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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.**

Achievement

TOTAL 10

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## QUESTION ONE: ROTATIONAL MOTION

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Universal gravitational constant = $6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$

$G = 6.67 \times 10^{-11}$ Nm$^2$kg$^{-2}$

$r = 6.96 \times 10^8$ m

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

$T = \frac{2\pi r}{v}$ $\theta = 14.7$

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

~~Fg = 2.6.67×10^-11 x~~ $d = r\theta$ ~~$d = 6.96 \times 10^8 \times 14.7$~~

~~$d = 1.02$~~

N

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

Shows correct equation, working and answer.

$T = 2.12 \times 10^6$ $\omega = \frac{2\pi}{T}$ $\omega = 2.96 \times 10^{-6}$ rads$^{-1}$

$v = r\omega$

$v = 6.96 \times 10^8 \times 2.96 \times 10^{-6}$

linnear speed = $v = 2062.7$ 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.

If the radius of the inner core collapse into a much smaller radius them this means that distance of the circumfrance of the sun inner core becomes smaller ($C = 2\pi r$ which also means T time period for it takes for one revolution is shortend if the linnear speed stays the same. ($T = \frac{2\pi r}{v}$) with T decreased it also means $\omega = \frac{2\pi}{T}$ angular speed will ~~decrease~~ increase as well. we can also see this in $V = r\omega$ decreasing r and v unchanged $\omega = \frac{v}{r}$ means angular speed will increase.

the angular speed of the inner core will increase.

The candidate uses the argument that linear speed stays the same. However, there is no fundamental principle that says linear speed should be constant. To get marks for this question they could have to like to conservation of angular momentum or state rotational inertia decreases as a cause for the increased angular speed.

N

M T

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

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

$T = 5.067_E{}^6$
$M = 3.30_E{}^{23}$
$G = 6.67_E{}^{-11}$
~~g~~
$d = ?$

$\omega = \frac{2\pi}{5.067 \times 10^6}$

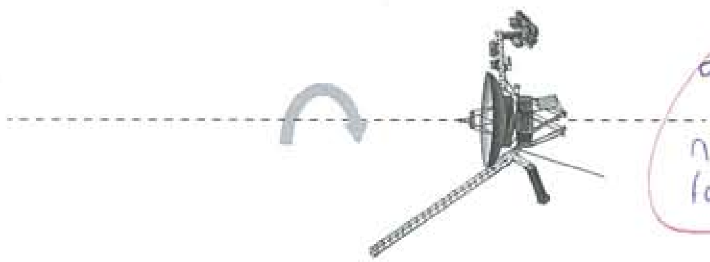
$\omega = 31836899$ rads$^{-1}$

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

$=$

N

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



a-constant
no external forces

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.

when the instrument comes loose from the ship, mass is lost which leads to a lose in rotational inertia $(I = \Sigma mr^2)$

A

The candidate correctly indicates rotational inertia decreases with the loss of mass. To gain Merit they need to also indicate angular momentum is lost proportionally.

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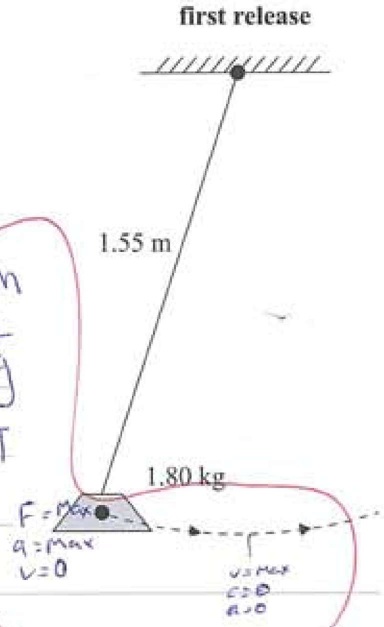
A3

## 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.

m
L
g
T

$T = 2\pi\sqrt{\frac{L}{g}}$ $T = (2\pi)\sqrt{\left(\frac{1.55}{9.81}\right)}$

Correct equation and working used

$T = 2\pi \times 0.397$

$T = 2.49\,s$

$2.5\,s$

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.

from the position shown force which are acting on the bob is Centripetal force which is the resultant of gravity and the tension forces acting on the bob, when it is released and heading towards the centre the gravitational force acting on the weight (bob) decreases and is at its lowest in the centre.

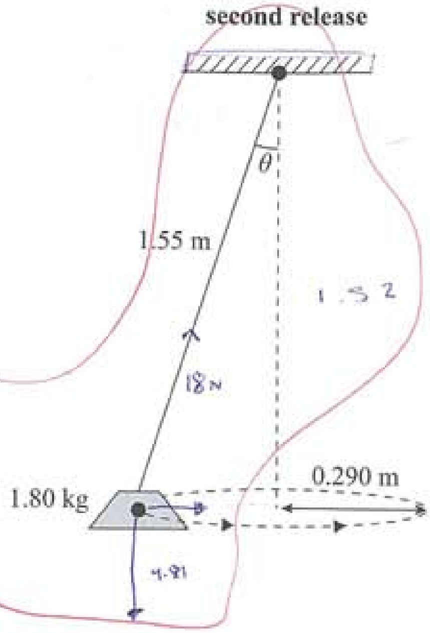
- when in the max amplitude ~~position~~ shown in the diagram there it is in that position were the max force is, accelerations at its max F=ma and ~~F~~ Graveriational ~~c~~ is acting at its fullest at max amplitude. This force ~~provides the bob~~ with increasing velocity up ~~to~~ until in the centre position were velocity is at its max.

A

A

The candidate correctly identifies the two forces acting on the bob, and states the bob increases velocity. To gain Merit the candidate needs to draw or describe the direction of the forces to explain how the restoring force is formed, OR to explain how this restoring force towards the centre varies with displacement 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.




ASSESSOR'S USE ONLY

(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.

Soh
~~Sin~~
~~Sin~~
Sin

angle =

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

$\sin^{-1}\theta = 0.187$

$\theta = 0.187 - \sin^{-1}$


checked with calculator

$\theta = ~~3.265~~\ 10.7°$

Tension force acting on the string

$F_T = mg \qquad F_T = 1.80 \times 9.81$

$F_T = 17.658\text{N} \Rightarrow F_T = 18\text{N}$

The angle is correctly calculated, and the gravitational force is also correctly calculated, but this is incorrectly identified as the tension force. To gain Merit the candidate would need to use trigonometry to calculate the tension force which is in the direction of the string.

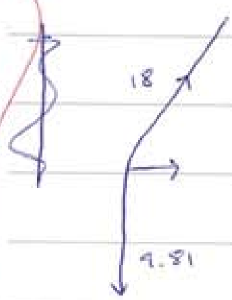
A

(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.

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

$20.49 = \frac{1.80 \times v^2}{0.290}$

$20.49 \div 1.80 = \frac{v^2}{0.290}$




$11.38 = \frac{v^2}{0.29}$

$v = \sqrt{11.38 \times 0.29} = \sqrt{3.3}$

$v = 1.8\ \text{ms}^{-1}$

Uses correct equation for centripetal force, but uses the incorrect value for this force. To gain Excellence they needed to use the tension and/or gravitational force and trigonometry or pythagorus to get the centripetal force.

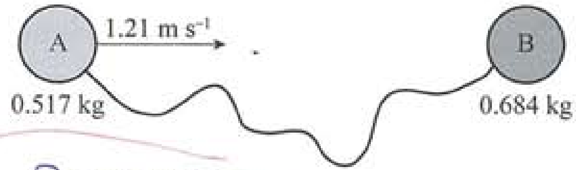
A

A4

## 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$^{-1}$.




$P = 0.62557$

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

T = Total
b - before

Show all your working.

$\cancel{V_{com} = \sum \frac{m}{v}}$

$V_{com} = P_T \div M_T$

$0.62557 = (0.517 + 0.684)\,v$

$V_{com} = \frac{0.62557}{1.201}$

$V_{com} = 0.5208 \text{ ms}^{-1}$

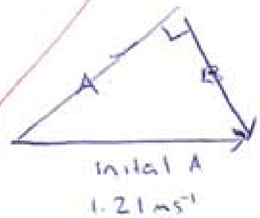
$0.521 \text{ ms}^{-1}$

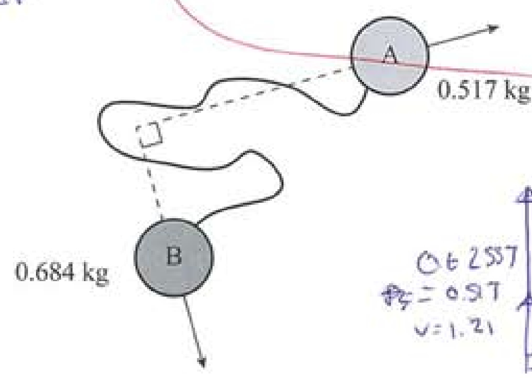
Correct equation and substitution.

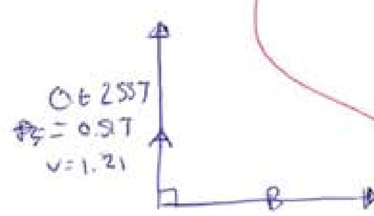
M

(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.

$\Delta P$




N

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

Explain your reasoning.

$0.517 \times 1.21 + 0.684 \times 0 = 0.517 \times 1.21 \;\; 0.684 \times$

No reason given, and no calculation of speed

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

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$m_1v_1 + m_2v_2 = m_1v_1\ m_2v_2 \rightarrow (0.517 \times 1.21) + (0.684 \times 0) = (0.517 \times v) + (0.684 \times 0.365)$

$P = 0.517 \times 0.727$

$P = 0.727$

$0.62557 = 0.517v + 0.24966$

$0.62557 \div 0.517 = v + 0.24966$

$1.21 = v + 0.24966$

N

The working in this answer assumes that the momenta is in a straight line. To gain Merit or Excellence for this question vectors and pythagorus is needed to find the unknown momentum.

(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 a system ~~[illegible]~~ is conserved if there are no external forces acting on the system, all of the forces in this collision are internal forces.

A

Correctly states no external forces results in the conservation of momentum. To get Merit they need to elaborate by saying this is due to the frictionless surface or by stating the tension in the cord is an internal force.

A3