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SUPERVISOR'S USE ONLY

OUTSTANDING SCHOLARSHIP EXEMPLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Tick this box if you have NOT written in this booklet

Scholarship 2022
Physics

Time allowed: Three hours
Total score: 32

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

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 the correct SI unit.

Formulae you may find useful are given on page 3.

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 2–20 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area. This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Question	Score
ONE	
TWO	
THREE	
FOUR	
TOTAL	

ASSESSOR'S USE ONLY

This page has been deliberately left blank.
The examination starts on page 4.

The formulae below may be of use to you.

$$v_f = v_i + at$$
$$d = v_i t + \frac{1}{2}at^2$$
$$d = \frac{v_i + v_f}{2}t$$
$$v_f^2 = v_i^2 + 2ad$$
$$F_g = \frac{GMm}{r^2}$$
$$F_c = \frac{mv^2}{r}$$
$$\Delta p = F\Delta t$$
$$\omega = 2\pi f$$
$$d = r\theta$$
$$v = r\omega$$
$$a = r\alpha$$
$$W = Fd$$
$$F_{net} = ma$$
$$p = mv$$
$$x_{COM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$
$$\omega = \frac{\Delta\theta}{\Delta t}$$
$$\alpha = \frac{\Delta\omega}{\Delta t}$$
$$L = I\omega$$
$$L = mvr$$
$$\tau = I\alpha$$
$$\tau = Fr$$
$$E_{K(ROT)} = \tfrac{1}{2}I\omega^2$$
$$E_{K(LIN)} = \tfrac{1}{2}mv^2$$
$$\Delta E_p = mg\Delta h$$
$$\omega_f = \omega_i + \alpha t$$
$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$
$$\theta = \frac{(\omega_i + \omega_f)}{2}t$$
$$\theta = \omega_i t + \tfrac{1}{2}\alpha t^2$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$
$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$E_p = \tfrac{1}{2}ky^2$$
$$F = -ky$$
$$a = -\omega^2 y$$

$$y = A\sin\omega t \qquad y = A\cos\omega t$$
$$v = A\omega\cos\omega t \qquad v = -A\omega\sin\omega t$$
$$a = -A\omega^2\sin\omega t \qquad a = -A\omega^2\cos\omega t$$

$$\Delta E = Vq$$
$$P = VI$$
$$V = Ed$$
$$Q = CV$$
$$C_T = C_1 + C_2$$
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$
$$E = \tfrac{1}{2}QV$$
$$C = \frac{\varepsilon_0\varepsilon_r A}{d}$$
$$\tau = RC$$
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$R_T = R_1 + R_2$$
$$V = IR$$

$$F = BIL$$
$$V = BvL$$
$$\phi = BA$$
$$\varepsilon = -\frac{\Delta\phi}{\Delta t}$$
$$\varepsilon = -L\frac{\Delta I}{\Delta t}$$
$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$$E = \tfrac{1}{2}LI^2$$
$$\tau = \frac{L}{R}$$
$$I = I_{MAX}\sin\omega t$$
$$V = V_{MAX}\sin\omega t$$
$$I_{MAX} = \sqrt{2}\,I_{rms}$$
$$V_{MAX} = \sqrt{2}\,V_{rms}$$
$$X_C = \frac{1}{\omega C}$$
$$X_L = \omega L$$
$$V = IZ$$
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$
$$v = f\lambda$$
$$f = \frac{1}{T}$$
$$n\lambda = \frac{dx}{L}$$
$$n\lambda = d\sin\theta$$
$$f' = f\frac{V_W}{V_W \pm V_S}$$
$$E = hf$$
$$hf = \phi + E_K$$
$$E = \Delta mc^2$$
$$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$$
$$E_n = -\frac{hcR}{n^2}$$

QUESTION ONE: PHOTONS

Radius of Earth	$= 6.37 \times 10^6$ m	Mean Earth-Sun distance	$= 1.50 \times 10^{11}$ m
Mass of Earth	$= 5.98 \times 10^{24}$ kg	Mass of Sun	$= 1.99 \times 10^{30}$ kg
Speed of light	$= 3.00 \times 10^8$ m s^{-1}	Planck's constant	$= 6.63 \times 10^{-34}$ J s
Surface area of a sphere	$= 4\pi r^2$		

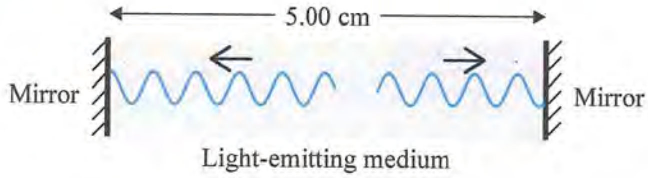
(a) The description of the photoelectric effect and the Bohr model of the atom both involve the concept of the quantisation of energy. There are similarities and differences in how this concept is applied in these contexts.

Describe ONE difference in the use of the concept of the quantisation of energy between the photoelectric effect and the Bohr model of the atom.

The photoelectric effect uses the quantisation of energy in photons (discrete energies carried by photons) while the Bohr model of the atom uses the quantisation of energy in the electron orbitals around the nucleus (discrete binding energies of electrons around ~~atom~~ nucleus).

✓

(b) A laser typically consists of a medium that emits light placed between two mirrors that form a cavity, as illustrated on the right. The cavity is similar to a closed box for the emitted light waves.



The light-emitting medium can emit a continuous spectrum of light within a narrow range of wavelengths. The minimum wavelength of emitted light is 480 nm (4.80×10^{-7} m), and the maximum wavelength is 490 nm (4.90×10^{-7} m). The cavity is 5.00 cm long.

Some wavelengths within this range are able to form standing waves within the cavity. These are called standing wave modes.

Calculate the total number of standing wave modes possible in the cavity within the emitted 480–490 nm range.

(Assume continuous spectrum :)

5.00 cm = 5×10^{-2} m (Standing wave modes = integer wavelengths)

number ~~ow~~ of wavelengths of 490 nm in a 5 cm cavity:

$n = l/\lambda = (5 \times 10^{-2})/(4.9 \times 10^{-7}) = 102040.8$ (wavelengths) ~~(waves)~~.

number of wavelengths of 480 nm in a 5 cm cavity:

$n = l/\lambda = (5 \times 10^{-2})/(4.8 \times 10^{-7}) = 104166.6$ (wavelengths)

✓

∴ All wavelengths, between 102041 and 104166 inclusive have ~~can~~ a light wave between 480 nm and 490 nm that produces exactly this many wavelengths in the medium.

104166 − 102041 = 2125. (not rounded).

∴ There are 2125 standing wave modes in the cavity within the emitted 480 nm − 490 nm range.

(c) The process of nuclear fusion in the Sun releases energy which spreads through space in the form of electromagnetic radiation. The photons that make up this radiation carry momentum as well as energy, with the momentum per photon given by:

$$p = \frac{h}{\lambda}$$

where h is Planck's constant, and λ is the photon wavelength.

The Sun loses 4.30×10^9 kg of mass each second due to nuclear reactions.

Estimate the force exerted on the Earth by the photons it receives from the Sun.

Assume each photon has a wavelength of 550 nm (5.50×10^{-7} m), and that every photon that reaches Earth is absorbed.

r(Earth) = 6.37×10^6 m. Surface area of Earth (Assume completely spheircal)

$= 4\pi(6.37 \times 10^6)^2 = 5.0990 \times 10^{14}$ m^2, half faces the sun.

Total area of a 1.5×10^{11} m sphere:

$A = 4\pi(1.5 \times 10^{11})^2 = 2.8274 \times 10^{23}$ m^2

Energy released (in 1 second) by the sun: $E = (4.3 \times 10^9) \times (3 \times 10^8)^2 = 3.87 \times 10^{26}$ J (in a second)

Photon momentum ~~energy~~: $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{5.5 \times 10^{-7}} = 1.205 \times 10^{-27}$ kg ms^{-1}

Photon energy: $E = hf = (6.63 \times 10^{-34}) \times \frac{(3 \times 10^8)}{(5.5 \times 10^{-7})} = 3.616 \times 10^{-19}$ J

Total photons released in 1 second: $n = \frac{3.87 \times 10^{26}}{3.616 \times 10^{-19}} = 1 \times 10^{45}$ (photons)

Please check extra working space: Q1 c) Question not finished.

(d) (i) Comment on the significance of the size of the force exerted on the Earth by the photons.

The photons exert a large force on the Earth of billions of Newtons, but the mass of the Earth is so large this force is negligible in comparison.

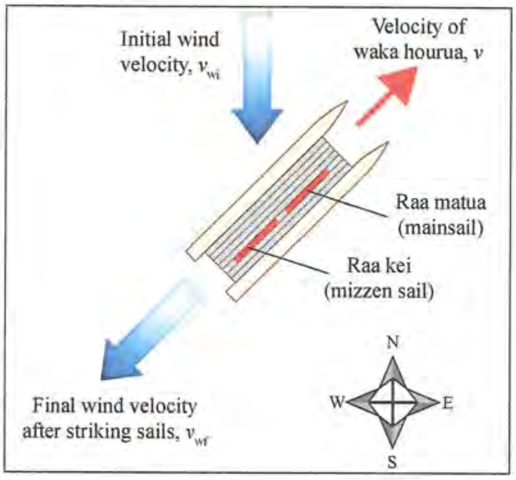
(ii) If the Earth were covered by ice it would be more reflective.

Explain how this would affect your answer to part (c).

If the Earth were covered in ice, not only will the photons that strike Earth change direction, they will get reflected back towards the Sun. By the conservation of momentum, the Earth gets a larger force pushing back by the reflected photons, and the answer to part (c) increases. (By a visible amount)

QUESTION TWO: WAKA HOURUA

The history of sailing in New Zealand goes right back to the original settlement by ancestors of Māori, more than 700 years ago. The ancestors, from Polynesia, designed double-hulled boats with triangular sails, called waka hourua, that were strong, stable, and most importantly, able to sail into the wind. This allowed them to carry out exploratory voyages. From such exploration, they were able to plan and carry out their migration to Aotearoa. Waka hourua are able to sail against the wind by heading at an angle to the wind, as shown in the simplified diagram below right.



Adapted from: www.sciencelearn.org.nz/images/701-te-aurere

As measured by a stationary observer, the initial wind velocity is 10.0 m s^{-1} from the north, the velocity of the waka hourua is 6.00 m s^{-1} to the north-east, and the final wind velocity is 10.0 m s^{-1} towards the south-west, in the opposite direction to the velocity of the waka hourua.

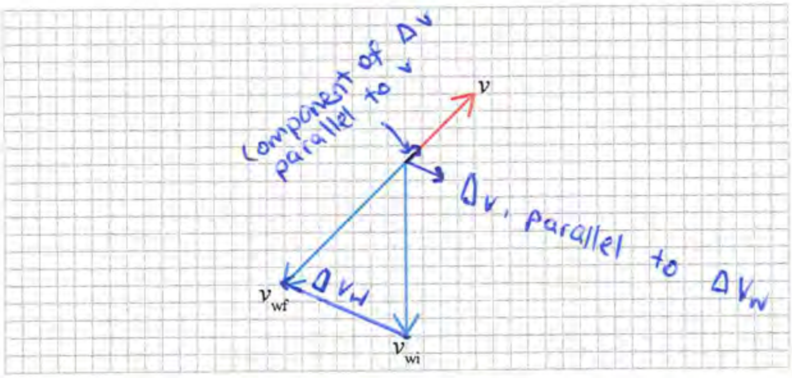
(a) (i) By considering the wind direction before and after striking the sails, use impulse and momentum to explain how the wind produces a force on the sail.

The wind is many air particles moving, which carry momentum.

The wind strikes the waka hourua's sail from the north direction. ~~Afte~~ The wind then leaves the sail in the south-western direction. By the conservation of momentum, the wind produces a force on the sail equal and opposite to the change in wind's direction. ✓

(ii) Explain how the wind produces a force on the waka hourua that has a component in the direction that the waka hourua is travelling.

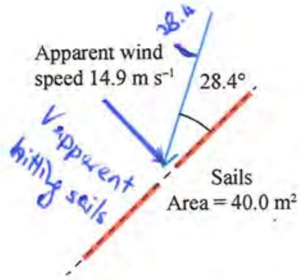
Use the grid below to draw a vector diagram to help your explanation. The vectors for the initial wind velocity v_{wi}, the final wind velocity v_{wf}, and the velocity v of the waka hourua are drawn on the grid to help you.
Start your answer by finding the vector for the change Δv_w in the velocity of the wind.



If you need to redraw your response, use the diagram on page 14.

The wind strikes the sails and is deflected to the west and slightly to the north. This in turn imparts momentum to the sails and waka hourua to the south east, opposite to how the wind is deflected. A component of this force acts in the north-east direction, in the direction that the waka hourua is travelling.

(b) The motion of the waka hourua combined with the motion of the wind changes both the apparent speed and direction of the wind hitting the sails. On board the moving waka hourua, the wind appears to have a higher speed, and to come from a direction further towards the front of the waka hourua. The captain measures the wind velocity as 14.9 m s^{-1} that hits the sails at an angle of 28.4°, as shown in the diagram on the right. The sails have a combined area of 40.0 m^2. The density of air is 1.23 kg m^{-3}.



Calculate the mass of air that hits the sails each second.

The wind has a component that hits the sails, and a component that moves parallel to the sails (which are discarded as they do not hit the sails).

$V_{perpendicular} = 14.9 \times \sin(28.4°) = 7.0868 \text{ ms}^{-1}$

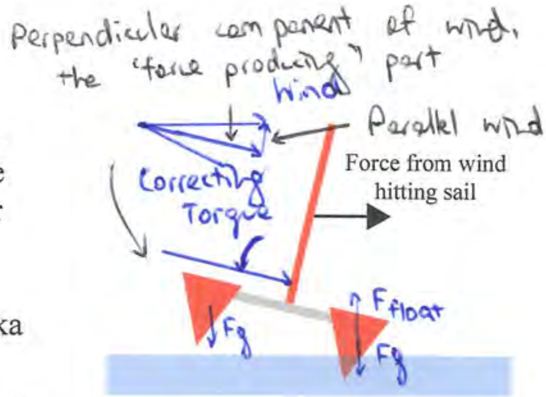
Perpendicular distance air travels in a second:

$d = vt = 7.087 \text{ m}$.

Q2 b)

Please check extra working space: Question not finished.

(c) The sideways force of the wind on the sails causes the waka hourua to tilt over sideways. In strong winds, the upwind side of the hiwi (hull) may lift out of the water altogether.



(i) Explain how the double-hulled design of the waka hourua helps it stay upright in strong winds.

You may wish to add information to the diagram to illustrate your answer.

A waka hourua has two hulls. When in a strong wind, One end will lift out of the water. This means the lifted hull does not experience a 'float' lift force, but the submerged hull does. This causes only one side to experience a normal reaction force, and the ship will turn back under this torque, helping it stay upright.

For a single hulled ship, if the wind is strong enough to shift the com outside the support then the ship will capsize because of the torque.

(ii) Explain how the tilting of the waka hourua will affect the force produced by the wind hitting the sails.

The tilting of the waka hourua causes the wind that is perpendicular to the sails that are providing the force to be shifted an angle equal to the tilt. This reduces the perpendicular wind hitting the ship's sails, and the waka hourua will not have as much force on it. (This will also decrease the sideways force on the ship, making it more stable.)

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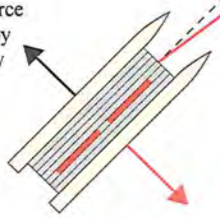
(d) Due to the sideways component of the force from the wind, the velocity of the waka hourua is in a slightly different direction to the direction that the hull is pointing. This slight difference in directions creates an asymmetrical flow of water around the sides of the hull, which produces a sideways force on the hull of the waka hourua, as shown in the diagram on the right.



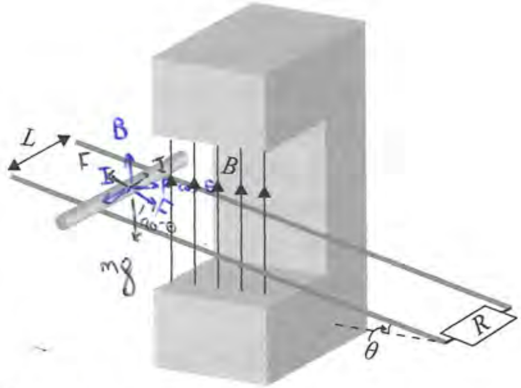
Explain the effect the sideways force produced by water flow around the hull will have on the direction of motion, and on the ability of the waka hourua to stay upright in strong winds.

The waka hourua 'cuts into' the water on the 'right side' of it, and 'steers away' from the water left of it. This produces the water flow force, which attempts to counteract the wind force and push the waka hourua back on to the direction it is pointing in. This reduces the 'error' the wind acts on the waka hourua. However, this force acts on the bottom of the ship. and the wind force acts on the sails at the top of the ship. There is a distance between the places where the wind and water acts on, and so ~~a force is~~ torque is produced by the normal forces. This torque rotates the ship in the direction the wind is pushing it, and contributes to the tilting of the ship, which undermines the ability of the waka hourua to stay upright in strong winds.

QUESTION THREE: MAGNET SLIDER

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

A metal roller of mass m slides without friction down parallel conducting rails of negligible electrical resistance. The rails are separated by a distance L, and are connected to each other at the bottom by a resistance R, forming a closed rectangular conducting loop with the rails and the roller. The plane of the rails makes an angle θ with the horizontal, and a uniform vertical magnetic field B exists throughout the region.



$F = mg \cos(90-\theta)$

As the metal roller slides down the rails through the magnetic field, it reaches a constant velocity v.

(a) (i) Show that the constant velocity achieved by the roller through the magnetic field is given by the relationship:

little v = velocity

$$v = \frac{mgR\tan\theta}{B^2L^2\cos\theta}$$ **Equation #1**

Big V = Voltage

mg sin θ

mg cos θ

mg

(perpendicular)

$V = BvL$, $\cancel{v = \frac{V}{BL}}$

$V = BvL\cos\theta$, $v = \frac{V}{BL\cos\theta}$ Force by gravity = mg

$V = IR$, $v = \frac{IR}{BL\cos\theta}$. F_{net} on object = mg sin θ

(perpendicular)

$F = BIL$, $I = \frac{F}{BL\cos\theta} = \frac{mg\sin\theta}{BL\cos\theta} = \frac{mg\tan\theta}{BL}$

$F = BIL\cos\theta$.

Constant velocity → no net force, so $F_{magnet} = F_{gravity} + F_{support}$.

∴ The constant velocity achieved by the roller through the magnetic field is $v = \frac{mgR\tan\theta}{B^2L^2\cos\theta}$

See Q3 a) - Extra space for a less messy copy.

(ii) Explain what difference, if any, it makes to the constant velocity v, if the magnetic field is in the opposite direction.

The magnetic field is now reversed. However, it still cuts the plane at an angle of 90 - θ. This means that the roller's plane is still θ degrees from the horizontal. The magnetic field with B reversed also has I reversed, so the force acting on the roller that is slowing it down is still opposing the combined force of gravity and the support force. As the magnetic field has not changed in strength, the constant velocity v will not change. The electric current through R will, however, change direction.

For small values of θ, Equation #1 may be approximated as:

$$v = \frac{mgR}{B^2L^2} \times \left(\theta + \frac{5\theta^3}{6} \right) \qquad \textbf{Equation \#2}$$

(b) An experiment is set up with $B = 2.00$ T, $L = 0.500$ m, $m = 5.00 \times 10^{-3}$ kg, and $R = 10.0\ \Omega$.

Determine the accuracy of **Equation #2**, compared with **Equation #1**, at $\theta = 25.0°$ (0.436 radians). Assume "accuracy" $= 1 - \frac{\text{error}}{\text{answer}}$

$\theta = 25.0° = 0.436$ rad.

Eq #1 : $v_t = \frac{5\times10^{-3} \times 9.81 \times 10.0}{2.00^2 \times 0.500^2} \times \frac{\tan 0.436}{\cos 0.436} = 0.25211\ ms^{-1}$ (5 sf. comparison)

Eq #2 : $v_a = \frac{5\times10^{-3} \times 9.81 \times 10.0}{2.00^2 \times 0.500^2} \times \left(0.436 + \frac{5}{6}(0.436)^3\right) = 0.24774\ ms^{-1}$

error $= V_{true} - V_{approximation} = 4.37 \times 10^{-3}\ ms^{-1}$

error ~~for~~ ratio $= 0.017$, accuracy $= 1 -$ error ratio

$= 0.983$. The approximation is 98% accurate and off by <2%.

(c) By calculating the velocity at the high angle of $\theta = 85.0°$, explain if this equipment would be suitable for testing whether **Equation #1** is accurate at high angles of θ.

$\theta = 85.0° = 1.4835$ rad $\quad E_p < 5\times10^{-3} \times 9.81 \times 0.5 = 0.02$ J $\quad E_k = \frac{1}{2}mv^2$

Eq #1 : $V_t = \frac{5\times10^{-3} \times 9.81 \times 10.0}{2.00^2 \times 0.500^2} \times \frac{\tan 1.4835}{\cos 1.4835} = 64.28\ ms^{-1}$: $\frac{1}{2}(5\times10^{-3})(64.28)^2$

~~Eq #2 V~~ It'd ~~reach~~ have too much more energy than the system can give. $= 10$ J

A rolling metal roller cannot reach $64.28\ ms^{-1}$ with the apparatus being 0.500 m and the magnetic field impeding motion.

Therefore, Equation #1 is not accurate at high angles of θ.

At high angles of θ, the velocity just does not have enough time to speed to the steady state before reaching the end of the loop in the field.

(d) Explain whether **Equation #1** remains valid if the roller rolls rather than slides down the slope.

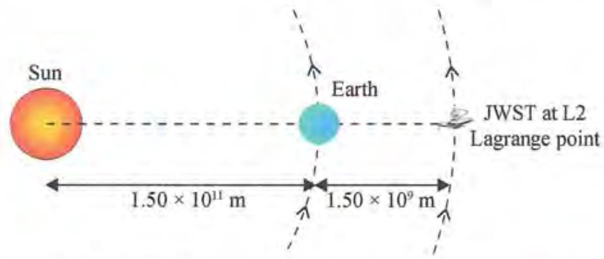
Entering the magnetic region: there will not be a net force on the whole object, as the magnetic force counteracts the gravitational force and the support force. Because angular momentum is conserved, by $L = I\omega$ and the rotational inertia does not change while rolling, the angular velocity must also stay constant. This ~~also~~ means that the rotational speed is constant ~~during~~ while in the magnetic field, and will not have an effect on the magnetic force or gravity, so Equation #1 will remain valid.

QUESTION FOUR: ORBITAL DYNAMICS

Universal Gravitational Constant $= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Period of Earth's orbit $= 365.25$ days

Mass of Sun $= 1.99 \times 10^{30}$ kg
Mass of Earth $= 5.98 \times 10^{24}$ kg

The James Webb Space Telescope (JWST) has a mass of 6.16×10^3 kg. It was launched on Christmas Day 2021 and is now orbiting at a point called the L2 Lagrange point, where it will remain in a direct line with the Sun and Earth as shown right.



(a) (i) State the period of the orbit of the JWST around the Sun.

Period = 365.25 days
or 3.16×10^7 s (3. s.f).

(ii) Calculate the net force acting on the JWST at the L2 point.

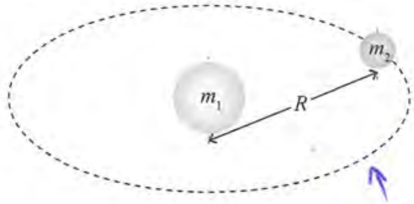
$F_{net} = \frac{GM_\odot M_J}{r_s^2} + \frac{GM_E M_J}{r_e^2}$

$= 6.67 \times 10^{-11} \times 6.16 \times 10^3 \times \left(\frac{1.99 \times 10^{30}}{(1.5 \times 10^{11} + 1.5 \times 10^9)^2} + \frac{5.98 \times 10^{24}}{(1.5 \times 10^9)^2}\right)$

$= 36.7$ N or 36.7 kg m s^{-2} (3. s. f.)

An approximation for two bodies in orbit around each other is that the period T of the orbit can be determined using the relationship:

$$T^2 = \frac{4\pi^2 R^3}{Gm_1}$$



where R is the distance between the centre of masses of the two objects, and m_1 is the mass of the more massive body.

ii): This is circular!

(b) One assumption of the relationship above is that m_1 is much greater than m_2.

(i) Explain why it is necessary to assume that m_1 is much greater than m_2 to derive this relationship.

If m_1 is not much greater then m_2, then m_1 and m_2 would be better approximated by two bodies orbiting a common point rather then just m_2 orbiting m_1. (If the gravitational effects of m_2 on m_1 is not negligible then m_2 should appear in the top equation).

(ii) State another key assumption of this relationship.

The system has circular symmetry, which means the two bodies in orbit around each other both traces circles, not ellipses. (ellipses are ~~very~~ common and are generalisations of circles)

(c) In the case that m_1 is **not** much larger than m_2, show that the period of the orbit is given by the relationship:

$$T^2 = \frac{4\pi^2 R^3}{G(m_1 + m_2)}$$

Any other assumptions made for the relationship given on page 12 are still valid.

Force of gravity on m_2 = Centripetal force on m_2

$\frac{Gm_1m_2}{R^2} = \frac{m_2v^2}{D}$ (D is the distance from m_2 to the centre of mass).

$D = \frac{m_1R}{(m_1+m_2)}$

$\frac{Gm_1m_2}{R^2} = \frac{m_2v^2(m_1+m_2)}{m_1R}$ $v = r\omega = (\frac{m_1R}{m_1+m_2})\omega$

$m_1R(Gm_1m_2) = R^2(m_1+m_2)(\frac{m_1R}{m_1+m_2})^2\omega^2 m_2$

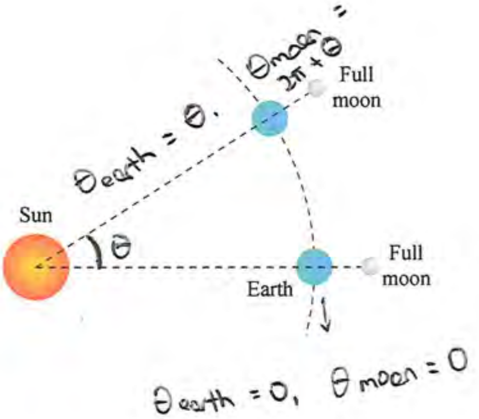
$m_1R(Gm_1m_2) = R^4 m_1^2 m_2 \frac{(2\pi)^2}{(m_1+m_2)} f^2$

$RG = R^4 \cdot \frac{4\pi^2}{m_1+m_2} \cdot \frac{1}{T^2}$

$T^2G = R^3 \cdot \frac{4\pi^2}{m_1+m_2}$

$\therefore T^2 = \frac{4\pi^2R^2}{G(m_1+m_2)}$, relationship shown.

(d) The phases of the Moon are caused by the relative positions of the Sun, Earth, and Moon. A full moon occurs when the Sun, Earth, and Moon are directly aligned. The Moon takes 27.3 days to complete one 360° orbit around the Earth. However, because the Moon must orbit more than 360° to return to a direct alignment with the Sun and Earth (as shown in the diagram on the right), the time between one full moon and the next is more than 27.3 days.



Show that the time between one full moon and the next is 29.5 days.

$T_{earth} = 365.25$ days, $T_{moon} = 27.3$ days

$= 365.25 \cdot 86400$ seconds $= 27.3 \cdot 86400$ seconds

$= 3.15576 \times 10^7$ s $= 2.35872 \times 10^6$ s

$f_{earth} = \frac{1}{T} = 3.1688 \times 10^{-8}$ Hz $f_{moon} = \frac{1}{T} = 4.2396 \times 10^{-7}$ Hz.

$\omega_{earth} = 2\pi f = 1.991 \times 10^{-7}$ rads^{-1} $\omega_{moon} = 2\pi f = 2.664 \times 10^{-6}$ rads^{-1}

There is no angular acceleration.

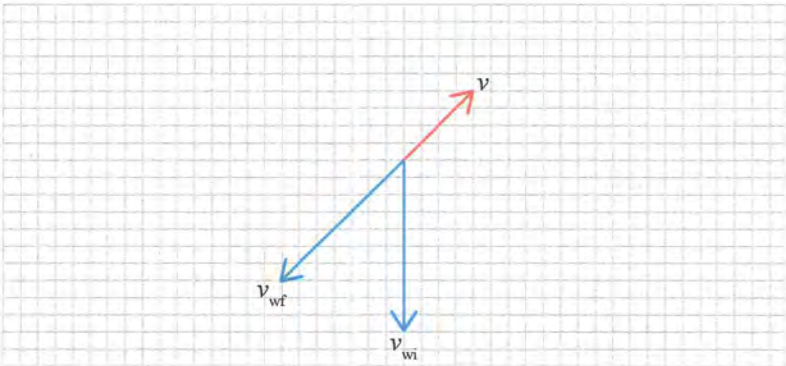
$\theta_{earth} = \omega t = 1.991 \times 10^{-7}$ rads$^{-1} \cdot t$. $\theta_{moon} = \omega t = 2.664 \times 10^{-6}$ rads$^{-1} \cdot t$

We want θ_{moon} to be $2\pi + \theta_{earth}$ ......

Please check extra working space Q4 d) : Question not finished.

SPARE DIAGRAMS

If you need to redraw your response to Question Two (a)(ii), use the diagram below. Make sure it is clear which answer you want marked.



Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Q1 c): $n = 1.07 \times 10^{45}$ photons

Photons that strike Earth: (per second).

$S = n \frac{\text{Area (Earth)}}{\text{Area (Orbit)}} = 1.07 \times 10^{45} \times \frac{5.099 \times 10^{14}}{2.827 \times 10^{23}} = 1.93 \times 10^{36}$ (photons)

Momentum of photons:

$p_T = S \cdot p = 1.93 \times 10^{36} \times 1.205 \times 10^{-27} = 2.3 \times 10^{9}$ kgms^{-1} (per second)

Velocity Imparted:

$\Delta v = \frac{\Delta p}{m} = \frac{2.3 \times 10^{9}}{5.98 \times 10^{24}} = 3.89 \times 10^{-16}$ ms^{-1} (per second)

Acceleration ~~Force~~ exerted:

$a = \frac{\Delta v}{\Delta t} = 3.89 \times 10^{-16}$ ms^{-2}

Force exerted:

$F = ma = 3.89 \times 10^{-16} \times (5.98 \times 10^{24}) = 2.33 \times 10^{9}$ kgms^{-2} (N)

∴ The total force exerted on the Earth by photons it receives from the sun is 2.33×10^{9} kgms^{-2}.

or 2.33×10^{9} N.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Q2 b). $d = vt = 7.087\ m$.

Volume of wind that hits the sails:

$V = l \cdot A_{perpendicular}$

$= 7.087m \times 40m^2$

$= 283.47\ m^3$, Density, assume uniform

$m_{air} = V_{air} \cdot \rho_{air}$

$= 283.47\ m^3 \times 1.23\ kgm^{-3}$

$= 348.67\ kg$.

The total mass of air hitting the sails in one second is 348.67 kg.

Q4 d).

$\theta_{earth} = 1.991 \times 10^{-7}\ rads^{-1} \cdot t$. $\theta_{moon} = 2.664 \times 10^{-6}\ rads^{-1} \cdot t$.

For the moon to align with the earth, the apparent angle seen from the sun must be the same (equal).

However, to calculate the next full moon, the moon must have overtaken the earth in orbiting and is now 2π radians ahead of earth.

$\therefore\ \theta_{moon} = 2\pi + \theta_{earth}$. This is because the moon has a faster angular velocity.

The times between the overtakings is equal, so we just calculated ~~the~~ from a full moon (t=0) to the next.

$\theta_{moon} = 2\pi + \theta_{earth}$

$w_{moon}\, t = 2\pi + w_{earth}\, t$.

$2.664 \times 10^{-6}\, t = 2\pi + 1.991 \times 10^{-7}\, t$

$(2.664 \times 10^{-6} - 1.991 \times 10^{-7})t = 2\pi$

$(2.4647 \times 10^{-6})t = 2\pi$

$t = 2\pi / (2.4647 \times 10^{-6})$

$= 2549260\ s$

$= 2.54 \times 10^6\ s$ (3.s.f.)

Convert to days:

$t = 2.54 \times 10^6\ s$

$= \frac{2.54 \times 10^6}{86400}$ days

$= 29.5$ days (3.s.f).

$\therefore$ The time between one full moon and the next is 29.5 days.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Q3 a) - Cleaner copy.

$F = BIL\cos\theta,\quad V = BvL\cos\theta,\quad F_B = F_g\sin\theta$

v

$= \dfrac{V}{BL\cos\theta}$

$= \dfrac{IR}{BL\cos\theta}$

$= \dfrac{R}{BL\cos\theta} \cdot \dfrac{F}{BL\cos\theta}$

$= \dfrac{R}{BL\cos\theta} \cdot \dfrac{F_g\sin\theta}{BL\cos\theta}$

$= \dfrac{R}{BL\cos\theta} \cdot \dfrac{F_g\tan\theta}{BL}$

$= \dfrac{R\tan\theta}{B^2L^2\cos\theta} \cdot F_g$

$= \dfrac{mgR\tan\theta}{B^2L^2\cos\theta}.$ $\therefore$,

$\therefore\ v = \dfrac{mgR\tan\theta}{B^2L^2\cos\theta}.$

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

93103

Outstanding Performance Scholarship exemplar 2022

Subject:	**Physics**	**NZS standard:**	**93103**	**Total score:**	**28**

Q	**Score**	**Annotation**
1	6	Scholarship level of understanding demonstrated throughout though marred by a lack of insight in relation to modes of standing waves and the effective area of the Earth.
2	7	Outstanding demonstration of understanding of torque, vectors and momentum.
3	8	Outstanding display of clarity of thought concerning components, induction, consequences and the full meaning of Newton's 1st Law of motion.
4	7	Outstanding understanding of orbital mechanics demonstrated. Exemplary communication of the algebraic calculations are a significant factor in this outstanding result.