91524

915240

3

SUPERVISOR'S USE ONLY

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.

Merit

TOTAL 15

ASSESSOR'S USE ONLY

QUESTION ONE: ROTATIONAL MOTION

ASSESSOR'S USE ONLY

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.

Shows conversion between days and seconds clearly, and shows an intermediate step with a unit.

Number of seconds in one day = 24×60×60 = 86,400 s.

$\frac{14.7}{360} = 0.0408$ rotations /day.

$T = 86400 \div 0.0408 = 2.12 \times 10^6$ s.

M

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

Correct equation, working and answer.

$v = r\omega$

$\omega = \frac{2\pi}{T}$. $v = \frac{2\pi r}{T} = \frac{2\pi \times 6.96\times10^8}{2.12\times10^6}$

$\therefore v =$ 2067 ms^{-1}.

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.

Correctly indicates the rotational inertia decreases. To get a higher grade they need to link this to conservation of angular momentum to explain that angular velocity increases.

~~This will decrease~~ A smaller radius would decrease the rotational inertia of the inner core ($I = mr^2$). This would result in the angular ~~acceleration~~ velocity to decrease, assuming that the ~~torque~~ rotational kinetic energy stays the same.

A

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

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.

ASSESSOR'S USE ONLY

$\omega = \frac{2\pi}{T} = 1.24 \times 10^{-6}\ \text{rad s}^{-1}$.

$\cancel{F_c = F_g}$ $\cancel{E_{k}} = \frac{1}{2} m r^2 \omega^2$ m ω T r

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

ω of M. = ω of satellite = $1.24 \times 10^{-6}\ \text{rad s}^{-1}$.

$\cancel{\sqrt{\frac{Gm}{r}} = v}$

$\cancel{r = \frac{Gm}{v^2}}$

$\cancel{r = \frac{Gm}{r^2\omega^2}}$

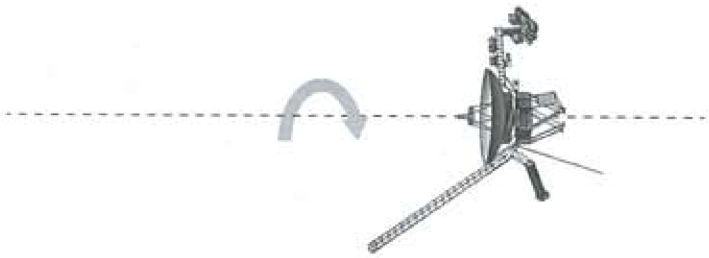
$\cancel{r^3 = \frac{Gm}{\omega^2}}$

$\cancel{r^3 = \frac{6.67 \times 10^{-11} \times 3.30 \times 10^{23}}{(1.24 \times 10^{-6})^2}}$

Gains Achieved from the identification that the angular velocity of the satellite is equal to the angular velocity of Mercury. To gain a higher grade they could have completed the calculation they started.

A

(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.

N

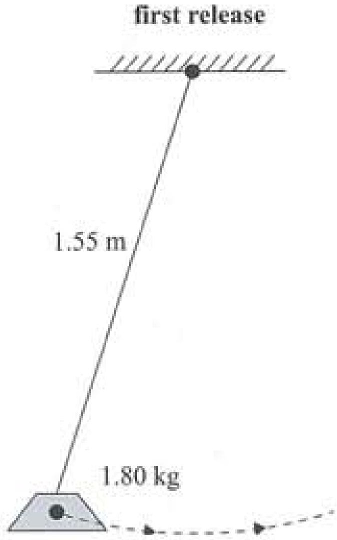
M5

QUESTION TWO: THE PENDULUM

ASSESSOR'S USE ONLY

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

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.



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

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

$T = 2\pi\sqrt{\frac{1.55}{9.81}} = 2.50\,s$

$\frac{T}{2} = \frac{2.50}{2} = 1.25\,s$

Correct equation and answer.

A

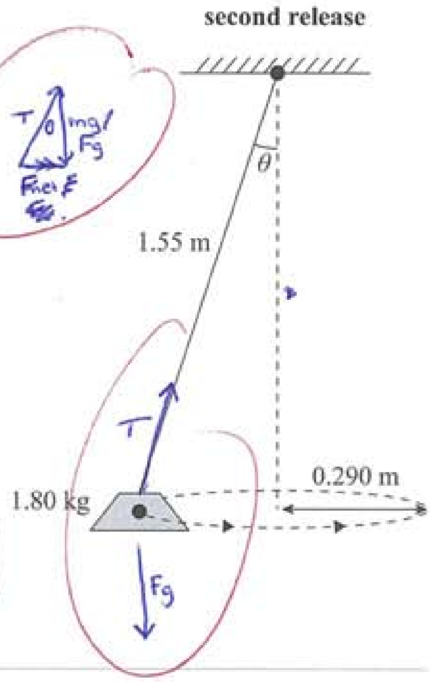
(b) Explain how the forces acting on the bob change the bob's speed as it travels from the point of release to the centre.

~~As the~~ When the bob is at maximum displacement from the centre point, a maximum restoring force is acting on the bob in the opposite direction, and as F=ma, there is also an acceleration in the ~~This causes the bob to return to the centre~~ opposite direction to the bob's motion immediately before reaching maximum displacement. This causes the bob to speed up towards ~~as it approaches~~ the centre ~~origin~~ point, where the velocity of the bob is maximum.

A

Correctly identifies the bob speeds up as it goes towards the centre. To gain a higher grade they needed to explain how tension and gravitational force combine to make the restoring force, or explain how the restoring force changes, and how that affects the acceleration.

(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.



(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.

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

$\theta = 10.8°$ or 0.188 rad.

$F_g = mg = 1.80 \times 9.81 = 17.7\text{ N}$.

$\cos(\theta) = \frac{F_g}{T}$

$T = \frac{F_g}{\cos(\theta)}$

$T = \frac{17.7}{\cos(10.8°)}$

$\therefore T = 18.0$

$\therefore$ The tension force is 18.0N

Correct working and answer.

(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.

$F_{net}^2 = (18.0)^2 - (17.7)^2$

$F_{net} = 3.36\text{N} = F_c$.

$3.36 = \frac{mv^2}{r} = \frac{1.80 \times v^2}{0.290}$

$v^2 = \frac{3.36 \times 0.290}{1.80} = 0.5418$

$v = \sqrt{0.5418}$

$\therefore v = 0.736\text{ms}^{-1}$.

Correct working and answer.

M

E

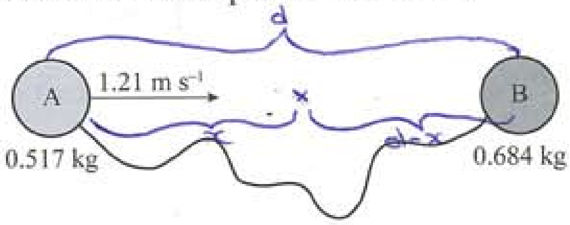
M5

ASSESSOR'S USE ONLY

QUESTION THREE: TRANSLATIONAL MOTION

ASSESSOR'S USE ONLY

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.

$p_i = 0.517 \times 1.21 = 0.626\ kgms^{-1}$.

$d \downarrow 1.21 ms^{-1}$

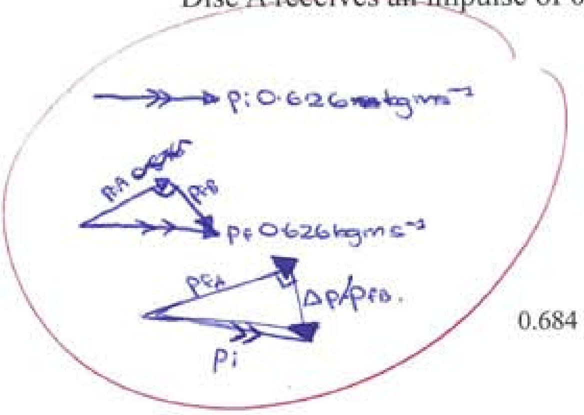
$F_A = 5.07N \quad F_B = 6.71N$.

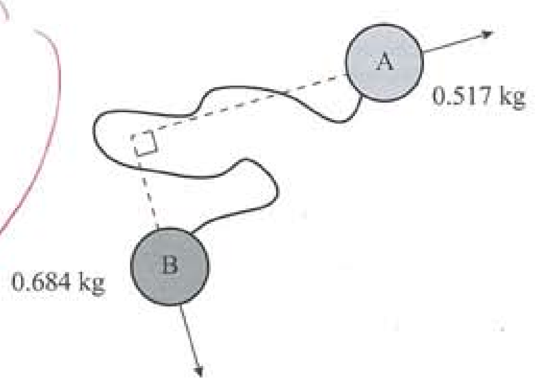
$6.71d = 11.8x$

Finds the initial momentum of the system but does not use the equation, or use this momentum to find the speed of the centre of mass.

N

(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.





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

Explain your reasoning.

$\Delta p = p_{FB}$

$p_{FA} = 0.573\ kgms^{-1}$. $p_{FB} = 0.250\ kgms^{-1}$.

$v = \frac{P}{m} = \frac{0.250}{0.684} = 0.365\ ms^{-1}$.

A

Correct equation and substitution to find the velocity. To get Merit they needed to state this was due to conservation of momentum.

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

ASSESSOR'S USE ONLY

$(p_{fA})^2 = ~~p_{os}~~ (p_i)^2 - (p_{fB})^2$

$(p_{fA})^2 = (0.626)^2 - (0.250)^2$

$p_{fA} = \sqrt{0.3288}$

$\therefore p_{fA} = 0.573\,kgms^{-1}$.

E

Uses Pythagorus correctly to ge the correct answer.

(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.

The momentum of the system must be conserved as there are no external torques such as friction acting on the system at any time. Although the individual momentums do change when the ~~string~~ cord becomes ~~tight~~ fully extended, the ~~total~~ momentum of the system remains the same.

A

Correctly identifies the lack of friction as the cause of the conservation of momentum. To get a higher grade they need to connect this to the lack of external unbalanced forces.

M5