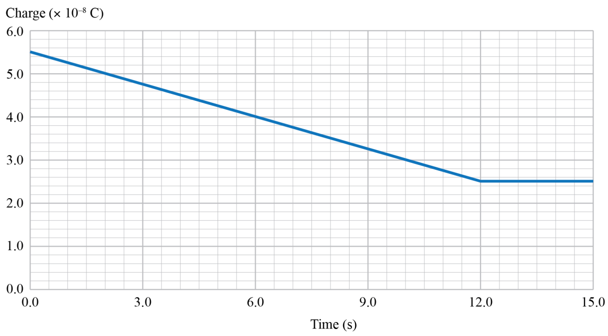
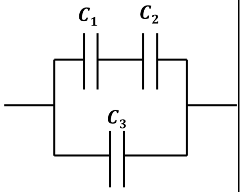
Assessment Schedule – 2024

Scholarship Physics (93103)

Evidence Statement

Q	Evidence	1–4 marks	5–6 marks	7–8 marks
ONE (a)(i)	$C = \frac{\varepsilon_0 \varepsilon_r A}{d} = \frac{8.85\times10^{-12}\times1.0\times0.52\times0.88}{0.0080}$ $= 5.06\times10^{-10}$ F $Q = CV = 5.06\times10^{-10}\times50.0 = 2.53\times10^{-8}$ C $= 2.5\times10^{-8}$ C (2 s. f.) Answer is stated to 2 s.f. as that is the least number of s.f. of the supplied data (plate separation).	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. 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)	Only half the energy provided by the supply is stored in the capacitor. The other half is dissipated as heat by resistance in the circuit (wires, contact resistance in the switch, internal resistance of the power supply, etc…).			
(b)(i)	Step 1: Close the switch – produces p.d. of 50 V between the capacitor plates. Step 2: Fill the tank with oil – increases capacitance, so increases the charge stored as V is fixed. Step 3: Open the switch – prevents charge leaving the capacitor / constant Q. Step 4: Drain the oil from the capacitor – decreases capacitance, which increases V when Q is constant.			
(ii)	$V_{max} = \varepsilon_r V = 2.1\times50.0 = 105$ V $= 110$ V (2 s. f.)			
(c)	Initial charge = 5.3 × 10^{-8} C. Final charge = 2.5 × 10^{-8} C. 			

(d)	This essentially splits the tank into three sections connected as shown.  C_1 and C_2 both have half the area and half the separation, so the same total capacitance, C, as the original tank. Connected in series C_1 and C_2 have a combined capacitance of $\frac{C}{2}$. C_3 has half the area, but the same separation as the original tank, so has a capacitance of $\frac{C}{2}$. The two sections, each with capacitance $\frac{C}{2}$, connected in parallel have a total capacitance of C, the same as the original tank. Adding the third plate has no effect on the total capacitance of the tank.			

<table>
<tr><th>Q</th><th>Evidence</th><th>1–4 marks</th><th>5–6 marks</th><th>7–8 marks</th></tr>
<tr><td>TWO
(a)</td><td>Potential energy is converted to linear and rotational kinetic energy:
$E_\text{p} = E_\text{klin} + E_\text{krot}$
$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$
$mgh = \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{1}{2}mr^2 \times \frac{v^2}{r^2}$
$mgh = \frac{1}{2}mv^2 + \frac{1}{4}mv^2$
$gh = \frac{3}{4}v^2$
$v = \sqrt{\frac{4gh}{3}} = 2\sqrt{\frac{gh}{3}}$
$d = \frac{v_\text{f} + v_\text{i}}{2}t$
$t = \frac{2d}{v_\text{f} + v_\text{i}} = \frac{2L}{2\sqrt{\frac{gh}{3}}} = L\sqrt{\frac{3}{gh}}$</td><td rowspan="2">Thorough understanding of these applications of physics.
OR
Partially correct mathematical solution to the given problems.
OR
Partial understanding of these applications of physics.</td><td rowspan="2">(Partially) correct mathematical solution to the given problems.
OR
Reasonably thorough understanding of these applications of physics.</td><td rowspan="2">Correct mathematical solution to the given problems.
AND
Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)(i)

(ii)</td><td>Statement 1 is valid. Linear acceleration means that linear momentum is changing as mass is constant. For linear momentum to change a non-zero net force must always be applied. (Or just refer to Newton’s second law.)

Statement 2 is not valid. A non-zero net torque will change the angular momentum, and so produce angular acceleration for constant rotational inertia. However, angular acceleration can also be achieved without a change in angular momentum by changing the rotational inertia (moving the mass closer or further from the axis of rotation). If the mass moves closer to the axis of rotation, the rotational inertia decreases and the angular velocity increases (angular acceleration), but the angular momentum has not changed as no non-zero net torque has been applied.</td></tr>
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(c)	Add inertias of the sections left and right of the CoR Left of CoR: $I_L = \frac{1}{3}\frac{m\left(\frac{L}{2}-d\right)}{L}\left(\frac{L}{2}-d\right)^2 = \frac{m}{3L}\left(\frac{L}{2}-d\right)^3$ Right of CoR: $I_R = \frac{1}{3}\frac{m\left(\frac{L}{2}+d\right)}{L}\left(\frac{L}{2}+d\right)^2 = \frac{m}{3L}\left(\frac{L}{2}+d\right)^3$ Total: $I = \frac{m}{3L}\left(\frac{L}{2}-d\right)^3 + \frac{m}{3L}\left(\frac{L}{2}+d\right)^3$ $I = \frac{m}{3L}\left(\left(\frac{L}{2}-d\right)^3 + \left(\frac{L}{2}+d\right)^3\right)$ $I = \frac{m}{3L}\left(\frac{L^3}{8} - \frac{3L^2 d}{4} + \frac{3Ld^2}{2} - d^3 + \frac{L^3}{8} + \frac{3L^2 d}{4} + \frac{3Ld^2}{2} + d^3\right)$ $I = \frac{m}{3L}\left(\frac{L^3}{4} + 3Ld^2\right)$ $I = m\left(\frac{L^2}{12} + d^2\right)$			
(d)(i)	For the staff to have angular acceleration, the CoM (which is to the right of the CoR) must accelerate in the direction of F_2. This means the net force on the staff must be in the direction of F_2, so F_2 must be larger than F_1.			
(ii)	The blocking force will be in the same direction as F_1. This produces a torque opposing the torques from F_1 and F_2. This will cause the staff's rotation to decelerate (or at least decrease the angular acceleration). To be most effective the blocking force should be applied at the very end of the rotating staff so the blocking torque is as large as possible and the angular deceleration produced is as large as possible.			

Q	Evidence	1–4 marks	5–6 marks	7–8 marks
THREE (a)	Treat the ring as two separate resistors in parallel: $R_{\text{RHS}} = \frac{R\theta}{2\pi}$ $R_{\text{LHS}} = R\left(1-\frac{\theta}{2\pi}\right)$ $\frac{1}{R_{\text{T}}} = \frac{1}{R_{\text{RHS}}}+\frac{1}{R_{\text{LHS}}} = \frac{2\pi}{R\theta}+\frac{1}{R\left(1-\frac{\theta}{2\pi}\right)}$ $= \frac{2\pi\left(1-\frac{\theta}{2\pi}\right)}{R\theta\left(1-\frac{\theta}{2\pi}\right)}+\frac{\theta}{R\theta\left(1-\frac{\theta}{2\pi}\right)}$ $= \frac{2\pi}{R\theta\left(1-\frac{\theta}{2\pi}\right)}$ $R_{\text{T}} = \frac{R\theta\left(1-\frac{\theta}{2\pi}\right)}{2\pi} = \frac{R\theta}{2\pi}\left(1-\frac{\theta}{2\pi}\right)$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. 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)	The resistance of two resistors in parallel is always less than the smaller of the two resistances, so the maximum resistance will be when the resistance of both sides are equal, when $\theta = \pi$. $R_{\text{T}} = \frac{R\theta}{2\pi}\left(1-\frac{\theta}{2\pi}\right) = \frac{10\times\pi}{2\pi}\left(1-\frac{\pi}{2\pi}\right) = \frac{10}{2}\left(1-\frac{1}{2}\right)$ $= 5\times\frac{1}{2} = 2.5\,\Omega$			
(c)(i)	Terminal velocity is reached when forces on the loop are balanced. $F_{\text{g}} = F_{\text{mag}}$ $mg = BILn = \frac{BVLn}{R} = \frac{BLn}{R}\cdot\frac{\Delta\phi}{\Delta t} = \frac{BLn}{R}\cdot BLvn$ $mg = \frac{B^2L^2n^2v}{R}$ $v = \frac{mgR}{B^2L^2n^2}$			

(ii)	Example order of magnitude estimates: $m \approx 0.1, g \approx 10, L \approx 0.1, n \approx 10^3$ $v \approx \frac{0.1\times10\times1}{\left(10^{-3}\right)^2\times0.1^2\times\left(10^3\right)^2} = \frac{1}{0.01} = 100 \text{ m s}^{-1}$ This is a very high terminal speed, so the motion of the coil as it enters the field will probably be indistinguishable from the motion of a coil falling without the magnetic field. The actual value of the terminal speed determined could vary by many orders of magnitude depending on the estimates of values used and could either be very high or very low. The description of the motion should match the value of the terminal speed based on reasonable estimates. $v >> 1$, no significant difference from free-fall. $v \approx 1$, approximately constant speed. $v << 1$, coil decelerates as it enters field.			
(d)	The second coil will have side length $2L$, but also only have half as many turns, $\frac{n}{2}$, as the initial coil. So $v = \frac{mgR}{B^2(2L)^2\left(\frac{n}{2}\right)^2} = \frac{mgR}{B^2 4L^2\left(\frac{n}{4}\right)^2} = \frac{mgR}{B^2L^2n^2}$, the same as the original coil. In the second coil the length of the side entering the field has doubled, so each turn in the coil experiences double the force, but there are only half as many coils so the magnetic force is the same. OR As the area of the coil has quadrupled each loop can enclose 4 × the flux, but it takes double the time for the coil to enter the field, so the rate of change of flux has doubled overall. However, there are now only half as many loops, so the overall induced EMF, and hence current, are the same. The same current flowing through the same total length of wire on one side $\left(n\times L = \frac{n}{2}\times 2L\right)$ will produce the same magnetic force, so the same terminal velocity. OR Each side is twice as long, but there are half as many turns, so the total length of wire on each side of the coil is the same. This means the magnetic force is the same and the terminal velocity is the same.			

Question	Evidence	1–4 marks	5–6 marks	7–8 marks
FOUR (a)	In order to absorb a photon, the energy of the photon must exactly match the energy difference between the electron levels. As the energy of the photon is slightly too low, the atom must be approaching the laser so that it experiences a slightly higher frequency photon with a higher energy that matches the difference between the energy levels.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. 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)	The atom moving away from the laser will not absorb the photon, so its momentum will not change. The atom moving towards the laser will absorb the photon and its momentum. As the photon is travelling in the opposite direction to the atom, the total momentum of the atom will be reduced.			
(c)	$\Delta f = \frac{fv}{c} = \frac{cv}{\lambda c} = \frac{v}{\lambda} = \frac{570}{589\times10^{-9}} = 9.67\times10^{8}$ Hz $f' = f + \Delta f = \frac{3.00\times10^{8}}{589\times10^{-9}} + 9.67\times10^{8} = 5.09\times10^{14}$ Hz (Or ***states*** that as $v << c$, there is no significant Δf and just use $\frac{c}{\lambda}$ for the same result, not just ignores Doppler). $p_{\text{atom}} = mv = 3.82\times10^{-26}\times570$ $= 2.18\times10^{-23}$ kg m s^{-1} $p_{\text{photon}} = \frac{h}{\lambda} = \frac{hf}{c} = \frac{6.63\times10^{-34}\times5.09\times10^{14}}{3.00\times10^{8}}$ $= 1.13\times10^{-27}$ kg m s^{-1} $= \Delta p$ % change $= \frac{1.13\times10^{-27}}{2.18\times10^{-23}}\times100 = 0.0052\%$			
(d)	If the photon is emitted away from the laser it will have a wavelength slightly shorter than the original photon, as when the photon is emitted the atom is moving slower than it was when it absorbed the original photon. A lower wavelength means the emitted photon has slightly more momentum than the original photon. The difference in momentum has been transferred to the atom, so the speed of the atom has changed. (In this case it actually ends up moving faster than it was originally.)			

Cut Scores

Scholarship	Outstanding Scholarship
18–26	27–32