Anderson Serangoon Junior College 2022 JC2 H2 Physics Prelim Mark Scheme

Paper 3

1a	The rate of change of momentum of a body is proportional to the resultant force acting on the body and takes place in the direction of the resultant force.	B1 B1
1bi	The acceleration of object X is dependent on the resultant of the two forces, weight and tension, acting on object X. Since the weight and tension are in opposite directions, the resultant force must be less than its weight and hence, has an acceleration less than g.	B1
1bii	Let T be the tension in the rope. Considering the FBD of object X, by N2L, ↓+: $m_X g - T = m_X a$ $T = m_X g - m_X a$ ………. (1) Considering the FBD of object Y, by N2L, ↑+: $T - m_Y g = m_Y a$ $T = m_Y g + m_Y a$ ………. (2) Equating (1) and (2), we have $m_X g - m_X a = m_Y g + m_Y a$ $g(m_X - m_Y) = a(m_X + m_Y)$ Hence, $a = \dfrac{m_X - m_Y}{m_X + m_Y} g$	 M1 M1 A1
1biii	Since the motion is linear with uniform acceleration, using $s = ut + ½ at^2$ ↓+: $5.0 = 0 + \frac{1}{2}[\frac{6.0-3.0}{6.0+3.0}(9.81)]t^2$ t = 1.749 s = 1.7 s	 C1 A1
2a	The object is in equilibrium and hence resultant force is zero. Before lowering into water, $F_s = mg$ After lowering into water $F_s' + Up = mg$ $F_s' + Up = F_s$ $Up = F_s - F_s' = k(x' - x)$ Hence, upthrust = decrease in spring force = kΔx [Note: cannot just be substituting numbers, but must indicate it is representing Δx] = 42 (0.0045) = 0.189 N = 0.19 N (to 2 s.f.)	 M1 A1
2b	Upthrust = $V\rho g$ V(1000)(9.81) = 0.19 V = 1.94 x 10^{-5} m^3	 M1 A1

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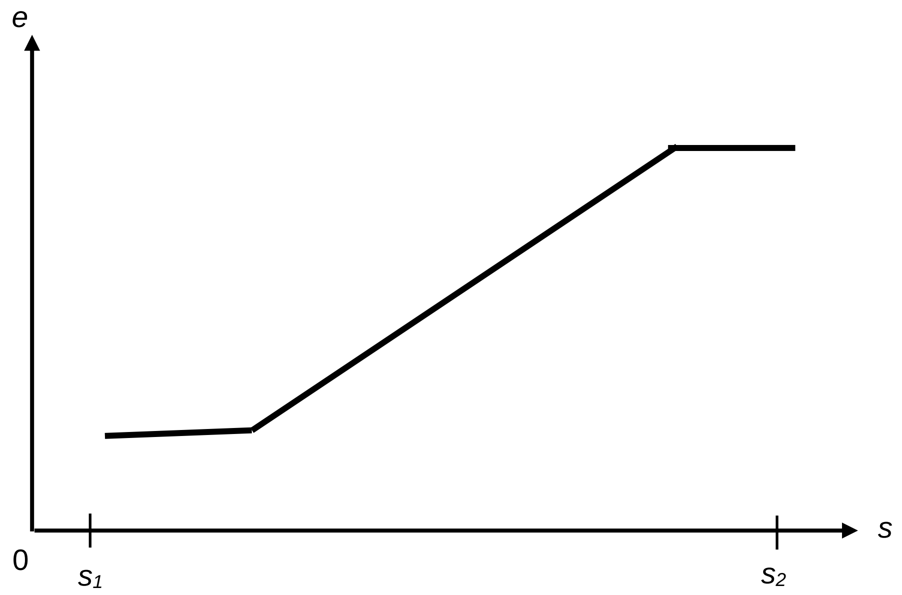
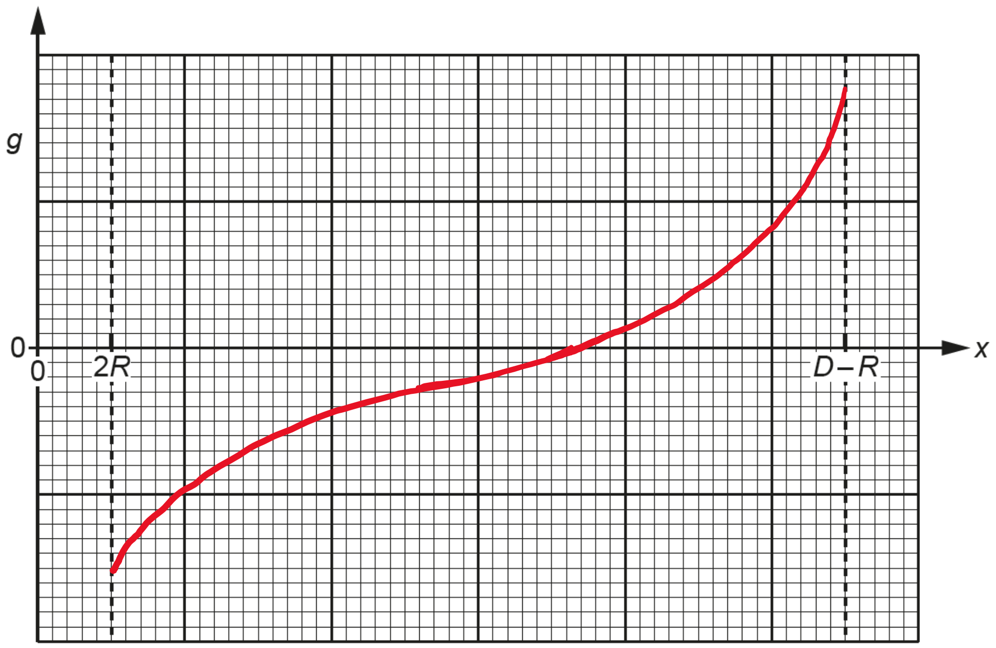
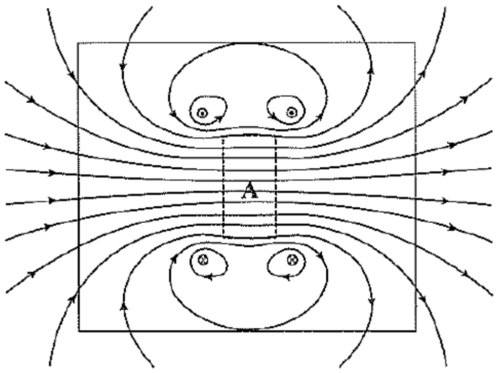
2c	By Newton's 3rd Law, force of water on mass = - force of mass on water. Since force of water on mass is the upthrust, magnitude of force of mass on water is therefore same magnitude as upthrust. Hence magnitude of force of mass on water = 0.19 N	M1 A1
2d	When fully inside water, $F_s + V\rho g = mg$ $ke + V\rho g = mg$ $e = \frac{1}{k}(mg - V\rho g)$ So, first part of graph while inside water is a horizontal flat line since *e* is independent of *s*. While it is moving out of water, $F_s + V\rho g = mg$ $ke + V\rho g = mg$ $e = \frac{1}{k}(mg - LA\rho g)$ *L* is the submerged height of the mass and thus varies linearly with *s*. So, the second part of the graph is a linear line with increasing *e*. When the mass is fully out of water, the spring force is thus equal to weight and there is no upthrust, so the graph is a horizontal flat line independent of *s*. 	 B1 B1 B1
3ai	The gravitational potential at a point is the <u>work done per unit mass</u> in bringing a <u>small test mass</u> from <u>infinity to that point</u>.	**B1** **B1**
3aii	Gravitational potential is always negative because the gravitational potential is taken to be <u>zero at infinity</u>	**B1**

	and gravitational forces are <u>attractive</u>, <u>work done by the external agent</u> on the point mass moving it from infinity is <u>negative</u>. OR (test) mass <u>getting closer</u> (from infinity) <u>loses potential energy</u>.	**B1** **B1**
3b	 one curve with negative field strength near planet with gradient of decreasing magnitude at $2R$ and finishing with positive field strength near the moon with gradient of increasing magnitude at $D - R$ field strength shown as zero (only) near the point of maximum potential (within the 4th big square from left, acceptable range of 4th to 8th small square).	**B1** **B1**
3ci	At Earth's surface, $g = \frac{GM}{R_E^2}$ $\Rightarrow gR_E^2 = GM$ where R_E is radius and M is mass of Earth gravitational force on Moon, $F = \frac{GMm}{r^2} = \frac{gR_E^2 m}{r^2}$ $= \frac{9.81(6.37\times10^6)^2(7.35\times10^{22})}{(3.84\times10^8)^2}$ $= 1.9841 \times 10^{20}$ $= 1.98 \times 10^{20}$ N	**M1** **M1** **A0**
3cii	Since the increase in orbit is significantly smaller than radius of orbit, the gravitational force remains constant. Hence, change in potential energy = $F \times 0.040$ $= 1.98 \times 10^{20} \times 0.040$ $= 7.9 \times 10^{18}$ J do not accept alternative method of finding change in p.e. if not using answer in **(c)(i)**	**B1** **C1** **A1**
4a	<u>thermal energy</u> <u>per unit mass</u> required to produce <u>unit rise of temperature</u> of the substance.	B1

4bi	p $= \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$ Since pV = NkT, $NkT = \frac{1}{3}Nm\langle c^2\rangle$ $\frac{3kT}{2} = \frac{1}{2}m\langle c^2\rangle$	M1 A1
4bii	Internal energy is the sum of the kinetic energy (due to random motion) of the molecules and the potential energy (due to intermolecular forces) between the molecules. However, for an ideal gas, there is no potential energy due to absence of intermolecular forces between the molecules.	B1 B1
4c	$\frac{1}{2}m\langle c^2\rangle = \frac{3kT}{2}$ $c_{r.m.s} = \sqrt{\frac{3\times1.38\times10^{-23}\times(25+273.15)}{3.34\times10^{-27}}}$ $=1.9\times10^3$ m s^{-1}	C1 A1
4di	At constant volume, no work is done by the gas. Thermal energy required to increase the temperature of unit mass of gas by one unit is solely to increase its internal energy. At constant pressure, work is done by the gas as it expands. Thermal energy is required for the increase of its internal energy and the work done by the gas. Hence the specific heat capacity of ideal gas at constant pressure is greater than the specific heat capacity at constant volume.	B1 B1
4dii	Small volume change/decrease and hence work done on ice is negligible/positive, <u>Thermal</u> energy is absorbed to break lattice structure / increase molecular potential energy. Hence, by first law of thermodynamics, internal energy increases.	B1 B1
5a	As current passes through the filament, <u>mobile charge carriers (electrons) transfer kinetic energy to the lattice ions</u> of the filament causing the filament to heat up gradually Filament produces light when it is at a <u>sufficiently high temperature</u> Heating process takes time and hence, full brightness is not immediately achieved.	B1 B1
5b	By potential divider principle, $V_{16\Omega} = \frac{16}{16+14}\times12$ $=6.4$ V	C1 A1
5ci	$V_{\text{one lamp}} = 6.0$ V Potential difference across XY = 6.4 – 6.0 = 0.4 V	 A1

5cii	Point Y is at a higher potential.	A1
5d	Current through resistors = $\frac{12}{14+16}$ $= 0.40$ A Current through lamps = 0.50 – 0.40 = 0.10 A	M1 A0
5e	$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by battery}}$ $= \frac{VI_{lamps}}{VI_{battery}}$ $= \frac{12\times0.10}{12\times0.50}$ $= 0.20$	 C1 A1
5f	No change to potential difference across lamps and hence (by $\frac{V^2}{R}$), power of lamps unchanged (Since effective resistance of circuit increases,) total current decreases and so power produced by battery decreases Ratio increases.	M1 A1
6a	$R = \frac{\rho l}{A}$ $= \frac{5.0\times10^{-7}\times2.0}{3.3\times10^{-7}}$ $= 3.03\ \Omega$ $= 3.0\ \Omega$	 M1 A1
6b	*Current through wire* = $\frac{1.5}{3.0+0.75}$ $= 0.40$ A *I = nAqv* v = $\frac{0.40}{8.5\times10^{28}\times3.3\times10^{-7}\times1.6\times10^{-19}}$ $= 8.91\times10^{-5}$ m s^{-1}	C1 A1
6ci	$V_{ST} = \frac{3.0}{3.0+0.75}\times1.5$ $= 1.2$ V E = V_{SP} $= \frac{1.4}{2.0}\times1.2$ $= 0.84\ V$	M1 A1

6cii	Second wire has higher resistance Potential difference (per unit length) across second wire increases (For the same E), balance length decreases.	M1 M1 A1
7a	The Helmholtz coil is made up of two flat circular coils, with a fairly uniform field strength in their central axis, similar to that of a solenoid. The magnetic field pattern is shown below.  Marking points: 1. Direction of field lines indicated correctly on every line 2. Overall pattern, resembling that of a solenoid, extending over the whole area of the board. 3. In region A, field is approximately uniform, with lines of equal spacing.	 B1 B1 B1
7bi	$B = \frac{\mu_0 I_X}{2\pi d}$ $= \frac{4\pi 10^{-7} \times 90}{2\pi(0.050)}$ $= 3.6 \times 10^{-4}$ T	 C1 A1
7bii	Force by wire X on wire Y = weight of wire Y $B I_Y L = mg$ $\frac{m}{L} = \frac{B I_Y}{g}$ $= \frac{3.6 \times 10^{-4} \times 60}{9.81}$ $= 2.2 \times 10^{-3}$ kg m^{-1}	 M1 A1
7c	Electric force is independent of the speed whereas for magnetic force, it is proportional to the speed. or Electric force is along the field direction, whereas for magnetic force, it is perpendicular to the field direction.	B1
7di	Into the plane of paper	A1
7dii	Electromagnetic force provides the centripetal force for the particle. $F_B = \frac{mv^2}{r}$ $Bqv = \frac{mv_2}{r}$ $Bqr = mv$ Hence momentum is proportional to the radius.	B1 M1

	$\frac{\text{final momentum of particle}}{\text{initial momentum of particle}} = \frac{5.7}{7.4}$ $= 0.77$	A1
7ei	Faraday's Law of electromagnetic induction states that the e.m.f. induced in a conductor is proportional to the rate of change of magnetic flux linkage (or rate of cutting of the flux).	A1
7eii	The changing/alternating current in coil A produces a changing/alternating magnetic flux density (*B*) (since magnetic flux density is directly proportional to the current). Hence, coil B experiences a changing magnetic flux linkage. By Faraday's law, an e.m.f. is induced in coil B.	B1 B1 A0
7eiii	t = 5.0 ms, 15.0 ms or 25.0 ms	A1
7eiv	Since the gradient of the tangent of the graph at this point is the largest, it corresponds to the greatest rate of change of current/magnetic flux density/magnetic flux linkage. Hence, induced e.m.f. is a maximum.	A1
7ev	From t = 10 ms to 15 ms, current in coil A is decreasing. The magnetic flux linkage through coil B is decreasing. According to Lenz's law, the induced e.m.f. will be directed such that the induced current produced in the coil B will produce an induced magnetic flux density to oppose this decrease in magnetic flux linkage experienced by coil B. Hence, the induced current in coil B flows in the same direction as the current in coil A.	M1 M1 A1
8ai1	Gain in KE = loss in EPE $KE_{final} - KE_{initial} = q\Delta V$ (as electron starts from rest, $KE_{initial} = 0$) $KE_{final} = 140$ eV	A1
8ai2	$E_K = p^2 / 2m$ $p = (2m\, E_K)^{1/2}$ $= (2 \times 9.11 \times 10^{-31} \times 140 \times 1.6 \times 10^{-19})^{1/2}$ $= 6.39 \times 10^{-24}$ kg m s^{-1} **Alternative method:** $\frac{1}{2} mv^2 = q\,\Delta V$ $\frac{1}{2}(9.11 \times 10^{-31})\, v^2 = (140) \times 1.60 \times 10^{-19}$ $v = 7.013 \times 10^6$ m s^{-1} $p = mv = (9.11 \times 10^{-31})(7.013 \times 10^6)$ $= 6.39 \times 10^{-24}$ kg m s^{-1}	C1 A1
8aii1	Electrical potential energy to kinetic energy when accelerated by potential difference. Kinetic energy to light energy upon colliding with fluorescent screen.	B1 B1
8aii2	The electrons must exhibit a smaller de Broglie's wavelength λ ($d\sin\theta = n\lambda$). According to de Broglie's equation ($\lambda = h / mv$), in order to have a smaller λ, the momentum / velocity of the electron must be larger. This is done by increasing the potential difference between the electrodes.	M1 M1 A1

8bi	$(-5.45 + 5.00) \times 10^{-19} = -0.45 \times 10^{-19}$ J Hence the highest energy level which the atom can be excited to is A_4.	A1
8bii	Highest energy photon emitted from A_4 to A_1 transition: $\frac{hc}{\lambda} = E_4 - E_1$ $\frac{(6.63\times10^{-34})(3.0\times10^{8})}{\lambda} = [(-0.78)-(-5.45)]\times10^{-19}$ $\lambda = 4.26\times10^{-7}$ m	C1 A1
8biii	Visible light (accept blue / violet light) Must tally with answer in (b)(bii)	A1
8ci1	The minimum energy required to eject an electron from the metal surface.	A1
8ci2	KE is maximum when electrons at the surface are ejected. KE of emitted electrons can be lower than the maximum energy because energy is required to bring an electron deeper in the metal to the surface / electron loses energy when it makes its way to the surface (upon collisions with other electrons and metal lattice), hence even though the energy absorbed by each electron from a photon is the same, the electrons can be emitted from the surface of the metals with a range of kinetic energies.	B1 B1
8cii1	$\frac{hc}{\lambda} = \phi + E_{max}$ $\frac{1}{\lambda} = \frac{\phi}{hc} + \frac{E_{max}}{hc}$ When $\frac{1}{\lambda} = 0$, ie. at x-intercept, $\phi = -E_{max}$ Extend line to intersect on x-axis $\phi = 4.00 \times 10^{-19}$ J (allow $\pm$ 0.2 $\times 10^{-19}$ J)	 M1 A1
8cii2	$\frac{hc}{\lambda} = \phi + E_{max}$ $\frac{1}{\lambda} = \frac{\phi}{hc} + \frac{E_{max}}{hc}$ Gradient of line = $\frac{1}{hc}$ Gradient = $\frac{(4.00-2.50)\times10^{6}}{(4.10-1.10)\times10^{-19}} = 5.00 \times 10^{24}$ h = $\frac{1}{(5.00\times10^{24})(3.0\times10^{8})}$ = 6.67×10^{-34} J s	 M1 M1 A1