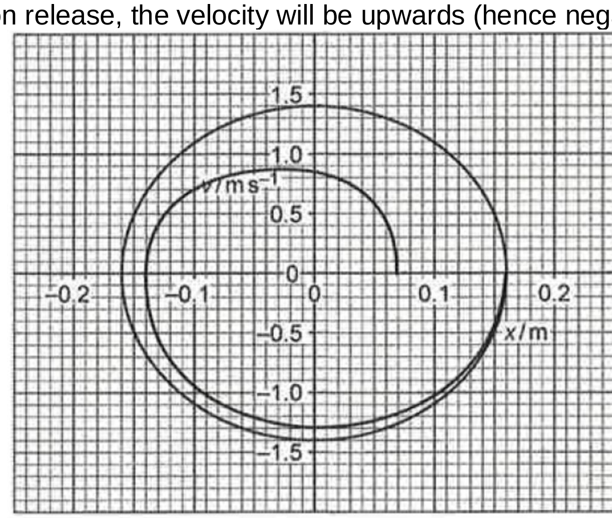
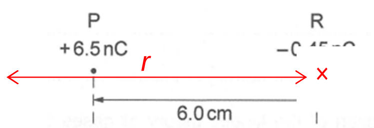
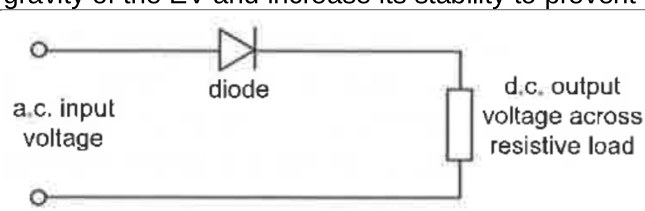
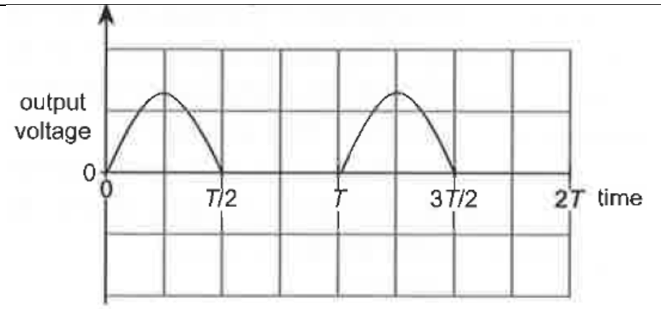
2022 A Levels H2 Physics 9749/02 Paper 2 suggested solutions

1a	$T = \frac{7.2}{10} = 0.72$ s $T = 2\pi\sqrt{\frac{m}{k}}$ $\Rightarrow k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2(0.120)}{(0.72)^2} = 9.1385$ N m^{-1} $\frac{\Delta k}{k} = \frac{\Delta m}{m} + 2\frac{\Delta T}{T}$ $\frac{\Delta k}{9.1385} = \frac{1}{100} + 2\left(\frac{0.2}{7.2}\right) \quad \left[\because \frac{\Delta T}{T} = \frac{\Delta t}{t}\right]$ $\Delta k = 0.6$ N m^{-1} (1 s.f.) $\therefore k = 9.1 \pm 0.6$ N m^{-1}
1bi	From Fig. 1.2, $v_0 = 1.4$ m s^{-1} and $x_0 = 0.16$ m $v_0 = \omega x_0$ $1.4 = \omega(0.16)$ $\omega = 8.75$ rad s^{-1} $\therefore \lvert a_0 \rvert = \omega^2 x_0 = (8.75)^2(0.16) = 12.3$ m s^{-2}
1bii	Taking downwards as positive, the initial displacement will be positive (assuming the mass is pulled down), and upon release, the velocity will be upwards (hence negative. 
2ai	Vector is a quantity that has both magnitude and direction.
2aii	Force or velocity or momentum etc.
2bi	Component of weight along the slope = $W \sin\theta$ = 16 sin35° = 9.18 N
2bii	When going down the slope at constant speed, Fnet =ma = 0 Frictional force is equal to the component of weight along the slope = 9.18 N. On the way up the slope at constant speed, Fnet = ma = 0 P – frictional force – component of weight along slope = 0 Hence P = 9.18 x 2 = 18.4 N

2ci	Impulse on X = change in momentum of X = $mv_f - mv_i$ = 0.22 (3.5) – 0.22 (2.6) = 0.198 N s.
2cii	Impulse on Y = – impulse on X = – 0.198 N s Hence Impulse on Y = $mv_f - mv_i$ – 0.198 = 0.40 (v_f) – 0.40 (3.3) v_f = 2.81 m s^{-1}.
2ciii	Distance travelled by X = area under graph from 1.8 seconds to 2.0 s. = (0.5) (2.6+3.5) (0.20) = 0.61 m
3a	For a mass in a gravitational field, the gravitational force is in the direction of the field. For a charge particle in an electric field, the electric force is either in the direction of the field for a positive charge or opposite for a negative charge. In both cases, the direction of the force is perpendicular to both its *initial* direction of motion. This causes an acceleration only in the direction of the force but no component in the direction of its initial velocity. Its component of velocity parallel to its initial direction of motion thus remains unchanged while its component of velocity parallel to the force increases from zero. This results in the object moving in a parabolic path.
3bi	Gravitational force is always attractive in nature, thus the direction of the gravitational force F_G is towards each proton. Since both protons have a positive charge, hence the electric force F_E is a repulsive force and the direction is away from each proton.
3bii	No. The protons are of extremely small mass, hence their gravitational force of attraction is many orders of magnitude smaller than their elector force of repulsion.
3ci	No. The electric field strength due to positive charge P points away from P (rightwards) and the electric field strength due to negative charge R points towards R (rightwards). Being in the same direction, they add up vectorially thus the resultant electric field strength between P and R points towards the right.
3cii	Yes. The electric potential due to positive charge P is positive and the electric potential due to negative charge R is negative. Electric potential being a scalar, their scalar sum will result in a point between P and R where the resultant electric potential is zero.
3ciii	The point where g_{net} = 0, hence F_{net} = 0 will be found at the region nearer to the charge of smaller magnitude of charge.  $\left\|F_{\text{between P \& e-}}\right\| = \left\|F_{\text{between R \& e-}}\right\|$ $\frac{Q_P Q_{e-}}{4\pi\varepsilon_o r^2} = \frac{Q_R Q_{e-}}{4\pi\varepsilon_o (r-6.0)^2}$ $\frac{6.5\times10^{-9}}{r^2} = \frac{0.45\times10^{-9}}{(r-6.0)^2}$ $\sqrt{\frac{6.5\times10^{-9}}{r^2}} = \sqrt{\frac{0.45\times10^{-9}}{(r-6.0)^2}}$ $\frac{r}{r-6.0} = 3.8$ $r = 8.1\text{ cm}$

4a	The gas molecules are in continuous random motion. When the molecules collide and rebound from the walls of the vessel, the walls exert a net force on the molecules. By N3L, the molecules will in turn exert a force on the wall. The pressure exerted by the gas on the wall will be the total force exerted by the molecules on the wall divided by the total area of the walls.
4bi	The total volume of the gas particles is negligible in comparison to the volume of the gas. The separation between gas particles is very large in comparison to their diameter,
4bii	PV=NkT N= PV/kT $= \frac{180 \times 3.2 \times 10^{-4}}{1.38 \times 10^{-23} \times 299} = 1.4 \times 10^{19}$ Volume between each gas particle= $\frac{3.2 \times 10^{-4}}{1.4 \times 10^{19}} = 2.28 \times 10^{-23} m^3$ Average distance $\approx \sqrt[3]{2.28 \times 10^{-23}} = 2.8 \times 10^{-8} m$
4biii	The assumption is valid as the average distance of separation between gas particles is 280 times bigger than the diameter of a gas particle.
5a	• Wave profile of a stationary wave varies from one extreme position to another, but does not advance. Wave profile of a progressive wave advances with the speed of the wave. • Amplitude of the particles in a stationary wave depends on its position along the wave, whereas all the particles in a progressive wave has the same amplitude. • For a stationary wave, all the particles between 2 adjacent nodes are in phase, and particles in alternate segments are in anti-phase. For a progressive wave, wave particles have different phase within a wavelength.
5b	The incident waves from the source and the reflected wave from the metal plate are identical waves of similar amplitude, frequency and speed. When they travel along the same line in opposite directions, they interfere to form a stationary wave.
5ci	At the minimum points, the incident wave from the source and the reflected wave from metal plate always meet in anti-phase resulting in destructive interference. However as the wave would have travelled further for the reflected wave than the incident wave to reach the point, following the inverse square law, the intensity and hence the amplitude of the reflected wave would be lower. Hence there will not be complete cancellation at the minimum points, leading to non-zero amplitude and intensity.
5cii	From Fig. 5.2, wavelength = 7.5 – 2.3 = 5.2 cm
5ciii	Frequency = c/λ = (3.00 x 10^8) / 0.052 = 5.8 x 10^9 Hz
6a	Half-life of a radioactive isotope is the time taken for half the original number of the radioactive nuclei of the isotope to decay
6b	At the steep part of the curve, the activity is high. The decrease of activity to half of its original value will thus be significantly large on the graph, and thus it will be easier to determine the time interval for this decrease (i.e. the half-life) from the graph.
6c	The momentum of the system of the nucleus (and its emissions) must be conserved in all directions, since there is no external force acting on the system. Since there was zero total momentum in the vertical direction before emission, therefore there must be another emitted particle with component of momentum in the upward direction, to cancel out the component of momentum of the emitted beta particle in the downward direction.
6di	${}^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e + \nu_e$

6dii	A = λ N. So the gradient of the graph gives the decay constant λ $\lambda = \frac{4.6\times10^{9}-0}{6.0\times10^{18}-0} = 7.666\times10^{-10}\ \text{s}^{-1}$ half life = $\frac{\ln 2}{\lambda} = 9.0\times10^{8}\ \text{s}$
6e	Let N_0 be original number of atoms of J, N be the number of atoms of J after 3.5 half-lives $\frac{N}{N_0} = (\frac{1}{2})^{3.5}$ $N = 0.08838\ N_0$ Number of atoms of K after 3.5 half-lives = $N_0 - N = 0.9116\ N_0$ Hence, $\frac{\text{number of atoms of J}}{\text{number of atoms of K}} = \frac{0.08838 N_0}{0.9116\ N_0} = 0.097$
7ai	For EV, cost to travel 1.0 km $= \frac{1.0\ \text{km}}{400\ \text{km}} \times 72\ \text{kW h} \times \$0.23\ \text{kW h}^{-1} = \$0.0414$ For ICE, cost to travel 1.0 km $= \frac{1.0\ \text{km}}{800\ \text{km}} \times \$80 = \$0.10$ Ratio $= \frac{\$0.0414}{\$0.10} = 0.414$
7aii	A car in Singapore typically travels 290 km a week, but the range of the EV is 400 km, which is more than the distance travelled in a week. Hence the EV needs to be charged less than once per week.
7bi	Charging p.d. $= \frac{P}{I} = \frac{7200}{32} = 225\ \text{V}$ No. of parallel branches needed $= \frac{32\ \text{A}}{2.0\ \text{A}} = 16$ branches No. of cells in series in each branch $= \frac{225\ \text{V}}{3.0\ \text{V}} = 75$ cells in each branch Minimum no. of cells $= 16 \times 75 = 1200$
7bii	Since the range of the EV is 400 km, and it takes 10 hours to fully charge the EV, the range which can be achieved with each hour of charging is $\frac{400\ \text{km}}{10\ \text{h}} = 40\ \text{km h}^{-1}$.
7biii	It means that the amount of energy stored in each kg of the battery is 141 W h.
7biv	Mass of battery $= \frac{72000\ \text{W h}}{141\ \text{W h kg}^{-1}} = 511\ \text{kg}$
7bv	The battery is located under the floor of the EV (stated in passage). Since the battery takes up about 30% of the EV's mass, being located under the floor of the EV will lower the centre of gravity of the EV and increase its stability to prevent overturning of the EV.
7ci	

7cii	
7d	Note: $1\ \text{kW h} = 1000\ \text{W} \times 60\ \text{min} \times 60\ \text{s} = 3.6 \times 10^{6}\ \text{J}$ Kinetic energy of EV $= \frac{1}{2}(1685)(25)^{2} = 5.266 \times 10^{5}\ \text{J} = 0.1463\ \text{kW h}$ Distance which the EV can travel $= \frac{0.1463\ \text{kW h}}{72\ \text{kW h}} \times 400\ \text{km} = 0.813\ \text{km}$
7ei	The wireless charger works by electromagnetic induction. By Faraday's law, an e.m.f. can induced in the EV's coil by a changing magnetic flux linkage. Hence an a.c. voltage is needed to produce the changing magnetic field in the ground pad coil.
7eii	The magnetic flux density decreases with distance from the ground pad coil. Hence, to maximise the magnetic flux linkage through the EV's coil, the ground pad coil and the EV's coil need to be as close as possible.
7fi	$\tau = F \times d$ $395 = F \times d$ $F = \frac{395}{d}$ $F = NBIL$ $\frac{395}{d} = (1200)B(96)L$ $B = \frac{395}{(1200)(96)Ld} = \frac{395}{(1200)(96)(6.1 \times 10^{-3})}$ [since Ld = area of coil] $= 0.562\ \text{T}$

7fii	The advantage of four pairs of magnetic poles is that the maximum torque can be achieved 4 times* in a single rotation of the coil, compared to only once for a one-pair of magnetic poles. This produces a more consistent rotation (or smoother rotation) of the motor. [*Note to students: This is because whenever the plane of the coil is aligned with the plane of the pairs of the magnets, the electromagnetic force will be perpendicular to the plane of the coil, achieving maximum torque.]