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90521

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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2008

90521 Demonstrate understanding of mechanical systems

Credits: Six
9.30 am Tuesday 25 November 2008

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 numerical answers, full working must be shown. The answer should be given with an SI unit to an appropriate number of significant figures.

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

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 2–15 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 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 are advised to spend 55 minutes answering the questions in this booklet.

You may find the following formulae useful.

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

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QUESTION ONE: ROTATIONAL MOTION

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Revolving doors like the one on the right are used in many big buildings. You may assume that the effects of friction can be ignored in this question.

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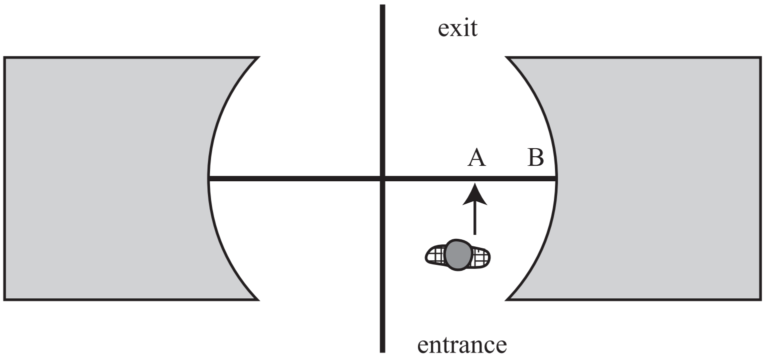
http://www.usgates.com/images/mirrorfinishmaroon.jpg



Jenny enters a revolving door, which is initially stationary (above diagram). She pushes on the door at point A: it accelerates at 0.48 rad s^{-2}. She stops pushing when it reaches an angular velocity of 0.58 rad s^{-1}.

(a) Jenny pushes, at right angles to the door, with a force of 132 N at a point 83 cm from the central axis.

Show that she exerts a torque of 110 N m.

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(b) Show that the rotational inertia of the door is 230 kg m^2.

____

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(c) Calculate the rotational kinetic energy gained by the door from Jenny.

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rotational kinetic energy = ________________

(d) Explain how this gain in energy is related to the force Jenny exerted on the door.

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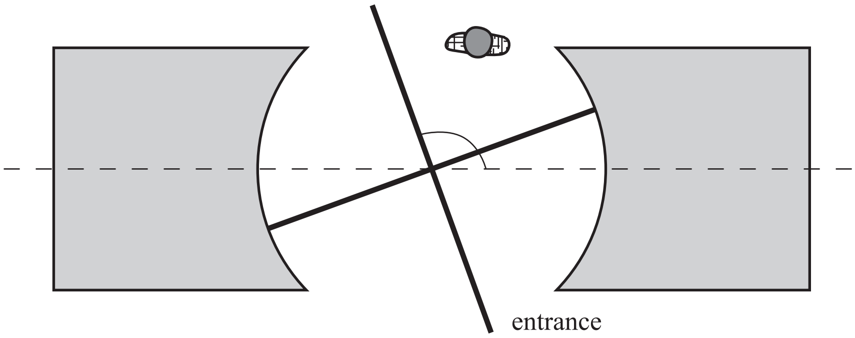
(e) Dorothy tells Jenny that by pushing at B (see diagram on previous page), she can get the door rotating to the same speed in the same time with less force.

Discuss whether this idea is correct.



(f) The door has to rotate through a **total** angular displacement of 2.0 rad to allow Jenny to walk through the door (above diagram). This total includes the angular displacement during acceleration **and** the angular displacement at constant angular velocity.

Calculate the angular displacement of the door, from the instant it reaches a constant angular velocity, until it has rotated through a total of 2.0 rad.

angular displacement = ___________________

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(g) Show that the total time (t_{total}) that Jenny is inside the revolving door (from the moment she starts pushing until she exits), can be expressed as an equation:

$$t_{total} = \frac{\omega}{\alpha} + \frac{\theta_2}{\omega}$$

where ω is the maximum angular velocity of the door, α is the angular acceleration of the door and θ_2 the angle through which the door rotates from when she stops pushing until when she exits.

QUESTION TWO : CENTRE OF MASS

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Many ski resorts provide chairlifts to carry skiers to the top of the mountain. The chairs hang from a single suspension point on a steel cable.

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http://www.danheller.com/images/Europe/Italy/Dolomites/Misc/foggy-chair-lift-2.jpg

Figure A shows a front view of an empty chair. (Note that the term *chair* refers to the whole frame, from the pivot down, and the seat.) The whole chair is rigid. It hangs freely from a pivot point on the cable.

(a) An empty chair hangs with the centre of mass (C) vertically below the pivot point (S).

Draw vector arrows to represent the two forces that act **on the chair**. Add labels naming these forces.

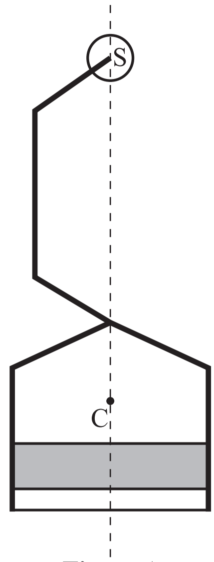

Figure A

(b) A heavy skier sits in the chair at X (Figure B).

Explain why the chair moves and why it hangs in this new equilibrium position.

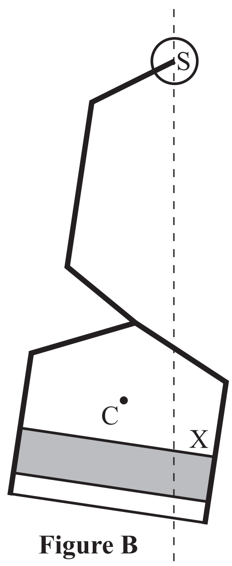

Figure B

QUESTION THREE: SIMPLE HARMONIC MOTION

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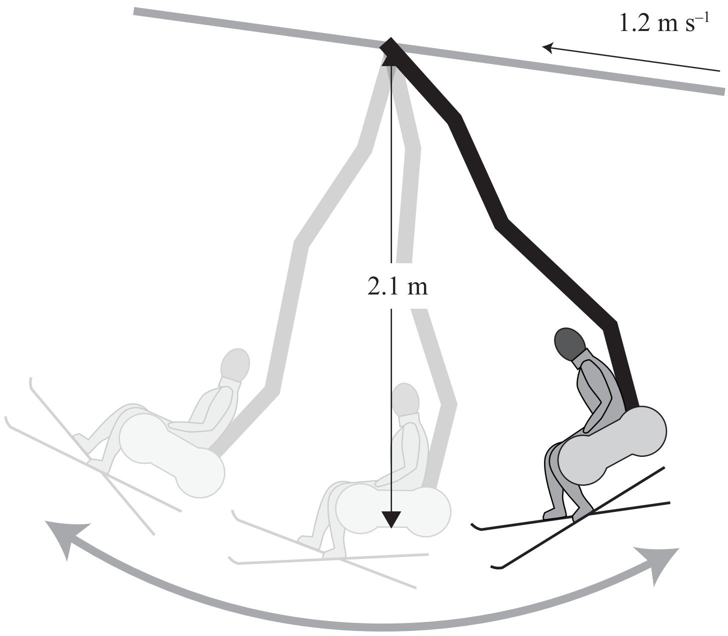
Acceleration due to gravity = 9.81 m s^{-2}

Chairlifts carry skiers to the top of the mountain (see above) by way of a continuously-moving steel cable to which the chairs are attached.

As soon as the skiers sit down, the chair is lifted from the ground by the cable. The chair swings back and forth for a while. The diagram below shows a side view of a chair as it oscillates (amplitude not to scale).



The swinging motion of the chair and skier approximates to a simple pendulum 2.1 m long with a mass of 2.0 × 10^2 kg.

(a) Show that the period of swing of the pendulum is 2.9 s.

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(b) The moving cable carries the chair up the hill, and so it has translational motion as well as swinging motion. The swinging motion of the chair is parallel to its translational motion, as shown in the diagram. The pendulum swing of the chair has amplitude 0.69 m. The average translational speed of the chair is 1.2 m s^{-1}.

Calculate the maximum speed at which the chair can travel past a stationary observer on the snow.

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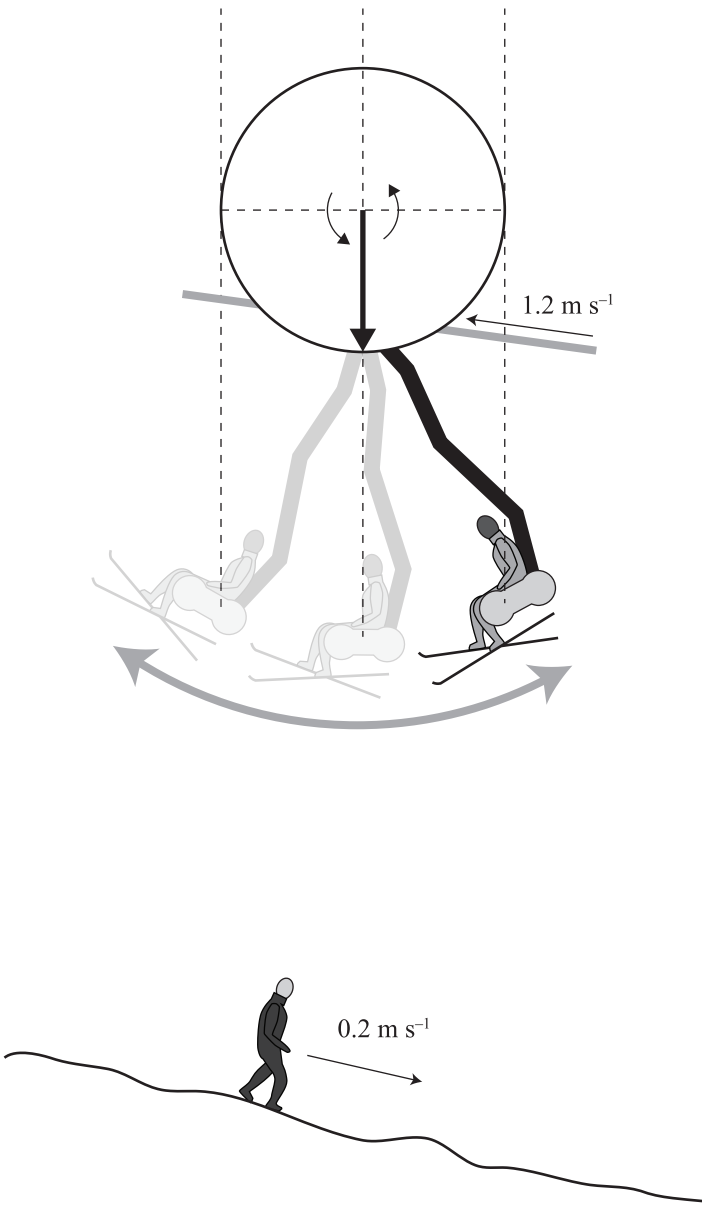
maximum speed = ____________________

(c) Mike is walking slowly **down** the hill at 0.20 m s^{-1}. At one instant the chair is moving at exactly the same **velocity** as Mike.



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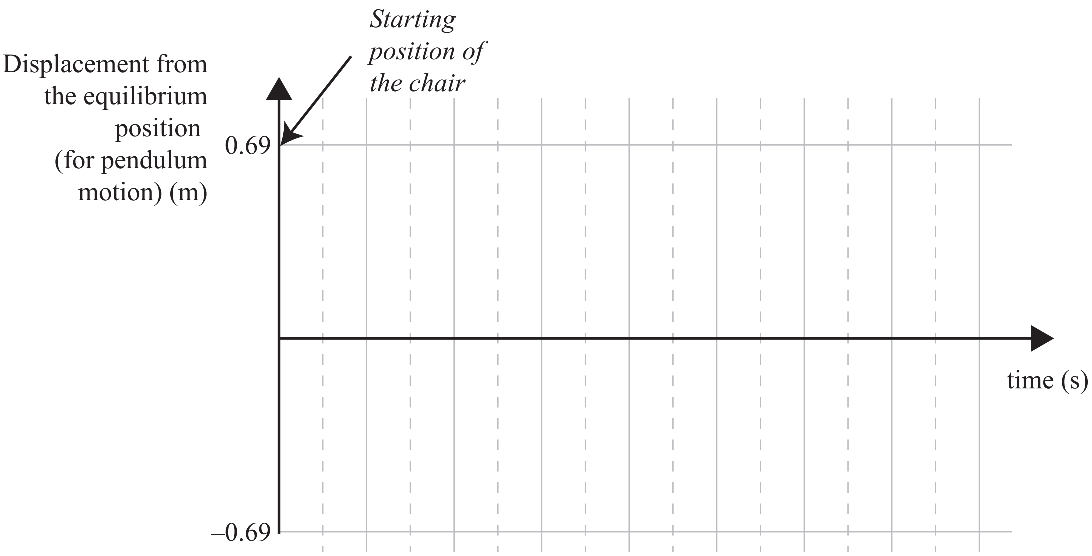
Determine a position of the chair where this occurs. Describe this position by calculating its angle relative to the phasor shown on the previous page, which represents an equilibrium position.

(d) This swinging is uncomfortable, so the chairs are designed to stop swinging within about four oscillations.

Sketch a graph to show how the displacement of the chair (relative to the pendulum motion equilibrium position) varies with time. Show FOUR complete oscillations from the moment the chair starts to swing.



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QUESTION FOUR: GOLF IN SPACE

The universal gravitational constant = 6.67×10^{-11} m^3 kg^{-1} s^{-2}
The radius of the Earth at the equator = 6.38×10^6 m
Mass of the Earth = 5.97×10^{24} kg

In November 2006, flight engineer Mikhail Tyurin hit a golf ball while he was in space, orbiting Earth on a mission on the International Space Station.

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http://img.dailymail.co.uk/i/pix/2006/11/golfspace_228x366.jpg

(a) The golf ball was a special light design with a mass of only 3.0×10^{-3} kg. The shot took place in low Earth orbit, 350 km above the surface of the Earth.

Calculate the force of gravity between the ball and the Earth.

force of gravity = ____________

(b) Explain why the tiny, light ball could remain in a stable orbit at the same velocity as the massive, heavy space station.

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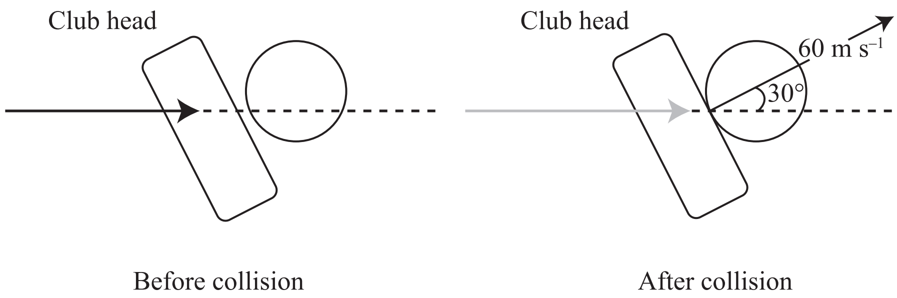
(c) Consider a golf shot as a collision between a club head, of mass 0.20 kg, and the ball. Velocities are measured relative to the orbiting space craft. The ball (mass 3.0×10^{-3} kg) is initially stationary. After being hit, it has a velocity of 60 m s^{-1}.

(i) Calculate the momentum lost by the club head during the collision **and** show the direction of this lost momentum on the 'After collision' diagram.



momentum lost =

(ii) The initial velocity of the club head is 40 m s^{-1} horizontally.

Analyse the collision using momentum vectors to show that the velocity of the club head is virtually unchanged by the collision.

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(iii) Explain how it is possible for the ball to leave the club head faster than the initial speed of the club head.

(d) When Tyurin took the shot from outside of the space craft, his feet were held by his colleague.

Describe what sort of motion would have occurred if he had taken the golf shot while he was floating freely in orbit.

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

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Question number