ rads}^{-1}$

$a = -Aw^2 \cos wt$

$a = -0.1 (4)^2 \cos(4 \times 0.25)$

$a = -0.1 (4)^2 (0.5398)$

$a = -0.8638 \text{ ms}^{-2}$, $a = 0.864$ ms^{-2} (3 s.f.) towards the equilibrium position

Correct working and answer for the bumble bee's acceleration.

(c) Tom pushes the toy bumble bee with a very small force at regular intervals of time (periodically), so that eventually it is moving up and down with a very large amplitude.

State the name of this phenomenon.

Explain how the bumble bee's motion develops a very large amplitude.

The phenomenon is resonance. Resonance is when the spring is ~~on~~ given a force that will oscillate at the natural frequency of the spring, the spring will be in resonance where it will have maximum amplitude. The force provided by Tom will be converted between elastic potential energy and kinetic energy. The spring will oscillate in simple harmonic motion.

The candidate correctly states the name of the phenomenon as resonance and links matching driving frequency to natural frequency.

(d) Tom stops pushing the bumble bee when its displacement is 20 cm.

Using the axes given below, draw a graph of displacement against time for three complete oscillations, starting from $y = +20$ cm.

Include appropriate values on both axes.

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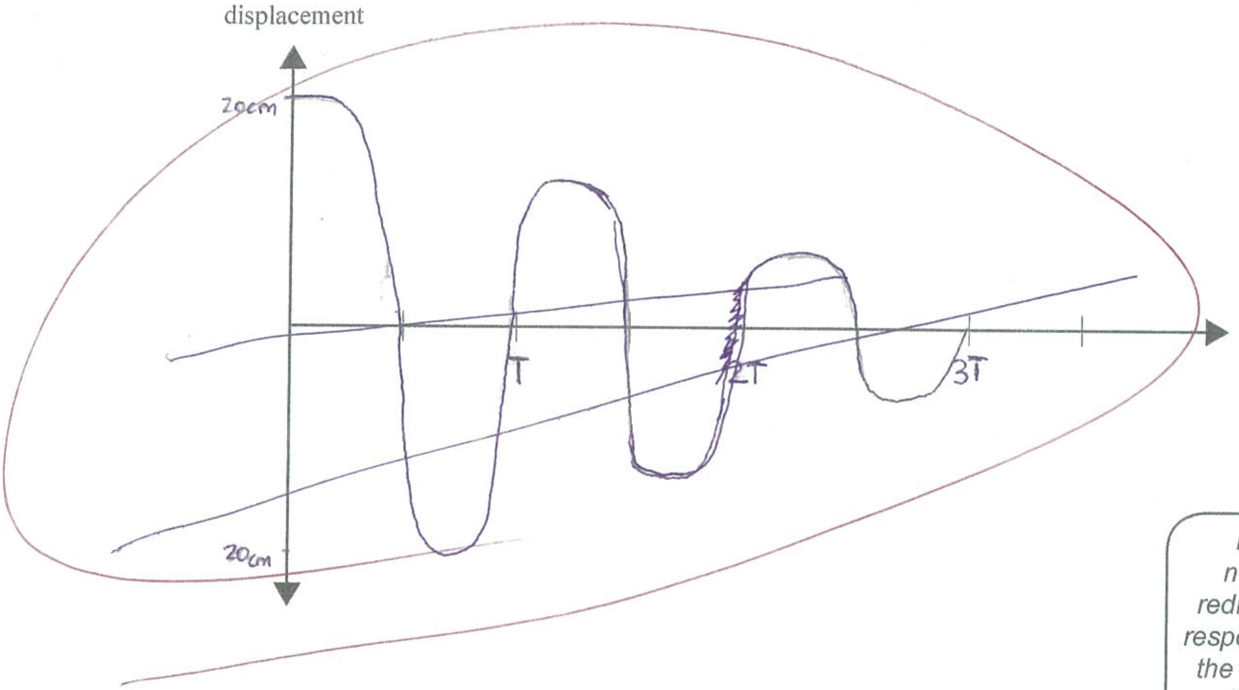
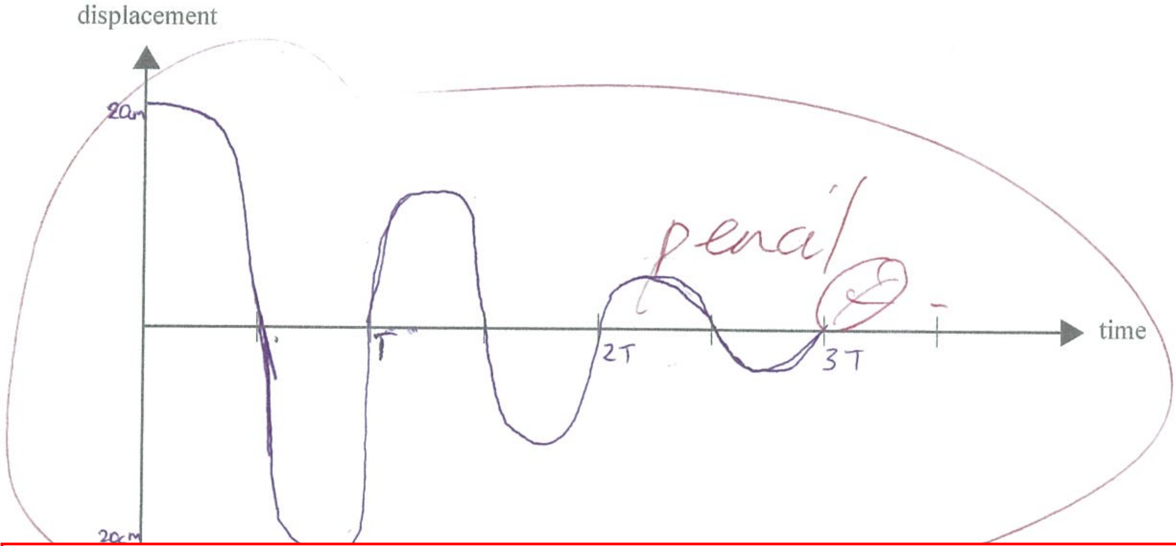


If you need to redraw your response, use the diagram below.

SPARE DIAGRAM

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



For an Achieved, the candidate needs to correctly draw the damped shape for 3 complete cycles starting at +20cm. To gain a Merit, the candidate needs to have a constant period and include appropriate values on both the axes for 3 complete cycles.

M5

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

QUESTION NUMBER

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91524