Assessment Schedule – 2022

Scholarship Physics (93103)

Evidence Statement

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
ONE (a)	PE effect quantisation of energy of light / photons vs. Bohr model quantisation of energy of electron.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	Require [electric field] nodes at mirrored ends: $n\lambda = 2L$ where $n = 1,2,3,\ldots$ and L = the cavity length For $\lambda = 490$ mm, $n = \dfrac{2\times 0.05}{490\times 10^{-9}} = 204\,082$ For $\lambda = 480$ mm, $n = \dfrac{2\times 0.05}{480\times 10^{-9}} = 208\,333$ All values of n between these limits will give allowed modes, so there are 208 333 – 204 082 = 4251 allowed modes.			
(c)	Energy associated with mass loss: $E = mc^2 = 4.3\times 10^9 \times (3\times 10^8)^2 = 3.87\times 10^{26}$ J each second For 550 mm light, $f = \dfrac{3\times 10^8}{550\times 10^{-9}} = 5.45\times 10^{14}$ Hz So $\dfrac{E}{\text{h}f} = \dfrac{3.9\times 10^{26}}{6.63\times 10^{-34}\times 5.5\times 10^{14}}$ $= 1.07\times 10^{45}$ photons per second Proportion of total emitted photons absorbed by Earth is $\dfrac{A_{\text{Earth}}}{A_{\text{Earth orbit}}} = \dfrac{\pi\times 6\,370\,000^2}{4\pi\times 150\,000\,000^2} = 4.51\times 10^{-10}$ No. photons absorbed by Earth = $1.07 \times 10^{45} \times 4.51 \times 10^{-10}$ = 4.82×10^{35} photons per second The momentum of one photon is $p = \dfrac{\text{h}}{\lambda} = \dfrac{6.63\times 10^{-34}}{550\times 10^{-9}} = 1.21\times 10^{-27}$ kg m s^{-1} Total momentum imparted to Earth in one second is $1.21\times 10^{-27}\times 4.82\times 10^{35} = 5.84\times 10^8$ kg m s^{-1} Force, $F = \dfrac{\Delta p}{\Delta t} = 5.84\times 10^8$ N			
(d)(i)	Gravitational / Centripetal / Net force on Earth is in the order of 10^{22} N, force from photons is only 10^8 N, so is insignificant. OR The acceleration caused by this force is $a = \dfrac{F}{m} = \dfrac{6\times 10^8}{5.98\times 10^{24}} = 1\times 10^{-16}$ m s^{-2} which is insignificant (would take about 4.5 years to move Earth 1m).			
(ii)	The reflected light bounces back, rather than stopping / being absorbed. So it has a larger impulse and transfers more momentum to the Earth than absorbed light. So the force would increase (but is still insignificant).			

<table>
<tr><th>Q</th><th>Evidence</th><th>1–4
Below Schol</th><th>5–6
Scholarship</th><th>7–8
Outstanding</th></tr>
<tr><td>TWO
(a)(i)</td><td>The wind has a change in direction, so also has a change in momentum. As the air has a change in momentum / impulse, there is a force on the mass of air. There is an equal and opposite reaction force on the sail.</td>
<td rowspan="3">Reasonably thorough understanding of this application of physics.
OR
Partially correct mathematical solution to the given problems.
AND / OR
Partial understanding of this application of physics.</td>
<td rowspan="3">(Partially) correct mathematical solution to the given problems.
AND / OR
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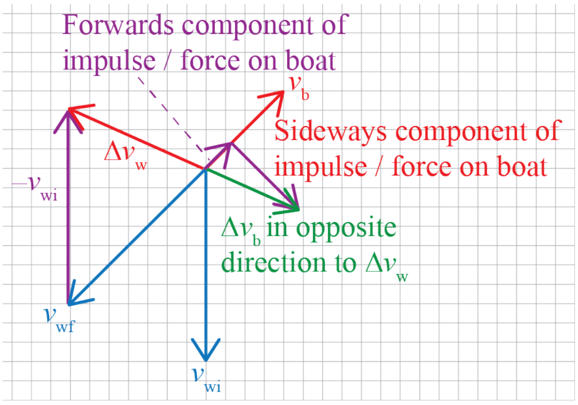
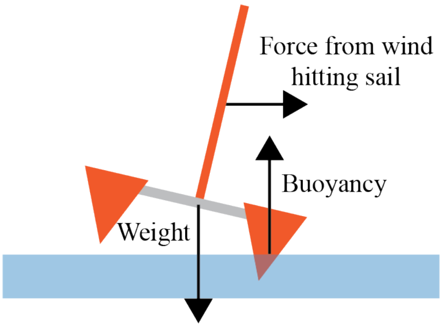
<td rowspan="3">Correct mathematical solution to the given problems.
AND
Thorough understanding of this application of physics.</td></tr>
<tr><td>(ii)</td><td>

The direction of the force on the wind is in the same direction as the Δv of the wind ($\Delta v = v_f - v_i$). The direction of the force on the boat is in the opposite direction to the Δv of the wind. The direction of $-\Delta v$ is not perpendicular to the velocity of the boat, but has a small forwards component, meaning there is a small forwards force on the boat.</td></tr>
<tr><td>(b)</td><td>Mass = density × area of sails × velocity of air normal to sails.
Density = 1.23 kg m^{-3}
Area of sails = 40 m^2
Velocity of air relative to sails = 14.9 m s^{-1}
Velocity of air normal to sails = 14.9 × sin 28.4°
m = 1.23 × 40.0 × 14.9 × sin 28.4° = 349 kg
(An equivalent approach is to look at the area normal to the wind defined by the sails.)</td></tr>
</table>

(c)(i)	Torques about downwind hull: Lifting one side of the hull up means the hull is pivoting about the downwind hull. The weight of the boat, acting at the CoM of the boat, is now acting at a horizontal distance from the pivot point, so produces a torque that acts against the torque of the force from the wind. OR Torques about CoM: When one side of the hull is lifted out of the water, the downwind hull sinks deeper into the water until its buoyancy balances the weight of the boat. This buoyancy is horizontally displaced from the CoM, so produces a torque that acts against the torque of the force from the wind.  			
(ii)	As the boat tilts, the area of the sails that is perpendicular to the wind is decreased. This reduces the mass of air intercepted by the sails each second, and so reduces the force from the wind on the sails.			
(d)	The sideways force from the water flow acts against the force from the wind that pushes the boat sideways in the water. This will reduce the net sideways force, reducing the angle and making the boat travel in a direction closer to the direction in which the boat is pointing. The sideways force on the hull also produces a torque that acts in the same direction as the torque from the wind on the sails, so will make the boat lean over further (and be more likely to tip over).			

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
THREE (a)(i)	Component of gravitational force down the rails: $F_g = mg\sin\theta$ Magnetic force up the rails: $F_{mag} = BIL\cos\theta = B\frac{V}{R}L\cos\theta = B\frac{BvL\cos\theta}{R}L\cos\theta$ $= \frac{B^2vL^2\cos^2\theta}{R}$ $F_g = F_{mag}$ $mg\sin\theta = \frac{B^2vL^2\cos^2\theta}{R}$ $v = \frac{mgR\sin\theta}{B^2L^2\cos^2\theta} = \frac{mgR\tan\theta}{B^2L^2\cos\theta}$ OR Equate power due to loss of gravitational potential energy to power dissipated in the resistor, to get the same equation.	Reasonably thorough understanding of this application of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of this application of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of this application of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of this application of physics.
(ii)	No difference. It is the change in magnetic flux that is important in creating an electromagnetic force, not its direction. Although *B* and *I* will change by 180°, the combined effect of both will be to create a force that still opposes the motion of the roller down the ramp.			
(b)	Equation 1: $v = \frac{mgR\tan\theta}{B^2L^2\cos\theta}$ $= \frac{0.005\times 9.81\times 10\times \tan 25°}{2^2\times 0.5^2\times \cos 25°}$ $= 0.252 \text{ m s}^{-1}$ Equation 2: $v = \frac{mgR}{B^2L^2}\left(\theta + \frac{5\theta^3}{6}\right)$ $= \frac{0.005\times 9.81\times 10}{2^2\times 0.5^2}\times\left(0.436 + \frac{5\times 0.436^3}{6}\right)$ $= 0.248 \text{ m s}^{-1}$ Difference: $\frac{\Delta v}{v} = \frac{0.252-0.248}{0.252} = 0.016 = 1.6\%$ OR compares $\frac{\tan\theta}{\cos\theta}$ to $\theta + \frac{5}{6}\theta^3$ for the same result.			

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(c)	$v = \dfrac{mgR\tan\theta}{B^2L^2\cos\theta}$ $= \dfrac{0.005\times 9.81\times 10\times \tan 85°}{2^2\times 0.5^2\times \cos 85°}$ $= 64.3\ \text{m s}^{-1}$ For free fall under gravity, this would require a minimum height of more than 200 m for the constant velocity to be reached. Therefore, the experimental set-up is unsuitable for testing the equation at high angles.			
(d)	There will be no effect of the rolling on Equation #1, because the rotational energy (and the kinetic energy for that matter) has no effect on the balance of forces (or, from an energy viewpoint, on the balance between the gravitational potential energy loss and the resistive energy loss).			

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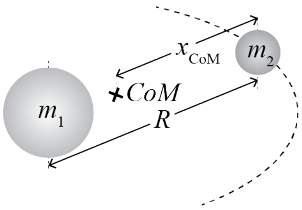
FOUR (a)(i)	$T = 365.25$ days	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(ii)	$F_{\text{net}} = F_{\text{c}} = \frac{mv^2}{r} = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 mr}{T^2}$ $= \frac{4\pi^2 \times 6160 \times (1.50 \times 10^{11} + 1.50 \times 10^9)}{(365.25 \times 24 \times 60 \times 60)^2}$ $= 37.0$ N OR $F_{\text{net}} = F_{\text{G Sun}} + F_{\text{G Earth}}$ $F_{\text{net}} = \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 6160}{(1.50 \times 10^{11} + 1.50 \times 10^9)^2} + \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 6160}{(1.50 \times 10^9)^2}$ $F_{\text{net}} = 36.7$ N *(Slight differences between methods due to assumptions used.)*			
(b)(i)	The CoM of the system must be at the centre of the larger mass. OR The r terms in the equations for F_C and F_G must be the same. Or m_1 effectively stays in the same position.			
(ii)	The orbit is circular. Or a closed system of only two bodies / no external forces.			

Question	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
(c)	 For m_2 : $x_{CoM} = \frac{m_1 R + m_2 0}{m_1 + m_2} = \frac{m_1 R}{m_1 + m_2}$ Assuming m_2 has a circular orbit with radius x_{CoM} : $F_c = F_g$ $\frac{m_2 v^2}{x_{CoM}} = \frac{G m_1 m_2}{R^2}$ $v^2 = \frac{G m_1 x_{CoM}}{R^2}$ $\left(\frac{2\pi x_{CoM}}{T}\right)^2 = \frac{G m_1 x_{CoM}}{R^2}$ $\frac{4\pi^2 x_{CoM}}{T^2} = \frac{G m_1}{R^2}$ $T^2 = \frac{4\pi^2 R^2 x_{CoM}}{G m_1}$ $T^2 = \frac{4\pi^2 R^2}{G m_1} \cdot \frac{m_1 R}{m_1 + m_2}$ $T^2 = \frac{4\pi^2 R^3}{G(m_1 + m_2)}$			

Question	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
(d)	During one period of the Moon's phases, t, the Earth moves through an angle θ_E. During this time the Moon will turn through one complete 2π radian orbit, plus an additional θ_E to return to the needed alignment with the Sun and Earth. $\theta_M = 2\pi + \theta_E$ $\omega_M t = 2\pi + \omega_E t$ $\omega_M t - \omega_E t = 2\pi$ $(\omega_M - \omega_E)t = 2\pi$ $\left(\frac{2\pi}{T_M} - \frac{2\pi}{T_E}\right)t = 2\pi$ $\left(\frac{1}{T_M} - \frac{1}{T_E}\right)t = 1$ $t = \frac{1}{\frac{1}{T_M} - \frac{1}{T_E}}$ $t = \frac{1}{\frac{1}{27.3} - \frac{1}{365.25}}$ $t = 29.5$ days OR Use iterative method to calculate time taken for Moon to 'catch up' with Earth. 1 orbit = 27.3 days In 27.3 days, Earth moves $\frac{27.3}{365.25} = 0.0747$ further around its orbit. 0.0747 × 27.3 = 2.04 days extra for Moon to catch up = 29.34 days total In extra 2.04 days, Earth moves $\frac{2.04}{365.25} = 5.59 \times 10^{-3}$ further round its orbit. $5.59 \times 10^{-3} \times 27.3 = 0.15$ days extra for Moon to catch up = 29.49 days total = 29.5 days (3 s. f.) (*Additional iterations do not change answer to 3 s. f.*)			