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91524

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NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2014

91524 Demonstrate understanding of mechanical systems

2.00 pm Tuesday 25 November 2014
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.

Excellence

TOTAL 22

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$\frac{1}{f}$ $\frac{\omega}{2\pi}$ $\frac{1}{\frac{\omega}{2\pi}}$

QUESTION ONE: ROTATIONAL MOTION

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Universal gravitational constant = 6.67×10^{-11} N m^2 kg^{-2}

(a) The radius of the Sun is 6.96×10^8 m. The equator of the Sun rotates at a rate of 14.7 degrees per day.

(i) Show that the period of rotation of a particle located on the equator of the Sun is 2.12×10^6 s.

$\theta = \frac{14.7}{360} \times 2\pi = 0.2567$ rad

$\omega = \frac{\Delta\theta}{\Delta t} = \frac{0.257}{86400} = 2.97 \times 10^{-6}$ rad s^{-1}

$f = \frac{\omega}{2\pi} = 4.73 \times 10^{-7}$ Hz

$T = \frac{1}{f} = \frac{1}{4.73 \times 10^{-7}} = 2.12 \times 10^6$ s

Correct equation and evidence for conversion from days to seconds

M

(ii) Calculate the linear speed of a particle at the Sun's equator.

$\omega = 2\pi f$ $\quad 2.97 \times 10^{-6}$

$v = r\omega$

$= 6.96 \times 10^8 \times 2.97 \times 10^{-6}$

$= 2070$ m s^{-1}

Correct working and answer.

M

(b) Gravity may cause the rotating inner core of the Sun to collapse down to a much smaller radius.

Explain how this will affect the angular speed of the inner core.

This will make it so that the centre of mass is closer to the centre of the sun, therefore its rotational inertia will decrease. Since angular momentum is conserved and $L = I\omega$, by decreasing the inertia the angular speed will increase since I is reversly proportional to ω.

E

Correctly explains speeding up of core using conservation of angular momentum.

m T

(c) The mass of Mercury is 3.30×10^{23} kg. Mercury has a period of rotation of 5.067×10^{6} s.

r

Show that a satellite needs to be positioned 2.43×10^{8} m from the centre of Mercury so that it remains stationary from the point-of-view of an observer on that planet.

$F_g = F_c$

$\frac{GM\cancel{m}}{r^2} = \frac{mv^2}{r}$

$\frac{GM}{r} = v^2$

$\frac{GM}{r} = (r\omega)^2$

$\frac{6.67\times10^{-11} \times 3.3\times10^{23}}{r} = 1.54\times10^{-12} \times r^2$

$r^3 = \frac{6.67\times10^{-11} \times 3.3\times10^{23}}{1.54\times10^{-12}}$

$r = \sqrt[3]{1.43\times10^{25}}$

$= 242806571.3$ m

$= 2.43\times10^{8}$ m

$T = \frac{2\pi}{\omega}$

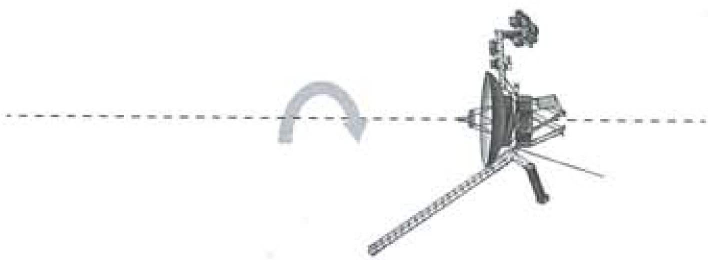
$\omega = \frac{2\pi}{T}$

$= 1.24\times10^{-6}$ rads^{-1}

Correctly equates the gravitational force with the centripetal force and shows all working.

E

(d) A space probe spins around an axis, as shown below.



An instrument comes loose from the space probe.

Explain why this loss of mass will have no effect on the angular speed of the space probe.

Angular momentum is conserved ~~so because the space probe~~ as well ~~&~~ as rotational kinetic energy.

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

there is no mass - instrument must have been center on axis.

ω remains the same.

N

To get credit for this question they need to identify either - that the probe loses angular momentum and rotational inertia OR - that the instrument doesn't provide a torque on the probe.

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E8

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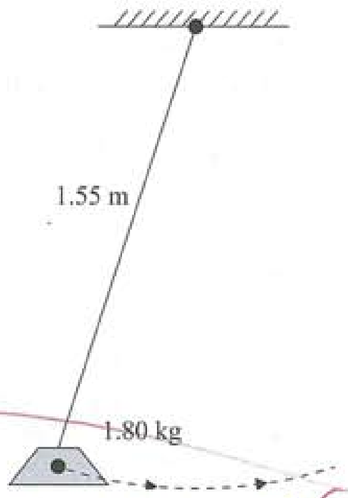
QUESTION TWO: THE PENDULUM

first release



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

A pendulum is set up, as shown in the diagram. The length of the cord attached to the bob is 1.55 m. The bob has a mass of 1.80 kg. m

L

(a) Calculate the time it takes for the pendulum bob to swing from one side to the other.

$T = 2\pi\sqrt{\frac{l}{g}}$

$= 2\pi\sqrt{\frac{1.55}{9.81}}$

$= 2.50$ s

$\frac{1}{2}T = 1.25$ s (T is there and back, so just there is $\frac{1}{2}T$)

A

Correct equation, working and answer.

(b) Explain how the forces acting on the bob change the bob's speed as it travels from the point of release to the centre.

The forces acting on the bob are ~~g~~ F_g and F_T. ~~Grav~~ Force due to gravity is always directly down, but the Tension force is in the direction of the ~~?~~ cord. This tension force provides a restoring force due to the horizontal component of F_T when the Bob is displaced. This means that at maximum displacement the bob would have ~~minimum~~ decelerated to its minimum speed. And at minimum displacement ~~there is no~~ $F_T = F_g$ so there is maximum velocity.

M

The answer clearly explains how the restoring force is due to the tension and gravitational force. To gain Excellence for this question they could have explained more clearly how this restoring force changes with displacement, and how this affects the acceleration.

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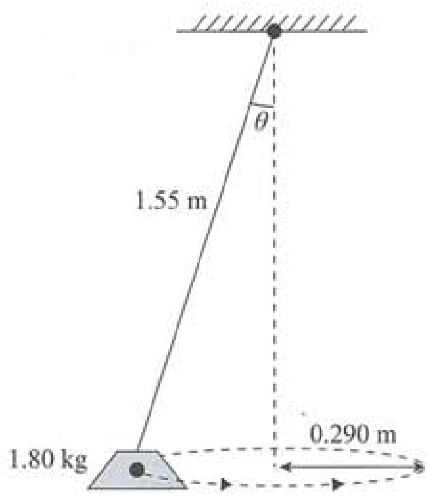
(c) The bob is released again in such a way that it swings in a horizontal circular path, with radius 0.290 m, as a conical pendulum.

second release

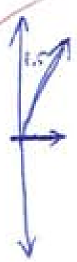


(i) By first calculating the size of the angle that the cord makes with the vertical, show that the tension force in the cord is 18.0 N.

$\sin\theta = \frac{0.290}{1.55}$

$\theta = \sin^{-1}\frac{0.290}{1.55}$

$= 10.8^{\circ}$ or $0.188\,\text{rad}$

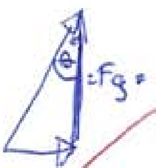


Vertical $F_T = F_g$

$= mg$

$= 1.8 \times 9.81$

$= 17.658\ N$



$\cos\theta = \frac{A}{H}$

$\cos 10.8 = \frac{17.658}{F_T}$

$F_T = 17.976\ N$

$= 18.0\ N$

Correct working to find the tension force.

M

(ii) Calculate the speed that the mass must have been given when released, in order to attain a horizontal circular path at a radius of 0.290 m.

T

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

$v^2 = \frac{F_c \times r}{m}$

$v = \sqrt{\left(\frac{3.37 \times 0.290}{1.8}\right)}$

$= 0.737\ ms^{-1}$

$F_c = \sin 10.8 \times 18$

$= 3.37\ N$

Correct working and answer for speed.

E

E7

QUESTION THREE: TRANSLATIONAL MOTION

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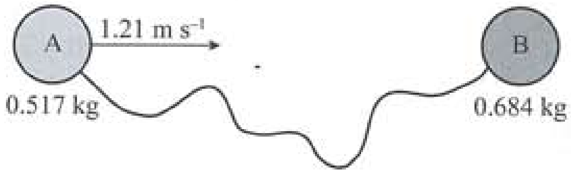
A system consists of two discs, A and B, attached together with a light cord. The discs slide across a frictionless surface. Disc A has mass 0.517 kg and disc B has mass 0.684 kg. Disc B is stationary, and disc A is moving towards disc B with a speed of 1.21 m s^{-1}.



(a) Show that the speed of the centre of mass of the system is 0.521 m s^{-1}.

Show all your working.

$P_{com} = M_{com} V_{com}$

$V = \frac{p}{m}$

$= \frac{1.21 \times 0.517}{1.201}$

$= 0.521 \text{ ms}^{-1}$

Correct working and answer for speed of centre of mass.

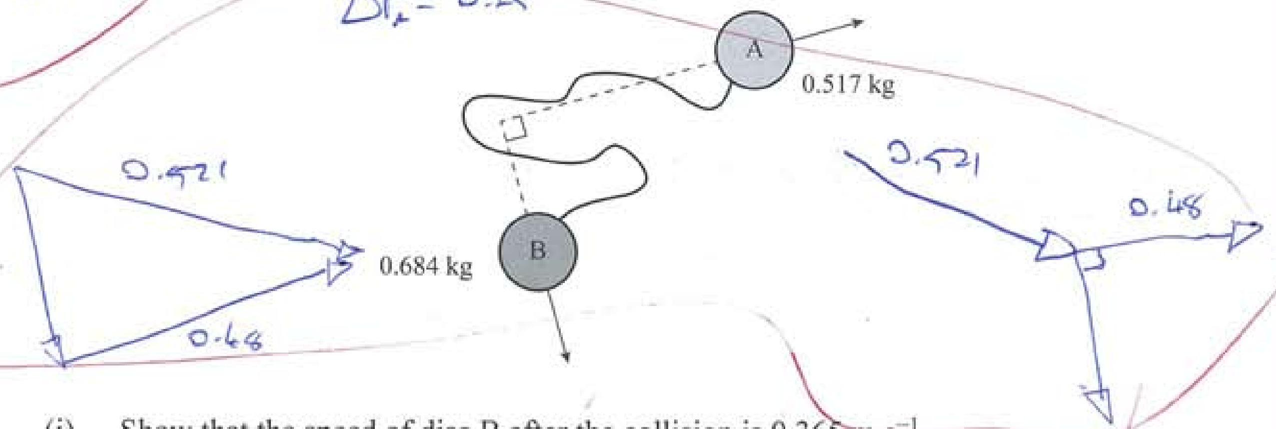
M

$P = 0.62557$

(b) The discs collide and after the collision they are moving at right angles to each other. Disc A receives an impulse of 0.250 N s.

$V_a = 0.726$

$\Delta P_A = 0.25$



A

(i) Show that the speed of disc B after the collision is 0.365 m s^{-1}.

Explain your reasoning.

Momentum is conserved

~~P_{com} ...~~

$P_B^2 = P_{com}^2 - P_A^2$

$= 0.62557^2 - 0.37557^2$

$= 0.25$

$P_B = 0.5$

$v = \frac{P}{m}$

$= \frac{0.73}{0.684}$

$= 0.365 \text{ ms}^{-1}$

Correctly states "momentum is conserved" as an explanation of the calculation. To gain Merit they needed to recognise that the momentum of B is equal to the change of momentum of A to calculate the speed correctly.

(ii) Determine the size of the momentum of disc A after the collision.

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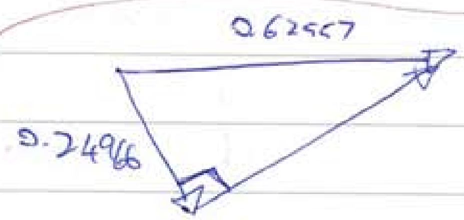

$$P_A^2 = P_{con}^2 - P_B^2$$
$$= 0.62557^2 - 0.2496^2$$
$$P_A = 0.574 \text{ kgms}^{-1}$$

Correct working and answer.

E

(c) The discs continue to slide until the cord is fully extended. When this happens, both discs change their speed and direction.

By considering the force(s) that act on the discs, explain why the momentum of the system must be conserved.

~~It~~ When the cord is fully extended, it acts as a tension force acting towards each others. Since the force on each disc will be equal and opposite the sum of external forces still equals zero. Therefore the collision is still elastic and momentum will be conserved.

M

Correctly recognises that the tension force does not count as an unbalanced external force, so momentum is conserved. To gain Excellence the answer needed to address that there is no friction in the system which would otherwise provide an unbalanced external force.

E7