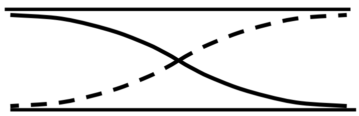
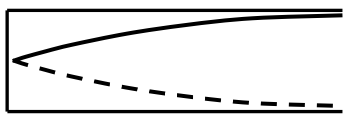
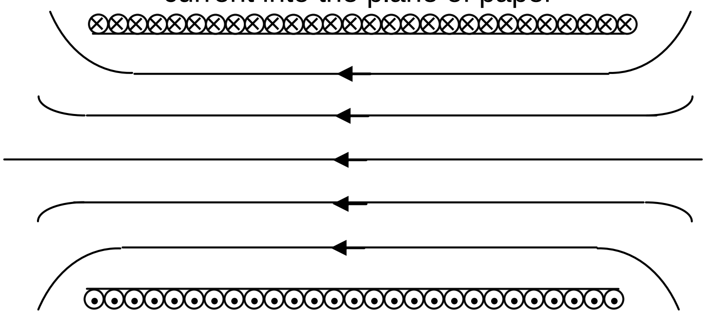
Answers to 2015 JC2 Preliminary Examination Paper 2 (H1 Physics)

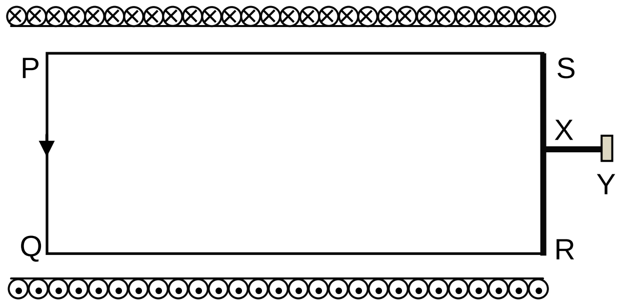
Suggested Solutions:

No.	Solution	Remarks
1(a)(i)	The gradient of the graph represents the acceleration, which is changing in value. This suggested the presence of air resistance, since weight cannot be the only force acting on the ball.	[1]
1(a)(ii)	The magnitude of acceleration due to free fall can be determined from the gradient of the graph at 1.75 s. At this time, velocity is zero which means the only force experienced by the ball is its own weight.	[1]
1(b)	$t_u < t_d$. At a given speed, the net retarding force ($W + F_{air}$) when the body is moving upwards is greater than the net accelerating force ($W - F_{air}$) when the body is moving downwards.	[1] for time comparison [1] for explanation
1(c)	At $t = 0$ s, the ball is moving with the largest speed and hence experiences the greatest air resistance. gradient of tangent at $t = 0$ s, $= \frac{25}{1.2}$ Since $W + F_{air} = ma$, $(0.010 \times 9.81) + F_{air} = 0.010 \times \frac{25}{1.2}$ $F_{air} \approx 0.110$ N	[1] for gradient at $t = 0$ s [1] for air resistance
2(a)	The rate of change of momentum of a body is proportional to the resultant force that acts on it and has the same direction as the resultant force.	[1]
2(b)(i)	Resistive force $= \frac{1}{2}(0.850)(1.20)(1.71)\left(\frac{300 \times 1000}{3600}\right)^2$ $= 6056.25$ N ≈ 6060 N	[1] for correct substitution 1] for correct answer
2(b)(ii)1.	$P = F_D v$ $5.67 \times 10^5 = F_D \left(\frac{300 \times 1000}{3600}\right)$ $F_D = 6804 \text{ N} \approx 6800 \text{ N}$	[1] for correct substitution and correct answer

2(b)(ii)2.	$F_D - F_r = ma$ $a = \dfrac{6804 - 6056.25}{691}$ $a \approx 1.08 \text{ m s}^{-2}$	[1] for correct substitution [1] for correct answer
2(b)(iii)	The impulse acting on the car takes place over an extended period of time. The average force on the car is therefore reduced.	[1] [1]
3(a)	By the principle of conservation of energy, $\frac{1}{2}mv^2 = mgh$ $v = \sqrt{2gh}$ $v = \sqrt{2(9.81)(30)} = 24.3 \text{ m s}^{-1}$	[1] for correct application of principle [1] for correct answer
3(b)	By the principle of conservation of energy, $mg(h+x) = \frac{1}{2}kx^2$ $(70)(9.81)(30) + (70)(9.81)x = \frac{1}{2}(200)x^2$ $100x^2 - 686.7x - 20601 = 0$ $x = \dfrac{686.7 \pm \sqrt{(-686.7)^2 - 4(100)(-20601)}}{200}$ $= 18.2 \text{ m}$ $d = 15 + 18.2 = 33.2 \text{ m}$	[1] for correct application of principle [1] for correct value of x [1] for correct value of distance
3(c)	Equilibrium of forces is reached when climber comes to a stop $mg = kx$ $(70)(9.81) = (200)x$ $x = 3.43 \text{ m}$ $d = 15 + 3.43 = 18.4 \text{ m}$	[1] for correct equation [1] for correct answer
3(d)	The rope must be strong enough to withstand large tensions without breaking. OR The rope must be able to undergo large extensions when stretched in order to minimise the force exerted on climber during a fall.	[1] for any one correct answer
4(a)(i)	The intensity of the wave is the power carried per unit area perpendicular to the direction of travel of the wave.	[1]

4(a)(ii)	Let P be the power from the source Intensity at A = $\frac{P}{4\pi(100)^2}$ Distance from source to point C = $\sqrt{200^2+100^2}$ = 223.607 m Intensity at C = $\frac{P}{4\pi(223.607)^2}$ Ratio = $\frac{P}{4\pi(100)^2} \div \frac{P}{4\pi(223.607)^2}$ = $\frac{(223.607)^2}{(100)^2} = 5.00$	[1] Correct expression for intensity at A [1] Correct expression for intensity at C [1] Correct final answer OR [1] Correct relationship between intensity and distance from source $I \propto \frac{1}{r^2}$ [1] Correct substitution into formula [1] Correct final answer
4(b)(i)	<u>Two progressive waves</u> approach each other in the <u>opposite direction</u> with the same <u>amplitude and frequency (speed)</u>.	[1]
4(b)(ii)	As the level of fluid in the bottle decreases, the air column in the bottle increases. The <u>wavelength of the stationary wave increases</u>. Since speed of sound in the air column is constant, the <u>fundamental frequency decreases</u>.	[1] Wavelength increases [1] Fundamental frequency decreases (with explanation).
4(b)(iii) 1.	 Fig. 4.2  Fig. 4.3	[1] Correct fundamental modes for both Fig.3.2 and Fig.3.3

4(b)(iii) 2.	When both ends are open, $\frac{1}{2}\lambda_1 = L$ $\lambda_1 = 2L$ When one end is covered, $\frac{1}{4}\lambda_2 = L$ $\lambda_2 = 4L$ Since speed of sound, v is constant, $f_1 = \frac{v}{2L}$ $\quad$ $f_2 = \frac{v}{4L}$ $\frac{f_1}{f_2} = 2$	[1] Correct wavelength expressions [1] Correct final answer
5(a)	Magnetic flux density is defined as the magnetic force acting on a conductor of unit length, carrying unit current, placed perpendicularly to the magnetic field.	[1]
5(b)(i)		[1] for correct direction and uniform line spacing within solenoid
5(b)(ii)	$B = \mu_0 nI$ $= 4\pi \times 10^{-7}\left(\frac{900}{0.300}\right)(4.0)$ $= 0.015$ T	[1] for correct substitution [1] for correct answer
5(b)(iii)	The magnetic flux density increases.	[1] for correct effect on magnetic flux density.

5(c)(i)	current into the plane of paper  current out of the plane of paper	[1] for current in PQ direction
5(c)(ii)	Take moment about pivot line RS $\text{anti-clockwise moment} = \text{clockwise moment}$ $BI_{PQ}L_{PQ}(\sin 90°)(L_{QR}) = (mg)(L_{XY})$ $0.01508(I_{PQ})(0.080)(0.270) = (2.0\times10^{-3})(9.81)(0.030)$ $I_{PQ} = 1.8$ A	[1] for correct substitution [1] for correct answer
6(a)(i)	Work done by a force is defined as the product of the force and the distance moved in the direction of the force.	[1]
6(a)(ii)	Power is the rate at which work is done.	[1]
6(b)	Let the object be accelerated from rest where the initial velocity u = 0 and the final velocity is v. To give the object an acceleration a, a force F needs to be applied for a distance s. Using the equation of motion $v^2 = u^2 + 2as$ Since u = 0, $v^2 = 2as$ Multiplying both sides by $\frac{1}{2}m$ gives $\frac{1}{2}mv^2 = mas$ = work done by force F = kinetic energy E_k transferred to object	[1] for statements leading to $v^2 = u^2 + 2as$ [1] for $\frac{1}{2}mv^2 = mas$ [1] for $mas = F = E_k$
6(c)(i)	<u>Kinetic energy of blades of wind turbine and rotor of generator</u> and <u>thermal energy due to friction</u> at blades and rotor.	[1] [1]
6(c)(ii)1.	$\frac{m}{t} = \frac{V\rho}{t} = \frac{Al\rho}{t} = \pi r^2 v\rho = \pi(20.0)^2(10.0)(1.29) = 1.62\times10^4$ kg s^{-1}	[1] for correct formula and substitution [1] for correct answer

6(c)(ii)2.	$\frac{KE}{t}=\frac{1}{2}\frac{mv^2}{t}=\frac{1}{2}\left(1.62\times10^4\right)\left(10.0\right)^2=8.11\times10^5\text{ J s}^{-1}$	[1] for correct formula and substitution [1] for correct answer
6(c)(ii)3.	Power output = $\frac{40}{100}\left(8.11\times10^5\right)=3.24\times10^5$ W	[1] for correct substitution [1] for correct answer
6(d)	There is a rate of change of momentum of the moving air as it strikes the blades. This gives rise to a large turning force about the base of the supporting tower of the turbine. Therefore the weight of the tower must be large and hence tower must be rigid to counter this turning force.	[1] [1] [1]
6(e)	Any 2 of the following ●Power output from wind turbine is not constant as it depends on the speed of the wind. ●Need a lot of land to build more than a thousand wind turbines to give an equivalent of 500 MW. ●Construction of wind turbines can be costly.	[1] for each disadvantage and reason Overall [4]
7(a)(i)	The resistance of a conductor is defined as the ratio of the potential difference across the conductor to the current flowing through the conductor.	[1]
7(a)(ii)	The ohm is defined as being the resistance of a conductor through which a current of one ampere is flowing when the potential difference across it is one volt.	[1]
7(b)(i)	In circuit M, there is no current since the voltmeter has infinite resistance. Hence the potential difference across the voltmeter is the e.m.f of the 4 cells. In circuit N, the effective resistance is not infinite and hence there is a current through the circuit. As such there is a voltage drop across the internal resistance of the cells. Hence the potential difference the voltmeter read is lower than the e.m.f.	[1] [1]
7(b)(ii)	$R_{XY}=\frac{\rho L}{A}$ $=\frac{\left(1.72\times10^{-8}\right)\left(0.60\right)}{\pi\left(0.030\times10^{-3}\right)^2}$ $=3.65\ \Omega$	[1] for correct substitution [1] for correct answer

7(b)(iii)	$\text{current} = \dfrac{V_{\text{terminal}}}{R_{\text{external}}}$ $= \dfrac{3.0}{3.0 + 3.64995}$ $= 0.45 \text{ A}$	[1] for correct substitution [1] for correct answer
7(b)(iv)	$I = \dfrac{ne}{t}$ $\dfrac{n}{t} = \dfrac{I}{e}$ $= \dfrac{0.45113}{1.6 \times 10^{-19}}$ $= 2.8 \times 10^{18} \text{ s}^{-1}$	[1] for correct substitution [1] for correct answer
7(b)(v)	Using $\varepsilon = V + Ir$ $4.0 = 3.0 + \left(\dfrac{3.0}{3.0 + 3.64995}\right)(4r)$ $r = 0.55\ \Omega$	[1] for correct substitution [1] for correct answer
7(c)(i)	Using $\varepsilon = IR_{\text{total}}$ $R_{\text{total}} = R_{\text{XYnew}} + 3.0 + 4(r)$ $2.0 = 0.24\left[R_{\text{XYnew}} + 3.0 + 4(0.55416)\right]$ $R_{\text{XYnew}} = 3.1\,\Omega$	[1] for correct substitution [1] for correct answer
7(c)(ii)	A lower current of 0.24 A in **(c)** compared to 0.45 A causes lesser heating effect on wire XY. There is thus a decrease in the lattice ion vibrations of the wire. This results in less frequent collisions between the drifting electrons and the lattice ions. As such the resistance of the wire is lower in **c(i)** compared to **b(ii)**.	[1] [1]
7(c)(iii)	$\text{efficiency} = \dfrac{P_{\text{ext}}}{P_{\text{e.m.f.}}} \times 100\%$ $= \dfrac{I^2 R_{\text{ext}}}{I\varepsilon} \times 100\ \%$ $= \dfrac{(0.24)^2 (3 + 3.11668)}{(0.24)(2)} \times 100\ \%$ $= 73\ \%$	[1] for correct substitution [1] for correct answer
7(d)	For the battery to deliver maximum power to both the external resistors, the internal resistance of the battery must be equal to the total external resistance. Since the fixed resistance of 3.1 Ω is already larger than the internal resistance of 2.2 Ω, it is not possible to reduce the	[1] [1]

	resistance of the variable resistor below zero for the battery to deliver maximum power.	
8(a)(i) 1.	A photon is a <u>quantum of electromagnetic radiation with energy *hf*</u>, where *h* is the Planck constant and *f* is the frequency of the electromagnetic radiation.	[1]
8(a)(i) 2.	The energy level of an electron in an atom is the <u>sum of the kinetic energy and electric potential energy</u> of the electron in the atom.	[1]
8(a)(i) 3.	Work function energy, Φ of a metal refers to the <u>minimum amount of energy needed to release an electron</u> from the metal surface.	[1]
8(a)(ii)	$hf = \Phi + eV_s = (4.58)(1.6\times10^{-19}) + (1.6\times10^{-19})(7.51)$ $hf = 1.9344\times10^{-18}$ J Energy difference between n_f and n_i = 1.9344×10^{-18} J = 12.09 eV Energy at n_i = $-13.60 + 12.09 = -1.51$ eV	[1] Photon energy [1] Energy difference in eV [1] Correct final answer
8(a)(iii)	$\frac{hc}{\lambda} = 1.9344\times10^{-18}$ $\lambda = \frac{(6.63\times10^{-34})(3\times10^{8})}{1.9344\times10^{-18}}$ λ = 103 nm	[1] Correct final answer with correct working
8(a)(iv)	Ultraviolet radiation	[1]
8(a)(v)	By the photoelectric equation, $hf = \Phi + (K.E)_{max}$, since *hf* and Φ remains the same, the <u>maximum kinetic energy of the photoelectrons remain the same.</u> Therefore the stopping potential needed to repel (stop) the photoelectrons remains the same. The <u>increase in intensity only increases the rate of emission of the photoelectrons</u> and not the energy of the photoelectrons.	[1] energy of photon [1] $K.E_{max}$ and same rate of emission of photoelectrons.
8(a)(vi)	Let *v* be the velocity of the photoelectron emitted normally from the tungsten surface. $\frac{1}{2}mv^2 = eV_s$ For photoelectrons emitted at 60° to the tungsten surface, Velocity = $v\,sin60^o$ K.E = $\frac{1}{2}m(v\,sin60^o)^2 = \frac{1}{2}mv^2(sin^2 60^o) = eV_s(sin^2 60^o)$ New stopping potential = $V_s(sin^2 60^o) = 5.63$ V	[1] Correct working [1] Correct final answer

8(b)(i)	The neon gas atoms are excited through electron collisions from electrical discharge through the gas. The bounded electrons in neon atoms are excited to higher energy levels, which are unstable. The bounded electrons return to lower levels and energy is given off in the form of electromagnetic radiation/ photons. The energy of the emitted photon is equal to the difference between the energy levels.	[1] [1] [1]
8(b)(ii)	The light emitted by a neon discharge lamp consists of <u>only a few colours.</u> The neon atom has <u>discrete energy levels and the emission of light is due to transitions between the discrete energy levels.</u> Hence, only a few colours, corresponding to the wavelengths of the photons is emitted.	[2] Correct statement with correct explanation.
8(b)(iii)	Neon discharge lamp ultilise light from the visible spectrum. The wavelength of visible spectrum ranges from 400 nm to 700nm. Taking λ as 500 nm, $P = \frac{N\left(\frac{hc}{\lambda}\right)}{t}$ $\frac{N}{t} = \frac{P}{\left(\frac{hc}{\lambda}\right)} = \frac{40}{\left(\frac{6.63\times10^{-34}\left(3\times10^{8}\right)}{500\times10^{-9}}\right)} = 1.01\times10^{20}$ Note: The answer ranges from 8.04×10^{19} to 1.41×10^{20}	[1] Correct estimation of wavelength for visible light [1] Correct working [1] Correct final answer.