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90521

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Level 3 Physics, 2005

90521 Demonstrate understanding of mechanical systems

Credits: Six
9.30 am Tuesday 29 November 2005

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 answer ALL the questions in this booklet.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

For all numerical answers, full working must be shown, and the answer must be rounded to the correct number of significant figures and given with an SI unit.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–10 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.

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Achievement Criteria		
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and / or relationships.	Give concise explanations that show clear understanding in terms of phenomena, concepts, principles and / or relationships.
Solve straightforward problems.	Solve problems.	Solve complex problems.
Overall Level of Performance		

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You may find the following formulae useful.

$F_{\text{net}} = ma$	$p = mv$	$\Delta p = F\Delta t$	$\Delta E_P = mgh$
$W = Fd$	$E_{\text{K(LIN)}} = \frac{1}{2}mv^2$		
$d = r\theta$	$v = r\omega$	$a = r\alpha$	$\omega = \dfrac{\Delta\theta}{\Delta t}$
$\alpha = \dfrac{\Delta\omega}{\Delta t}$	$\omega = 2\pi f$	$f = \dfrac{1}{T}$	$E_{\text{K(ROT)}} = \frac{1}{2}I\omega^2$
$\omega_f = \omega_i + \alpha t$	$\theta = \dfrac{(\omega_i + \omega_f)}{2}t$	${\omega_f}^2 = {\omega_i}^2 + 2\alpha\theta$	$\theta = \omega_i t + \frac{1}{2}\alpha t^2$
$\tau = I\alpha$	$\tau = Fr$	$L = mvr$	$L = I\omega$
$F_g = \dfrac{\mathrm{G}Mm}{r^2}$	$F_c = \dfrac{mv^2}{r}$		
$F = -ky$	$E_P = \frac{1}{2}ky^2$	$T = 2\pi\sqrt{\dfrac{l}{g}}$	$T = 2\pi\sqrt{\dfrac{m}{k}}$
$y = A\sin\omega t$	$v = A\omega\cos\omega t$	$a = -A\omega^2\sin\omega t$	$a = -\omega^2 y$
$y = A\cos\omega t$	$v = -A\omega\sin\omega t$	$a = -A\omega^2\cos\omega t$	

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

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QUESTION ONE: LINEAR AND ROTATIONAL MOTION

The London Eye is a giant rotating wheel that has 32 capsules attached at evenly spaced intervals to its outer rim. Passengers riding in the capsules get spectacular views over London, especially at the top.

Capsule

The capsules each have mass 1.0×10^4 kg and are at a distance of 68 m from the centre of the wheel. They travel at a constant speed of 0.26 m s^{-1}.

(a) Calculate the size of the centripetal force that is maintaining the vertical circular motion of a capsule about the centre of the wheel.

centripetal force = ____________

(b) Show that the angular speed of the wheel is 3.8×10^{-3} rad s^{-1}.

(c) Calculate the time it takes the wheel to travel a complete revolution.

time = ____________

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When the London Eye is started up each day there are no passengers in the capsules and it takes 2.3 s for an average net torque of 4.6×10^7 N m to accelerate the wheel from rest to its operational speed of 0.26 m s^{-1}.

(d) Calculate the average angular acceleration of the wheel.

angular acceleration =

(e) Calculate the angle, in degrees, the wheel turns through during start-up.

angle =

(f) Calculate the rotational inertia of the wheel.

rotational inertia =

(g) In practice, the angular acceleration will gradually reduce to zero during the 2.3 s. It will continue to be zero after this time even though a torque continues to be applied. Explain why the angular acceleration behaves in this way.

(h) At what point on the wheel could a force be applied to give maximum torque?

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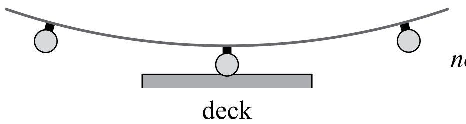
(i) By considering what happens to kinetic energy, gravitational potential energy and any other forms of energy, describe and explain the energy transformations that occur while the wheel rotates.

The passengers enter and leave the capsules from a deck at the bottom of the wheel. Because the wheel does not stop, each capsule is travelling in the arc of a circle as it moves past the horizontal deck.



It takes 29 s for a capsule to pass in front of the deck. The first part of the deck, which is passed during the first half of this time, is for passengers leaving the capsule. The second part of the deck is used by passengers entering the capsule.

(j) (i) Calculate the angle through which the wheel turns while one capsule is passing in front of the **whole** length of the deck.

angle = ______

(ii) Calculate the length of deck that is used by passengers entering the capsule.

deck length = ______

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(k) At the start of the day, when passengers are entering the capsules, will angular momentum of the wheel be conserved? Explain your answer. Assume the speed of the capsules stays constant.

A passenger is inside a moving capsule. At any position in the ride her motion can be considered to be linear (because she has a tangential velocity), or it can be considered to be rotational (because she is rotating about the centre of the wheel). Her kinetic energy, therefore, can be considered to be either linear or rotational.

(l) Using this energy consideration, derive a **formula** for her rotational inertia.

The mass of the passenger is 65 kg.

(m) Calculate the angular momentum of the passenger about the centre of rotation of the wheel.

angular momentum = __________

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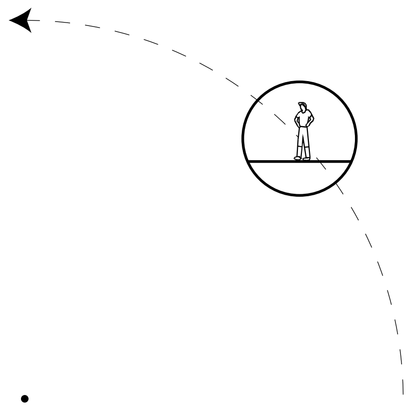
The diagram below is a cross section through the middle of the capsule and shows the capsule, with the passenger standing on the platform inside, rotating about the centre of rotation of the wheel.



(n) On the diagram above, draw a labelled free-body force diagram to show how the forces on the **passenger** combine to give the centripetal force causing her to move in a circle.

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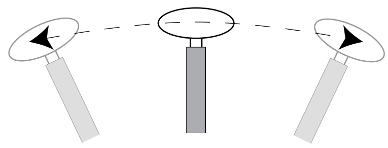
QUESTION TWO: SIMPLE HARMONIC MOTION



Wind can make the top of the wheel sway from side to side. The maximum total distance a capsule moves from one side to the other is restricted to 0.150 m.

The diagram shows just one capsule (at the top of the wheel) as it sways from side to side.

Assume the swaying motion is simple harmonic with a natural angular frequency of 1.8 rad s^{-1}.

(a) What is the amplitude of the motion?

amplitude = ______________________

(b) Calculate the maximum acceleration of a passenger. Give your answer to the correct number of significant figures.

____

____

maximum acceleration = ______________________

(c) At what displacement from the equilibrium position would this maximum acceleration occur?

____

displacement = ______________________

The restriction on the maximum amplitude of vibration is brought about by dampers that are incorporated into the rim structure. Without the dampers, strong wind could cause the top of the wheel to sway a total distance of as much as 3.0 m from one side to the other. This would be uncomfortable for the passengers. (Assume the natural frequency of the undamped SHM is the same as the damped SHM.)

(d) If the dampers were **not** present, calculate the speed of the capsule 0.75 s after it had reached an end position.

____

____

____

____

speed = ______________________

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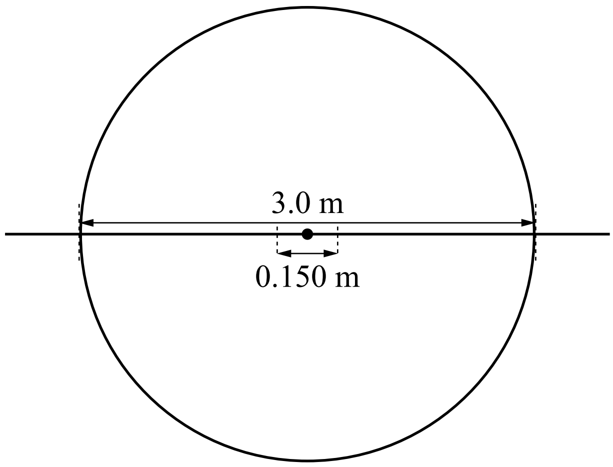
(e) In questions (b) and (c), the acceleration was calculated at a particular displacement with the dampers present. Explain why the acceleration would have had the same value at this displacement if the dampers had not been present.

(f) Calculate the period of the SHM.

period =

(g) If the dampers were not present the passengers would sway beyond the maximum damped displacement. Using the reference circle below (not to scale) or otherwise, calculate the time a passenger would spend **outside** the damped maximum displacement each cycle.



time =

**Extra paper for continuation of answers if required.
Clearly number the question.**

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Question number