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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, 2004

90521 Demonstrate understanding of mechanical systems

Credits: Six
9.30 am Thursday 18 November 2004

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 pages provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–11 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 (all criteria within a column are met)		

You may find the following formulae useful.

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

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

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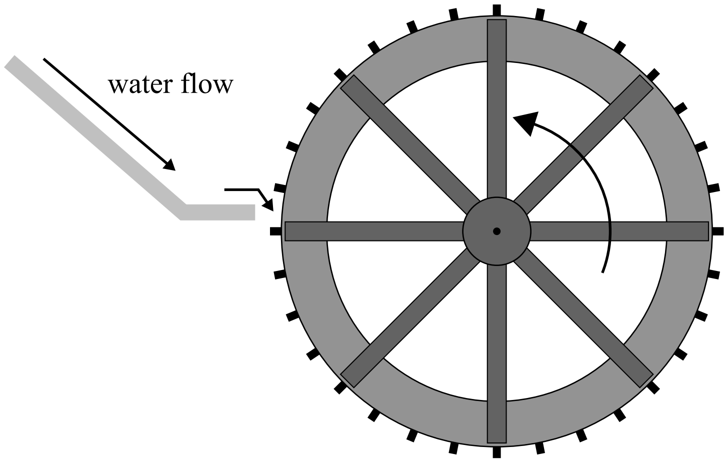
QUESTION ONE: JOHN BYCROFT'S WATERWHEEL

At Howick Historical Village in Auckland there is an old 19th century iron water wheel called the John Bycroft. It was used to generate power to turn grindstones that made flour for his famous biscuits. If you pay $1, you can activate a switch to turn on the water flow and see the wheel in action.

A diagram of the waterwheel is shown below.



When the water first turns the wheel, it accelerates. After some time the angular speed of the wheel reaches its maximum and then stays constant. At this constant angular speed, the wheel completes one revolution in 20.0 s.

(a) Show that the constant angular speed is 0.314 rad s^{-1}.

The rotational inertia of the wheel about its axis of rotation is 3.50×10^4 kg m^2.

(b) Calculate the rotational kinetic energy of the wheel at the constant angular speed.

rotational kinetic energy = ______

(c) (i) Calculate the angular momentum of the wheel about its axis of rotation, at this constant angular speed.

angular momentum = ______

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(ii) During the time the wheel is rotating at this angular speed, is angular momentum conserved? Give a reason for your answer.

(d) When the water first turns the wheel, it accelerates to an angular speed of 0.200 rad s^{-1} in 17.2 s.

Show that the angular acceleration is 0.0116 rad s^{-2}.

(e) The radius of the wheel is 1.375 m and its rotational inertia is 3.50×10^4 kg m^2.

Calculate the average force applied to the blades of the wheel by the water flow to make it accelerate.

average force = ______________

(f) Some school students were doing a project to decide how the angular acceleration of the wheel could be increased. They suggested making the wheel out of wood instead of iron, but with the same dimensions.

Assuming that the applied torque was the same, would this achieve their aim? Explain your answer.

QUESTION TWO: BOUNCING ON THE TRAMPOLINE

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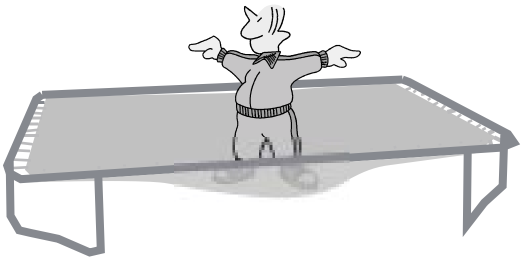
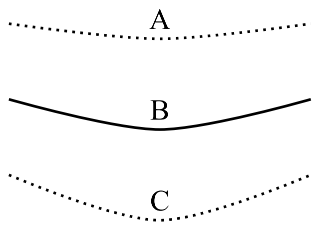
Use the gravitational field strength = 9.80 N kg^{-1} (or acceleration due to gravity = 9.80 m s^{-2}).

Ivan is practising for a national trampolining competition. After a while he takes a rest and just stands on the mat, allowing it to bounce him up and down. Assume this motion is like a mass on a spring, performing simple harmonic motion.





In each oscillation, the surface of the trampoline mat moves between positions A and C as shown in the diagram.

Initially the amplitude (maximum displacement) of the oscillation is 0.14 m.

(a) Calculate the distance AC.

AC = ________________

Ivan's mass is 62.0 kg and the period of his oscillations is 0.85 s.

(b) Show that the spring constant of the trampoline has a value of 3387.8 N m^{-1}. Give this answer to the appropriate number of significant figures.

spring constant = ________________

(c) Calculate the angular frequency for the motion.

angular frequency = ________________

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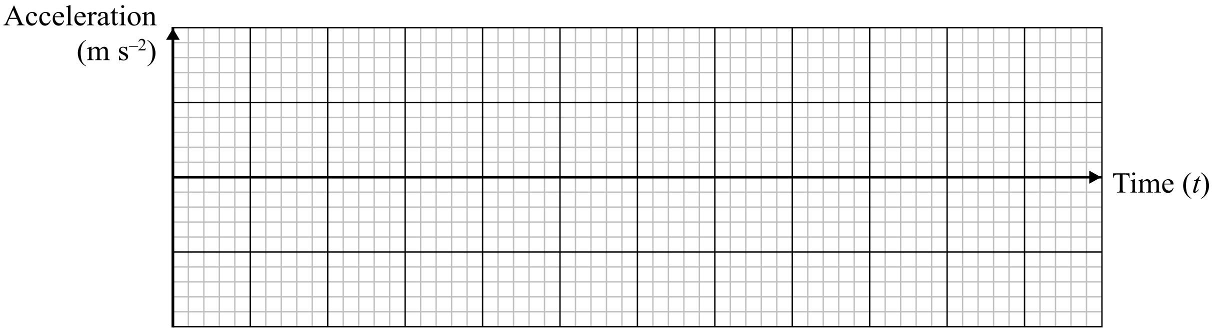
Positions B, A and C (page 5) show the middle and end positions of the oscillations of the trampoline mat.

(d) On the axes provided below, sketch the shape of the acceleration–time graph of Ivan's motion for one complete cycle. The maximum acceleration is 7.6 m s^{-2}.

Label at least one point on the time axis. Assume t = 0 when Ivan is at point C. (Ignore any loss of energy in the cycle.)



(e) (i) State a **position** at which Ivan's kinetic energy is maximum.

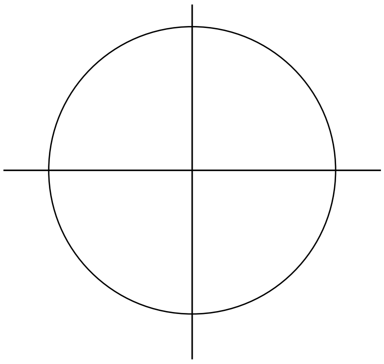
(ii) Calculate the speed that gives this maximum kinetic energy.

speed =

(f) Calculate Ivan's potential energy at position C in his motion.

potential energy =

(g) (i) On the reference circle below, show Ivan's position after one-eighth of a cycle. Label the distance of this position from the equilibrium position, y. Again assume t = 0 at point C.



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(ii) Calculate Ivan's distance, y, from the equilibrium position at this time.

distance = ____________________

(h) By working his legs, Ivan can input energy and increase the maximum distance from the equilibrium position of his bounce until his feet leave contact with the mat for part of each cycle.

Explain why his motion can no longer be considered as simple harmonic.

(i) On one occasion, Ivan's speed as he leaves the mat is 2.4 m s^{-1}. His potential energy at this instant is 54.5 J.

Calculate the maximum distance from the equilibrium position that Ivan must generate to give him this speed as he leaves the mat. (Assume Ivan does not input energy on the way up.)

maximum distance = ____________________

(j) Ivan needs to bounce at a particular frequency to get the greatest amplitude of oscillation on the mat.

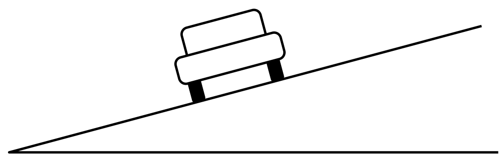
What is the name of this frequency?

QUESTION THREE: DRIVING ON BANKED CORNERS

Use the gravitational field strength = 9.80 N kg^{-1} (or acceleration due to gravity = 9.80 m s^{-2}).

Moana is driving home from work in her car. At one point she drives around a bend in the road that has a horizontal radius of 90.0 m and banking at an angle of 6.50°. Bends in roads are banked so that cars can travel around them at the same speed as on straight parts without sliding. The mass of Moana and the car is 995 kg. Assume the friction force acting up or down the slope is zero.

(a) On the diagram below, draw a free body force diagram to show the reaction force, F_R, and the gravitational force, F_g, acting on Moana's car. Label both vectors.



(b) On the diagram, draw and label an arrow to show the direction of the unbalanced force acting on the car.

(c) Calculate the value of the vertical component of the reaction force.

vertical component of the reaction force = ______________

(d) In terms of the forces acting on the car, explain why the car will travel around the bend.

(e) Calculate the speed of the car as it drives around the bend.

speed = ____________________

(f) Explain what would happen to this speed if the banking angle of the road had been greater but friction remained zero.

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

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Question number

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

Assessor's use only

Question number