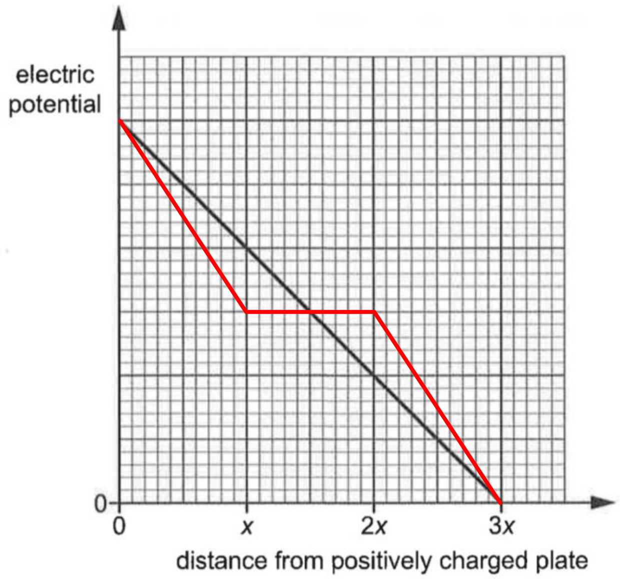
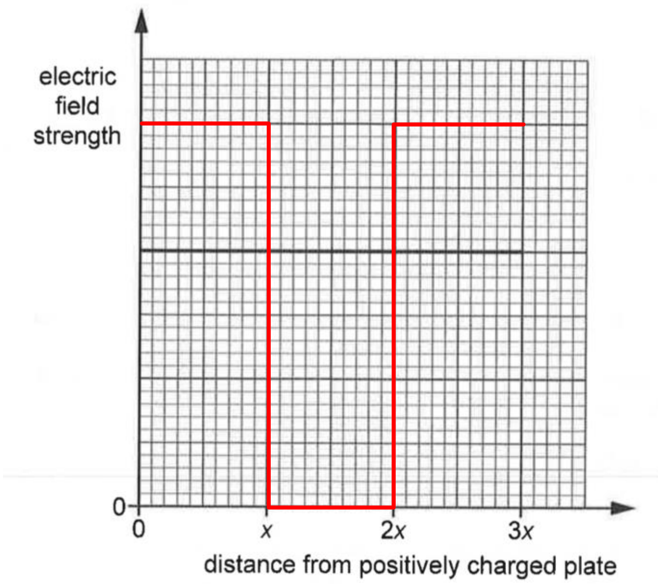
2020 A Levels H2 Physics 9749/02 Paper 2 suggested solutions

1a	Since the forward driving force is equal and opposite to the backwards frictional forces on the cyclist, there is zero net force on the cyclist. By Newton's 1st law, given that there is zero resultant force on the cyclist, the cyclist continues in its state of uniform motion at constant speed in a straight line.
1b	$v = \frac{\sqrt{2}F^{0.5}}{C_D^{0.5}\rho^{0.5}A^{0.5}} = 11.411$ $\frac{\Delta v}{v} = \frac{1}{2}\left(\frac{\Delta F}{F} + \frac{\Delta C_D}{C_D} + \frac{\Delta \rho}{\rho} + \frac{\Delta A}{A}\right) = \frac{1}{2}\left(\frac{2}{22} + \frac{0.01}{0.88} + \frac{0.1}{1.2} + \frac{0.02}{0.32}\right) = 0.12305$ $\Delta v = 0.12305 \times 11.411 = 1.4041 = 1$ $v = 11 \pm 1 \text{ m s}^{-1}$
1ci	Power = rate at which work is done. $\text{Power} = \frac{\text{Work done}}{\text{Time taken}} = \frac{\text{Force} \times \text{Displacement in the direction of the force}}{\text{Time taken}}$ $\text{Power} = \text{Force} \times \text{velocity in direction of the force}$
1cii	$P = Fv = 22 \times 11.411 = 251.042 = 251 \text{ W}$
2a	It is the energy per unit mass required to bring a small test mass from infinity to that point without a change in its kinetic energy.
2b	$\Delta E_{\text{P}} = -\frac{GMm}{r_{\text{orbit}}} - \left(-\frac{GMm}{r_{\text{surface}}}\right)$ $= -(6.67 \times 10^{-11})(6.0 \times 10^{24})(1600)\left(\frac{1}{2.7 \times 10^{7}} - \frac{1}{6.4 \times 10^{6}}\right)$ $= 7.6334 \times 10^{10} \text{ J}$
2ci	Gravitational force provides for centripetal force $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{GMm}{2r}$ $\text{Kinetic energy} = \frac{GMm}{2r}$
2cii	$\frac{GMm}{2r} = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(1600)}{2(2.7 \times 10^{7})} = 1.19 \times 10^{10} \text{ J}$
2ciii	The method is incorrect. On the Earth's surface, the satellite is not orbiting around the Earth solely due to the gravitational attraction due to the presence of Normal contact force. Hence, the kinetic energy of the satellite on the surface of Earth will not follow the equation in **2(c)(i)**.

3a	 Correct shape [M1] Uniform potential at middle of potential of R and S [A1] The total change in potential in moving from R to S is the same. However, as a conductor will have a uniform potential within the entire conductor, the potential from *x* to 2*x* should be constant (and by symmetry, the potential is in the middle of the potentials of R & S). Tips: Draw the constant potential from *x* to 2*x* first, then connect to the potentials at R and S.
3b	 The electric field strength is given by the negative of gradient of the potential-distance graph (i.e. potential gradient). Uniform field strength between 0 to x and 2x to 3x [B1] Field strength is 1.5 times higher than original between 0 to x and 2x to 3x [B1] zero field strength between x to 2x [B1]

	Since the potential gradient is now 3/2 = 1.5 times higher between 0 to *x* and 2*x* to 3*x*, the electric field strength in these regions should be 1.5 times of that across PQ. Within the conductor, the potential gradient is zero, hence the electric field strength is also zero.
4a	*Diffraction refers to the spreading of waves after they pass through a small opening or round an obstacle.* **Note**: For diffraction to occur, the waves have to first pass through a slit or round an edge or obstacle. Avoid imprecise description such as "bending of waves".
4b	The waves from the 2 sources should be coherent with constant phase difference and same frequency. The waves from the 2 sources should be unpolarised or polarised in the same plane. **Note**: <u>incorrect answers include</u> - compare width of slit with wavelength or distance between screen and slit - refer to polarisation without any clear indication how waves need to be polarised - coherent wave and same frequency/wavelength as 2 separate condition
4ci	Using $X = \frac{\lambda D}{a}$ Gradient of the graph is $\frac{\lambda}{a}$ $\frac{\lambda}{0.12 \times 10^{-3}} = \frac{8.8 \times 10^{-3} - 4.4 \times 10^{-3}}{2.0 - 1.0}$ $\lambda = 528 \text{ nm}$
4cii	Recall that intensity is proportional to the square of the amplitude of the wave. $\text{Ratio} = \frac{(A + 0.5A)^2}{(A - 0.5A)^2} = \left(\frac{1.5}{0.5}\right)^2 = 9.0$ **Note**: Add together the individual amplitudes first before squaring.
5a	$I = Anqv$ $\frac{Q}{t} = \pi \left(\frac{d}{2}\right)^2 nev$ $\frac{Q}{30 \times 60} = \pi \left(\frac{0.38 \times 10^{-3}}{2}\right)^2 (5.9 \times 10^{28})(1.6 \times 10^{-19})(7.2 \times 10^{-5})$ $Q = 138.75 = 140 \text{ C}$ **Note**: n is the number density (the number of electrons per unit volume). Do not try to calculate a total number of charge particles in the volume of the wire using the given length of wire.
5bi(1)	$2\pi f = 120\pi$ $f = 60 \text{ Hz}$
5bi(2)	$V_{\text{rms}} = \frac{Vpeak}{\sqrt{2}} = \frac{9}{\sqrt{2}} = 6.4 \text{ V}$
5bii(1)	$R_{\text{eff}} = 12 + \left(\frac{1}{6} + \frac{1}{12}\right)^{-1} = 12 + 4 = 16\ \Omega$ $I_0 = \frac{V_0}{R_{\text{eff}}} = \frac{9}{16} = 0.5625 = 0.56 \text{ A}$

5bii(2)	By potential divider rule, pd across $6.0\ \Omega = \frac{4}{16} \times 6.3640 = 1.5910$ V Power dissipated in $6.0\ \Omega$ resistor $= \frac{V^2}{R} = \frac{1.5910^2}{6.0} = 0.42$ W
6a	It is the force experienced per unit electric current per unit length of conductor when an electric current flows in a straight conductor placed perpendicular to the magnetic flux density. The force experienced is perpendicular to both the magnetic flux density and the conductor.
6b	$R = \frac{\rho l}{A} = \frac{\rho l}{\pi\left(\frac{d}{2}\right)^2} = \frac{4\rho l}{\pi d^2} = \frac{4\left(1.7\times10^{-8}\right)\left(520\pi\times4.0\times10^{-2}\right)}{\pi\left(0.46\times10^{-3}\right)^2} = 6.68\ \Omega$ Note that the length of wire is using circumference of solenoid × number of turns = πd × number of turns
6c	$B = \mu_0 nI = \mu_0\left(\frac{N}{L}\right)\left(\frac{V}{R}\right) = \left(4\pi\times10^{-7}\right)\left(\frac{520}{520\times0.46\times10^{-3}}\right)\left(\frac{24}{6.6843}\right) = 9.8\times10^{-3}$ T
6d	No magnetic force. The current in the wire is parallel to the direction of the magnetic flux density generated by the solenoid, hence no magnetic force is experienced. (note that the magnetic flux density generated by the solenoid is parallel to the axis of the solenoid).
7a	A photon is a quantum of electromagnetic energy, it is a packet of energy in the form of electromagnetic radiation. The energy is equivalent to $E = hf = \frac{hc}{\lambda}$ **Note**: Reference to the electromagnetic spectrum must be made. There must be reference made to being a packet of energy.
7b	Some specific wavelengths of light within the white light spectrum is absorbed by the gas atoms. These wavelengths of light are absorbed by the gas atoms as it has energy that exactly corresponds to the energy required to excite the ground state electrons in the gas atoms to higher energy levels unique to this particular gas atoms. The energy levels present in this gas atoms are unique and distinct, only certain transition from ground state to the available higher energy levels are allowed. Since the energy of absorbed photons that cause transition from ground state energy level to higher energy levels must be exactly equivalent to the difference in energy of the two atomic energy levels involved in the transition, only specific wavelength and energy of photons are absorbed by the gas atoms. These absorbed wavelengths of photons are missing from the spectrum and hence appear as dark lines in the produced spectrum. **Note**: It is not necessary to described the electron de-exciting to produce a photon and that photons produced in this way were emitted in random directions.
7ci	$E_2 = \frac{-13.6}{2^2} = -3.4$ eV

7cii	$\Delta E_{2\to3} = E_3 - E_2 = \frac{-13.6}{3^2} - \frac{-13.6}{2^2} = \frac{17}{9}$ eV $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{\Delta E_{2\to3}} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{\frac{17}{9}(1.6\times10^{-19})} = 658\times10^{-9}\ \text{m} = 658\ \text{nm}$ **Note**: Remember to convert the energy difference calculated in eV to joule.
7ciii	The energy at infinity is defined as zero. Since electrons are attracted towards the positively-charged nucleus, positive work done is needed to bring it from any energy level to infinity. Hence, the energy levels should have energies less than zero. **Note**: The negative energy level is NOT not due to negative charge on the electron. Insufficient to only referred to the potential or the potential energy being zero at infinity.
8a	$v^2 = u^2 + 2as$ $0 = \left(185\times\frac{1000}{60\times60}\right)^2 + 2a(80)$ $a = -16.5$ m s^{-2} Deceleration $= 16.5$ m s^{-2}
8bi	Maximum centripetal acceleration (lateral because it is perpendicular to the direction of car’s motion, and is pointing towards centre of circular path) = 4g $a = \frac{v^2}{r}$ $4g = \frac{v^2}{30}$ $v = 34.3$ m s^{-1}
8bii	From Fig. 8.1, the maximum coefficient of friction is around 80 °C. Since the maximum friction is proportional to the coefficient of friction, the tires are heated up to increase the coefficient of friction towards its maximum value so that the maximum friction that can be provided by the tires increases. A higher maximum friction will allow a higher acceleration in the cars. From Fig. 8.2, there are air gaps between the road and the tires. By heating up the tires and causing them to be softened, this allows the tires to increase its contact with the uneven ground. When actual contact between tires and ground is increased, the maximum friction that can be provided by the tires increases, allowing for higher acceleration in the cars.
8c	The wings pushes the horizontally moving air upwards, this increases the momentum of the air in the upwards direction. By Newton’s 2nd law, since net force is directly proportional to the rate of change of the momentum and the change is in the direction of the force, it means that the wings exerts an upwards force on the air. By Newton’s 3rd law, the wings would exert a downwards force on the wings. This increased downwards force in addition to the weight of the car appears to have “increased the weight of the car”.
8di	*Note that $W = N_R + N_F$. By principle of moment, taking moments about the centre of gravity, Sum of clockwise moments = sum of anticlockwise moments about same pivot

	$N_R x_R = Dh + N_F x_F$ $N_R x_R = Dh + (W - N_R) x_F$ *see note $N_R x_R + N_R x_F = Dh + W x_F$ $N_R = \dfrac{Dh + W x_F}{x_R + x_F}$
8dii	$W = N_R + N_F$ $W = \dfrac{Dh + W x_F}{x_R + x_F} + N_F$ $N_F = \dfrac{W x_R + W x_F}{x_R + x_F} - \dfrac{Dh + W x_F}{x_R + x_F} = \dfrac{W x_R - Dh}{x_R + x_F}$
8diii	$N_R = \dfrac{W x_F + Dh}{x_R + x_F}$ $N_F = \dfrac{W x_R - Dh}{x_R + x_F}$ When the car is accelerating, the rear wheels experience an increase in force given by $\dfrac{Dh}{x_R + x_F}$ while the front wheels experience a decrease in force given of the same magnitude. Hence, there is weight transfer from the front wheels to the rear wheels since there is a larger normal contact force at the rear wheels.
8ei	Assume that all the loss in kinetic energy is used to heat up the brake discs (4). Loss in kinetic energy = gain in thermal energy of the 4 discs $\frac{1}{2} m_{car} v^2 - 0 = 4 m_{brake} c \Delta\theta$ $\frac{1}{2}(750)\left(185 \times \frac{1000}{3600}\right)^2 = 4(1.2)(1130)\Delta\theta$ $\Delta\theta = 183$ °C
8eii	All the kinetic energy lost in the slowing of the car is completely converted into the thermal energy of the brake discs.
8eiii	1. To allow for air flow and cooling of the discs. 2. To allow for expansion of the discs when it heats up. 3. As patterns for the brake pads to have a better grip onto the brake discs.