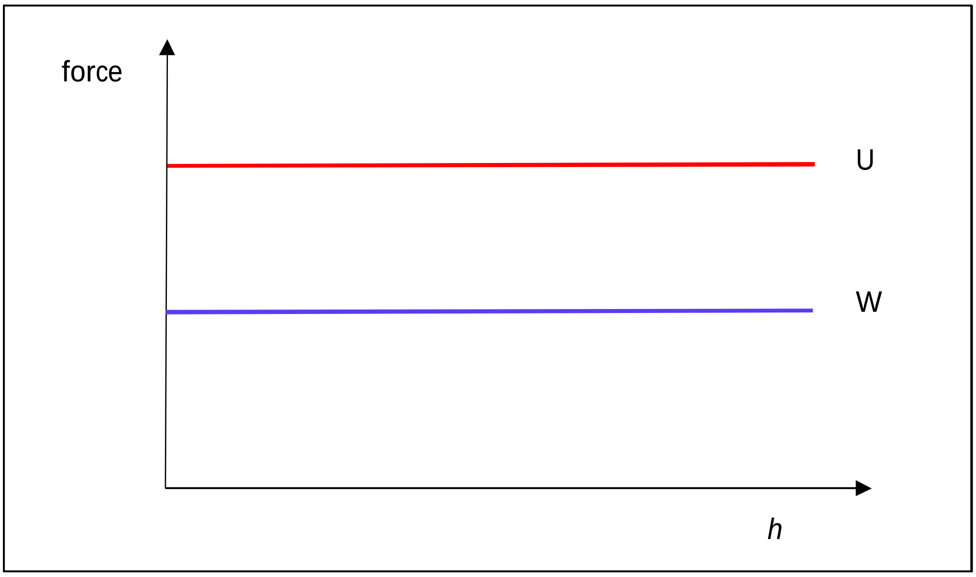
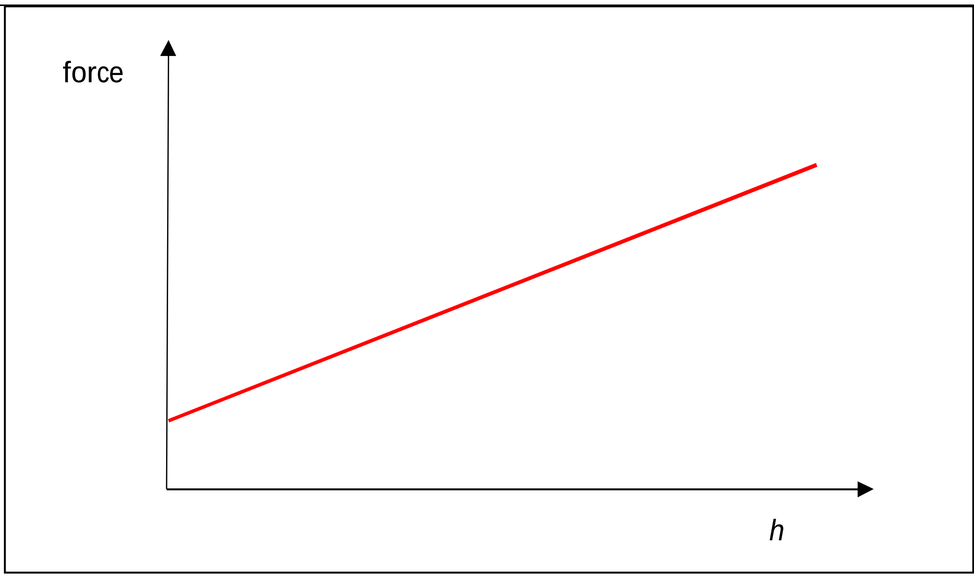
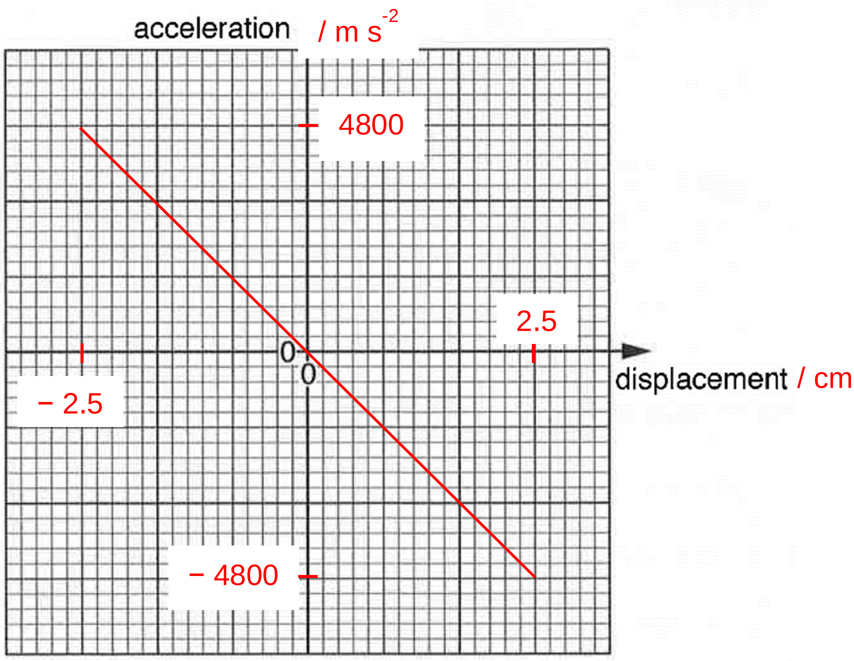
2020 A Levels H2 Physics 9749/02 Paper 3 suggested solutions

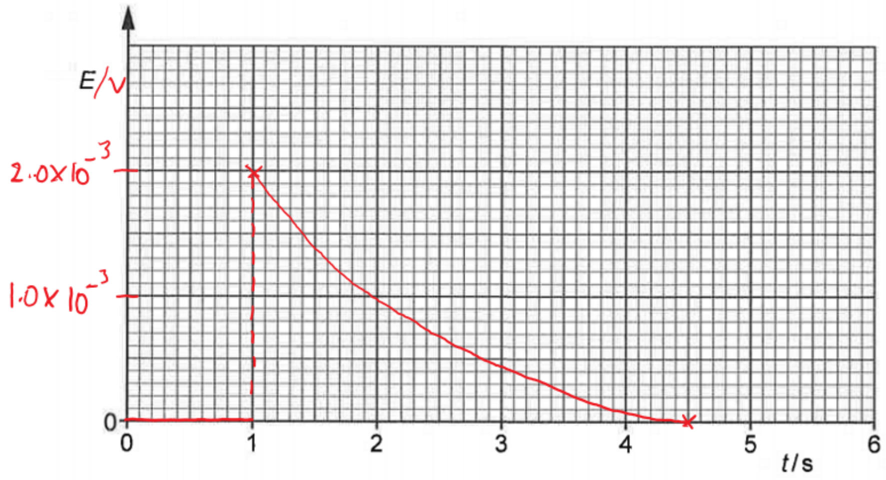
1a(i)	Pressure acting on the sphere increases with depth in the fluid (P=hρg). [B1] The pressure on the bottom surface of the sphere is larger than the pressure on the top surface, resulting in a pressure difference. [B1] This difference in pressure causes <u>a net upward force</u> and hence an upthrust on the sphere. [B1]
1a(ii)	<u>By Archimedes' principle</u> [B1] Upthrust = weight of liquid displaced Weight of liquid displace = mass of liquid x acceleration due to free fall = density x volume of liquid displaced x g = $\rho_L Vg$ Hence upthrust = $\rho_L Vg$ [B1]
1b	Since density of liquid (ρ_L) is larger than density of sphere (ρ_S) Upthrust on sphere ($\rho_L Vg$) > Weight of sphere ($\rho_S Vg$) Both forces are constant force (independent on depth of water). 
1c	At zero depth, h=0, there is atmospheric pressure acting downwards on the sphere. Hence there is a downward force acting on the sphere. The downward force acting on the sphere is increasing as the depth of water increases, due to P=hpg.



Q2a	Gas atoms have random direction and speed [B1] (i.e. random motion). Hence the vector sum of the velocity [B1] will yield an average of zero. **Note**: Though the gas is at specific temperature, it should be noted that the gas atoms have random directions **and** random speeds. Velocity is a vector quantity and as such it is important to add the velocities vectorially. Hence in the topic of Thermal Physics, it is often more useful to discuss about rms speed rather than mean velocity.
b	$pV = NkT$ $N = \frac{pV}{kT}$ [1] $= \frac{(3.6\times10^{5})(4.2\times10^{-3})}{(1.38\times10^{-23})(70+273.15)}$ [1] $= 3.193\times10^{23}$ [1] $= 3.2\times10^{23}$
c	Total volume of gas atoms $= \left(\frac{4}{3}\pi\left(\frac{2\times10^{-10}}{2}\right)^{3}\right)(3.2\times10^{23})$ $= 1.3\times10^{-6}\ \text{m}^3$ [1] **Note**: Leave your answer to 1 or 2 s.f. (max) as this is an estimate and diameter is given as 1 s.f. Answer of 3 s.f. or more is incorrect in this context.
d	The total volume of the gas atoms of 1 x 10^{-6} m^3 is much smaller than the volume of the container of 4.2 x 10^{-3} m^3. [M1] Hence it supports the ideal gas assumption that the total volume of the gas atoms is negligible as compare to volume of the container. [A1] **Note**: Important to make reference to the numerical evidence found/ given earlier in the question.
Q3a (i)	t_3 and t_7 [B1] (minimum x)
(ii)	t_4 and t_8 [B1]

	(equilibrium positions immediately after t_3 and t_7)
(b) (i)	$f = 4200 \text{ rev min}^{-1} = 70 \text{ rev s}^{-1} = 70 \text{ Hz}$ [A1]
(ii)	$Amplitude, X_0 = \frac{0.060 - 0.010}{2} = 0.025 \text{ m}$ [C1] $a_{max} = \omega^2 X_0 = (2\pi f)^2 X_0$ $= (2\pi(70))^2 (0.025)$ [C1] $= 4800 \text{ m s}^{-2}$ [A1] Note: Amplitude of the oscillation is given by half of the distance between the two extreme positions.
(c)	 negatively sloped straight line graph passing through origin [M1] graph symmetrical [M1] correctly labelled acceleration and amplitude with units [A1] Note: Since the question asked to “show qualitatively”, appropriate numerical values should be labelled with units.
4a)	A stationary wave is the result of interference between two identical waves (of same amplitude, frequency and speed) travelling along the same line but in opposite direction. **Note**: do not simply use wave and its reflection as it doesn’t imply that the 2 are moving in opposite direction. Use correct Physics terminology instead of using words like “meet” or “overlap”
b)	The representation shows the amplitude of vibration of the air particles parallel to the axis of the pipe. The amplitude of vibration is maximum at the open end of the pipe (antinode) while the amplitude of vibration is zero at the closed end of the pipe. **Note**: simply writing the definition of longitudinal waves is not sufficient. Many mentioned nodes and antinodes without explaining how these related to the representation of the wave, others referred to the amplitude of waves without mentioning particles. It is irrelevant to discuss about pressure.

c)	since $v = f\lambda$, smallest f means biggest wavelegth, a stationary wave with antinode at open ends and node in the middle will be formed. **Note**: Take great care when drawing diagram. It must demonstrate understanding of the salient features.
d)	*next highest frequency occur when wavelength decreases to the next lower value where L = λ_2 .* *from c) L = ½ λ_1 .* *Since wavelength halved, frequency will be doubled.* $f_2 = 2f_1$ $f_2 = 2 \times 540 = 1080 Hz$
5(a)	$\Delta R = \frac{3.0}{0.3} - \frac{1.5}{0.2} = 2.5\Omega$ **Note**: It is wrong to use gradient to calculate resistance. The resistance of a circuit component is the <u>*ratio*</u> of the *potential difference* across the component to the *current* flowing through it.
5(b)(i)	Pd across the 5.0Ω resistor = (5 x 0.36) = 1.8 V Pd across the lamp (read off from Fig. 5.1 at current of 0.36 A) = 4.5 V Total pd across 5.0Ω and lamp (same as that across the 14Ω) = 4.5 +1.8 = 6.3 V Current in resistor of 14Ω = 6.3/14 = 0.45 A. **Note**: possible common mistakes: either they did not include the lamp in their calculations, or they thought that the potential difference across the external circuit was 7.5V.
5(b)(ii)	Pd across the internal resistance = 7.5 – 6.3 = 1.2 V Total current flowing through the internal resistance = 0.45 + 0.36 = 0.81 A r = 1.2/0.81 = 1.5 Ω **Note**: common mistakes could include thinking that 5.0Ω resistor, the lamp and the internal resistance are in series with the e.m.f., without realising that the currents flowing through the two parallel branches are different.
6 (a)	Faraday's Law of Electromagnetic Induction states that the induced e.m.f is directly proportional to the rate of change of magnetic flux linkage.
6(b)(i)	Consider tangent to the graph at t = 1.0 s rate of change of magnetic flux density = gradient of tangent $= \frac{30 \times 10^{-3} - 0}{1.5 - 1.0}$ $= 6.0 \times 10^{-2}$ T **Note**: to find gradient of a tangent, one should use two points on it that are as far apart as possible
6(b)(ii)	By Faraday's Law,

	induced e.m.f. $= NA\dfrac{dB}{dt}$ $=140(2.4\times10^{-4})(6.0\times10^{-2})$ $= 2.02\ \times\ 10^{-3}$ V
6(b)(iii)	 From t = 0 to t = 1.0 s, since B = 0, no induced e.m.f. From t = 1.0 to t = 4.3 s, since $\dfrac{dB}{dt}$ is decreasing, the induced e.m.f. decreases. After t = 4.5 s*, since $\dfrac{dB}{dt}=0$, the induced e.m.f is zero. (*allow between 4.2 s to 4.5 s) **Note**: Remember to include units on the e.m.f. axis.
7ai	The nuclear binding energy of a nucleus is defined as the minimum energy required to completely separate a nucleus into its constituent nucleons. • Binding energy is related to the mass defect by Einstein's mass-energy equivalence equation: BE = $(\Delta m)c^2$
7aii	$\Delta m = (12m_n + 11m_p) - (m_{\text{Na}})$ $= 12(1.00898u) + 11(1.00814u) + (1.00898u) - (22.99706u)$ $= 0.20024u$

	binding energy $= \Delta mc^2$ $= (0.20024 \times 1.66 \times 10^{-27})(3.0 \times 10^8)^2$ $= 2.99158 \times 10^{-11}$ J $= \dfrac{1.806574 \times 10^{-10}}{1.60 \times 10^{-19}}$ eV $= 1.86974 \times 10^8$ eV binding energy per nucleon $= \dfrac{1.86974 \times 10^8}{23}$ $= 8.1293 \times 10^6$ ≈ 8.129 MeV
7bi	$\Delta m = m_{\text{products}} - m_{\text{reactants}}$ $= m_{Na24} - (m_{Na23} + m_n)$ $= 23.99857u - (22.99706u + 1.00898u)$ $= -0.00747u$ hence the change in mass is 0.00747*u.*
7bii	Energy released is associated with the mass defect. $E_{\text{released}} = \Delta mc^2$ $= (0.00747)(1.66 \times 10^{-27})(3 \times 10^8)^2$ $= 1.116018 \times 10^{-12}$ J Finding wavelength $E_{\text{released}} = E_{\text{photon}}$ $1.116018 \times 10^{-12} = \dfrac{hc}{\lambda}$ $\lambda = \dfrac{(6.63 \times 10^{-34})(3 \times 10^8)}{(1.116018 \times 10^{-12})}$ $= 1.78222 \times 10^{-13}$ $\approx 1.78 \times 10^{-13}$ m
7c	$N = N_o e^{-\lambda t}$ $\lambda = -\dfrac{1}{t}\ln\left(\dfrac{N}{N_o}\right)$ when $t = 65$ hours, $\dfrac{N}{N_o} = \dfrac{1}{20}$ $= -\dfrac{1}{65}\ln\left(\dfrac{1}{20}\right)$ $= 0.046088$ ≈ 0.046
8a(i)	In an inelastic collision, the relative speed of approach of the two objects is greater than their relative speed of separation. [important to make reference to the speeds especially relative speeds, not velocity]

	For the case of a completely inelastic collision, the relative speed of separation of the two object is zero.
8a(ii)	In an inelastic collision, the total kinetic energy of the two objects before collision is not conserved after collision. The loss in kinetic energy is converted to other form of energy.
8b	gain in kinetic energy = loss in gravitational potential energy $\frac{1}{2}mv^2 - 0 = mgL - mgL\cos 21°$ $\frac{1}{2}v^2 = gL - gL\cos 21°$ $\frac{1}{2}v^2 = 9.81(1.50) - 9.81(1.50)\cos 21°$ $v = 1.398 = 1.4 \text{ m s}^{-1}$
8c(i)	By conservation of linear momentum $m_A u_A + m_B u_B = m_A v_A + m_B v_B$ $0.096(1.4) + 0 = 0.096(-0.79) + m_B v_B$ $m_B v_B = 0.21 \text{ kg m s}^{-1}$
8c(ii)	14% of KE of sphere A = 0.14 x (0.5) (0.096) $(1.4)^2$ = 0.0131712 J KE of sphere B $= \frac{1}{2}m_A u_A{}^2 - \frac{1}{2}m_A v_A{}^2 - 0.0131712$ $= \frac{1}{2}0.096(1.4)^2 - \frac{1}{2}0.096(-0.79)^2 - 0.0131712$ $= 0.051 \text{ J}$
8d(i)	$\frac{KE \text{ of sphere B}}{m_B v_B} = \frac{\frac{1}{2}m_B v_B{}^2}{m_B v_B} = \frac{1}{2}v_B = \frac{0.051}{0.21}$ $v_B = 0.49 \text{ m s}^{-1}$
8d(ii)	Hence, $m_B(0.49) = 0.21 \text{ kg m s}^{-1}$ $m_B = 0.43 \text{ kg}$
8e	Before collision, total initial momentum of both sphere A and sphere B is not zero since sphere A has initial momentum as it moves towards sphere B. Total momentum is conserved throughout the collision. [must make reference to the fact that COLM is conserved throughout collision] Hence, it is not possible for the spheres to be stationary at the same time (i.e. zero total momentum) as this will violate the conservation of linear momentum.
8f	$impulse = change$ in momentum $= m_A v_A - m_A u_A$ $= 0.096(-0.79) - 0.096(1.4)$ $= -0.21 \text{ kg m s}^{-1}$

	magnitude of impulse = 0.21 kg m s^{-1}
8g	The direction of impulse in **(f)** is towards the left and horizontal. [must make reference to the direction of impulse as required by question!] By conservation of linear momentum, the impulse on B must be towards the right and horizontal. For this to occur, the centres of the spheres must be on the same horizontal level at the time of collision so that there will not be any other component of impulse besides the horizontal mentioned above.
9(a)(i)	A field of force is a region of space in which a body experiences a force without physical contact with another body. A force field is produced by the presence of another body (or bodies).
9(a)(ii)1	Gravitational field
9(a)(ii)2	Electric field, gravitational field **Note**: BOTH <u>uncharged</u> and <u>charged</u> particles felt the gravitational force. Also stationary charged particle would NOT feel a magnetic force.
9(b)(i)	Consider the horizontal motion, $\text{time} = \frac{s_x}{u_x} = \frac{0.12}{6.7 \times 10^7} = 1.8 \times 10^{-9}\,\text{s}$
9(b)(ii)	$E = \frac{\Delta V}{d} = \frac{960}{2.4 \times 10^{-2}} = 40\ 000\ \text{NC}^{-1}$ Electric force F = qE =$(1.6 \times 10^{-19})(40\ 000) = 6.4 \times 10^{-15}$ N Considering weight of electron to be negligible, $a = \frac{F}{m} = \frac{6.4 \times 10^{-15}}{9.11 \times 10^{-31}} = 7.0 \times 10^{15}\ \text{ms}^{-2}$
9(c)	Using the answers in (b)(i) and (b)(ii), the vertical displacement travelled by electron in the region is equal to ½ $(7.0 \times 10^{15})(1.8 \times 10^{-9})^2$ = 0.0113 m = 1.13 cm in the upwards direction Since the top plate is 1.2 cm above the electron's initial point of entry into the region, and vertical displacement travelled < 1.2 cm, the electron will not collide with the plates.
9(d)(i)	The magnetic force experienced by a particle is constant in magnitude and always perpendicular to the velocity/ direction of motion of the particle throughout its time in the magnetic field. Thus it provides the centripetal force that changes only the direction and not the magnitude of the velocity, resulting in a circular motion. **Note**: Important to give sufficient detail. Most would realise that a force acts perpendicular to the velocity of the particle; however must state that this occurs throughout its time in the field. Also one should make be clear and make reference to 'the direction of motion of the particle' and not just 'the motion of the particle'.

9(d)(ii)	Magnetic force provides the centripetal force. $Bqv = \frac{mv^2}{r}$ $0.090(1.6\times10^{-19}) = \frac{m(4.6\times10^{4})}{(7.4\times10^{-2})}$ $m = 2.317\times10^{-26} = 14$ u
9(e)(i)	Since $r = \frac{mv}{Bq}$, with same speed v, magnitude of charge q, and magnetic flux density B remaining constant, A smaller mass m will mean that the radius of curvature, r, of the path will be smaller.
9(e)(ii)	Since $r = \frac{mv}{Bq}$, with same speed v, same mass m, and magnetic flux density B remaining constant, Doubling the charge q will mean that the radius of curvature, r, of the path will be reduced by half. Hence the diameter of the path will change from 14.8 cm to 7.4 cm.