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90521

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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2007

90521 Demonstrate understanding of mechanical systems

Credits: Six
9.30 am Friday 30 November 2007

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, and the answer must be rounded to the correct number of significant figures and given with an SI unit.

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 2–13 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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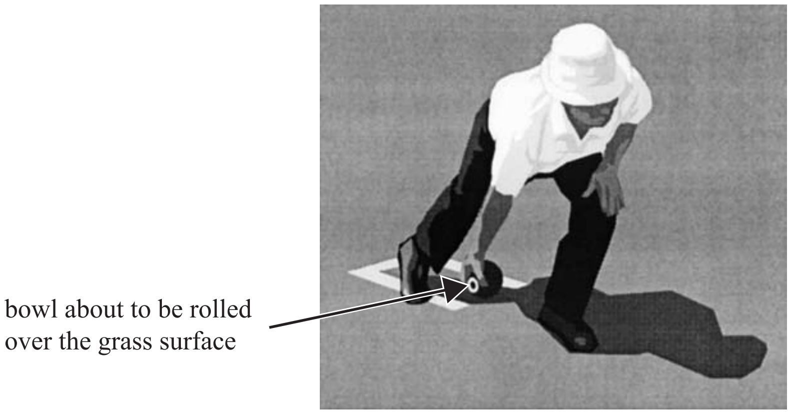
In lawn bowls, players roll the bowls over a horizontal grass surface towards a small target ball called a jack. The aim of the game is to get more of your bowls closer to the jack than those of your opponents.

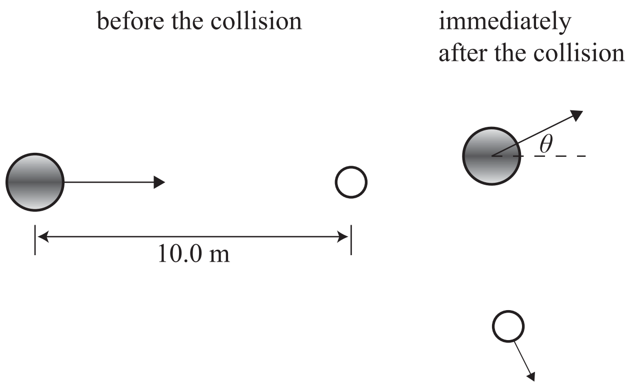


QUESTION ONE

When the bowl is rolled at high speed, the path of the bowl can be considered to be straight.

Consider the bowl hitting the stationary jack so that, immediately after the collision, the jack and the bowl are travelling **at right angles** to each other.

The bowl has mass 1.50 kg; the jack has mass 0.25 kg.



The speed of the **centre of mass** of the system of bowl and jack is 5.4 m s^{-1} (assume this speed is constant).

(a) Show that the momentum of the **system** of bowl and jack is 9.5 kg m s^{-1}.

(b) State why the momentum of the bowl **before** the collision is 9.5 kg m s^{-1}.

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In the diagram on the previous page, the position of the moving bowl, **before** the collision, is 10.0 m from the jack.

(c) Show that the distance of the **centre of mass** of the system of bowl and jack from the jack is 8.57 m.

(d) Calculate the time it takes the bowl to travel from the position shown to the jack.

time =

The momentum of the bowl **after** the collision is 8.7 kg m s^{-1}.

(e) Calculate the angle, θ (in the diagram on the previous page), through which the bowl turns during the collision.

angle, θ =

(f) During the collision, the bowl and jack are in contact for 0.025 s.

Calculate the size of the force exerted on the bowl.

force =

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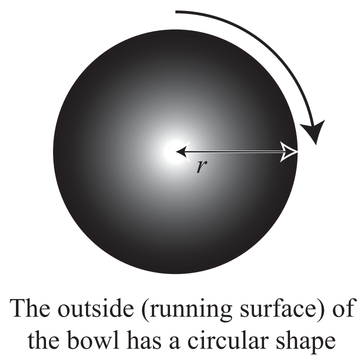
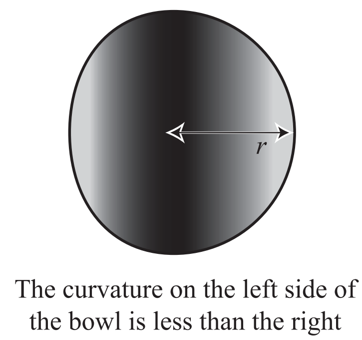
QUESTION TWO

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

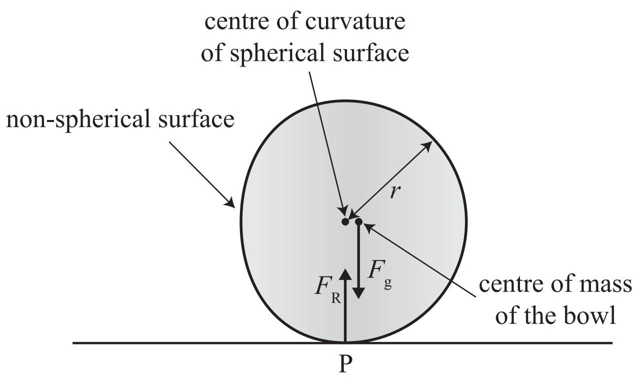
A slowly moving bowl will travel in a **curved** path, not a straight path.

The curved path of the bowl is due to its slightly non-spherical shape, which is created by shaving a small amount off one side of the bowl. The diagrams below show the shape of the bowl.



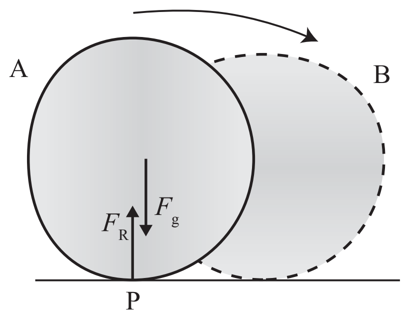


The diagram below shows the bowl, viewed from the **front**, held stationary on a flat surface. The reaction force, F_R, on the bowl acts from the point of contact, P, through the **centre of curvature** of the spherical part. The gravity force, F_g, acts through the **centre of mass** of the bowl.



(a) State why the centre of mass is **not** in the same position as the centre of curvature.

If the bowl is to stay in the position shown, it must be held there. If it is released it will **roll** over sideways, as shown in the diagram below, to position B.



(b) Explain why, when it is released, the bowl will not stay balanced at position A.

When the bowl reaches position B, it has **both** rotational and linear kinetic energy. At position B, the bowl has a rotational speed of 2.8 rad s^{-1}.

(c) The rotational inertia of the bowl is 2.16×10^{-3} kg m^2.

Show that the **rotational kinetic** energy of the bowl at position B is 8.5 mJ.

(d) The mass of the bowl is 1.50 kg and the radius, r, of its spherical surface is 0.060 m.

Show that the **linear kinetic** energy of the bowl when it reaches position B is 21 mJ. (You may assume that the centre of mass travels in an approximately horizontal line.)

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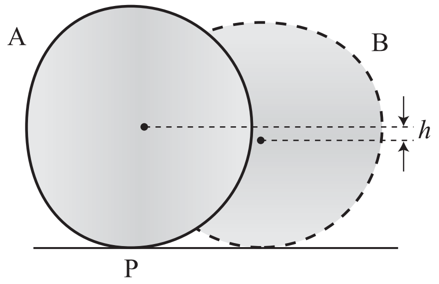
In fact, the centre of mass of the bowl **drops** slightly as shown in the diagram below.



(e) At position B, where has the linear and rotational energy come from?

(f) Calculate the distance the centre of mass of the bowl drops as it rolls from position A to position B. (Ignore any energy losses.)

distance = ______________

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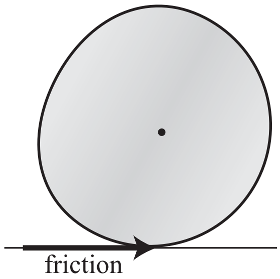
While the bowl is rolling over sideways, friction between the bowl and the flat surface is acting in the direction shown below.



(g) Explain why friction acts in this direction.

(h) When the bowl is rolling **forwards** (after it has been bowled), this frictional force will still be acting **sideways** (at right angles to the forward direction).

Explain why, after it has been bowled, the path of the bowl curves.

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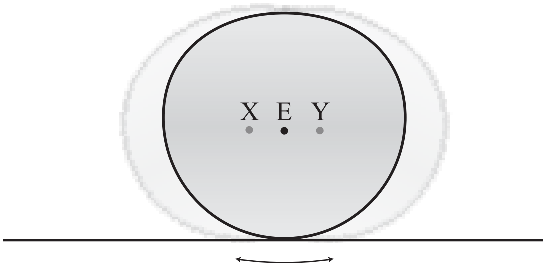
QUESTION THREE

Acceleration due to gravity = 9.81 $m\,s^{-2}$.

If the bowl is placed on a hard, flat surface, it will rock back and forth for a while, as shown in the diagram below.



While the bowl is rocking, the motion of the **centre of mass** of the bowl is modelled as simple harmonic motion.

(a) If a bowl completes exactly 13 cycles of its rocking motion in 9.32 s, calculate the **period** of the simple harmonic motion. Give your answer to the correct number of significant figures.

period =

It can be shown that an approximate expression for the period of the simple harmonic motion is $T = 2\pi\sqrt{\frac{R}{g}}$, where R is the radius of curvature of the path (XEY in the diagram above) of the centre of mass, and g is the acceleration due to gravity.

(b) Calculate the radius of curvature of the path of the centre of mass.

radius =

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The rocking motion of the bowl is due to the action of a restoring force on its centre of mass.

(c) State **one** of the conditions that must apply to this restoring force if the rocking motion is simple harmonic motion.

(d) The approximate size of this restoring force is given by $F_R = \frac{F_g y}{R}$, where R is the radius of curvature of the path of the centre of mass, and y is the displacement of the centre of mass from its equilibrium position, E.

By using the general equation for simple harmonic motion, show how the expression $T = 2\pi\sqrt{\frac{R}{g}}$ can be derived.

The bowl does not keep rocking; its motion is acted on by opposing force(s).

(e) Describe the force(s) that could cause the motion of the bowl to be damped.

Note that Question Three continues on the next page.

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(f) Explain why the bowl will come to rest **more** quickly on a **soft** surface. Your explanation should include how it loses its energy.

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

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