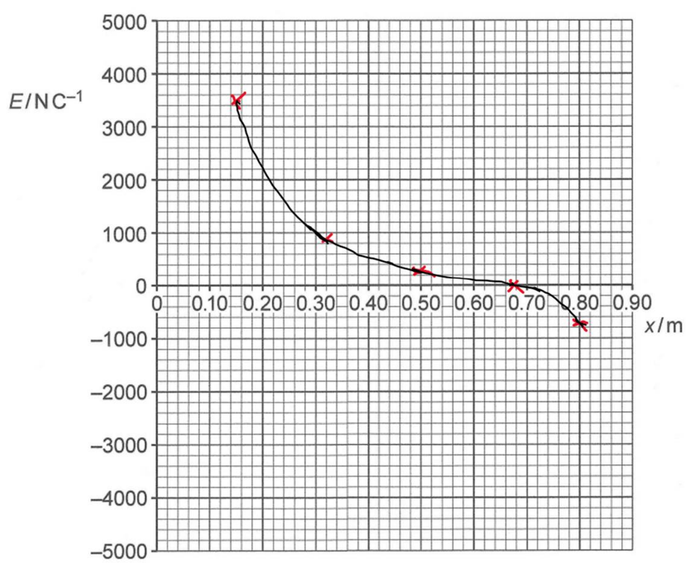
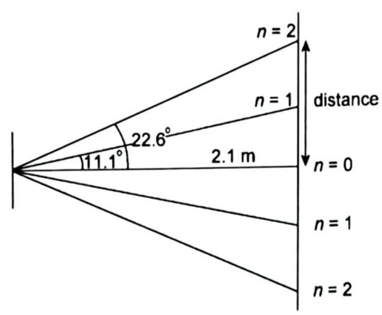
2022 A Levels H2 Physics 9749/02 Paper 3 suggested solutions

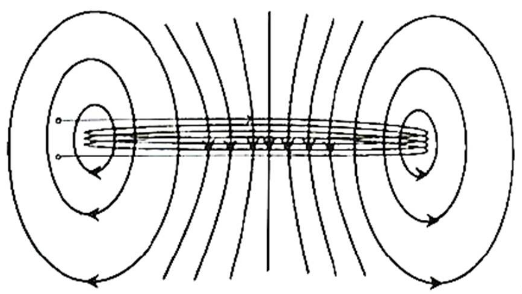
1a	Inertia is the tendency for bodies to resist changes in its motion.
1b	$g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11})(7.35\times10^{22})}{(1.74\times10^{6})^2} = 1.62 \text{ N kg}^{-1}$
1ci	Since a force of 10 kN is exerted on the rocket, by Newton's 3rd law, a force of 10 kN is also exerted on the gases in the opposite direction. $F_{\text{on gas}} = v\frac{dm}{dt}$ $10000 = v(70.0)$ $v = 143 \text{ m s}^{-1}$
1cii	After 15.0 s, mass of rocket $= 4000 - (15.0)(70.0) = 2950$ kg $F_{net} = ma$ $T - mg = ma$ $10000 - (2950)(1.62) = (2950)a$ $a = 1.77 \text{ m s}^{-2}$
1ciii	Actual acceleration is greater. At a greater height, the gravitational field strength is lesser since gravitational field strength is inversely proportional to the square of distance from centre of planet. Thus the weight of the rocket will be lesser, resulting in a larger net force on the rocket. Hence its acceleration is greater.
2a	$R = \rho\frac{l}{A}$ $\rho = \frac{R}{l}A$ $= 1.73\times\pi\left(\frac{1.02}{2}\times10^{-3}\right)^2$ $= 1.41\times10^{-6}\ \Omega\text{ m}$
2bi	(see table below)
2bii	At constant temperature, $\Delta U = 0$ work done by the power supply = Power x time Hence for 40 s, $w = Pt = IVt$ = 12 x 230 x 40 =110400 = 1.10×10^5 J By 1st law of thermodynamics, $q = -1.10 \times 10^5$ J
3ai	$\omega = 2\pi f$ $= 2\pi(\frac{1200}{60})$ $= 126 \text{ rad s}^{-1}$
3aii	$F - W = mr\omega^2$ $F = mr\omega^2 + W$ $= 1.20(0.230)(126)^2 + 1.2(9.81)$ $= 4370$ N

2bi:

time after being switched on / s	ΔU	q	w
0-59	positive	negative	positive
60-100	zero	Negative	positive

3aiii	Washing machines vibrate vigorously when spinning. The large masses serve as a mass damper by reducing the amplitude of vibration. The masses also reduce the natural frequency so that it will be below the frequency of spinning, to prevent resonance from happening. The masses are also placed at the bottom to lower the centre of gravity of the washing machine, increasing the stability to prevent toppling when it vibrates. By Newton's third law, the force on the towel by the machine **(a)(ii)** is equal in magnitude to the force on the machine by the towel. Hence, large masses placed at the bottom can also prevent such a large force from cracking the base of the machine.
3b	At the holes, there is no normal contact force exerted on the water droplet, so the only force it experiences is its weight which acts vertically downwards. There is no normal contact force present at the holes to provide for centripetal force, hence the water droplet is not able to remain in circular motion. The velocity of the water droplets at the holes will be tangential to the drum.
4a	The 2 spheres have the same sign. Based on Fig 4.2, the potential gradient of the graph changes from negative to zero before turning positive. This implies that electric field also changes direction since E=-dV/dx. Electric field between 2 charges will only be zero if the charges are of the same sign. Since potential between the 2 spheres is always positive and potential is a scalar, the 2 spheres are positively charged.
4b	Using Fig 4.2, Find negative potential gradient , -dV/dx (=E) at x=0.15m, x=0.80m and 2 other points between x=0.15 m and 0.68m. Graph cuts through x axis at x=0.68 m since potential gradient at that point is zero. Join up the points with 1/x shape in mind. 
4ci	$V = \frac{1}{4\pi\varepsilon_o}\frac{1\times10^{-8}}{0.15} = 599$ V
4cii	Since there's another charged sphere B nearby, the electric potential at the surface of sphere A will be the scalar addition of potential due to sphere A as well as sphere B. Thus, the potential on surface of sphere A shown in Fig 4.2 will be bigger.
5a	When the switch is closed, the voltmeter will record a non-zero reading for a short time before becoming zero. When the switch is opened shortly after, the voltmeter will recording a non-zero reading in the opposite polarity which goes back to zero after a short time.

5b	When the switch is open, there is no magnetic flux in the setup. When the switch is **closed**, there is a current flowing in the **primary coil** that produces a magnetic flux. The core confines the flux resulting in an increase in magnetic flux linkage in the **secondary coil** pointing downwards. By Faraday's Law an e.m.f. proportional to the **rate** of change of flux linkage is produced. When current in primary coil is constant, there is no change in flux produced. Hence flux linkage in secondary coil remains constant and hence no e.m.f. is produced. When the switch is **open** there is a decrease in magnetic flux linkage in the secondary coil pointing downwards. By Faraday's Law an e.m.f. will be produced. Since the magnetic flux linkage is now decreasing instead of increasing, the e.m.f. produce will be in opposite polarity.
6a	From graph, when temperature is 20°C, R = 60 Ω Using the potential divider rule, $0.43 = \frac{R_{fixed}}{60 + R_{fixed}} \times 1.50$, where R_{fixed} is the resistance of the fixed resistor $R_{fixed} = 24\ \Omega$ (shown)
6b	From graph, when temperature is 32°C, R = 40 Ω So current across thermistor = $\frac{1.50}{40} = 0.0375$ A current across fixed resistor = $\frac{1.50}{24} = 0.0625A$ current in cell = 0.0375 + 0.0625 = 0.10 A
7a	It means that the light waves have a constant phase difference and same frequency.
7b	For the grating, $d = \frac{0.001}{300} = 3.33 \times 10^{-6}$ m $d \sin\theta = n\lambda$ $\left(3.33 \times 10^{-6}\right)\sin\theta = 2\left(640 \times 10^{-9}\right)$ $\theta = 22.58^{o}$  $\tan\left(22.58^{o}\right) = \frac{y}{2.1}$ $y = 0.873 \text{ m} = 87.3 \text{ cm}$
8ai	The electric field strength at a point is the electric force per unit positive charge acting on a small stationary charge placed at that point.
8aii	The electron gun must be in a vacuum so that the electrons emitted from the cathode will not collide with gas molecules in the gun. The ensures that there would be sufficient electrons accelerated towards anode and emerges as electron beam.
8aiii	gain in KE = loss in EPE $2.48 \times 10^{-16} = eV = 1.6 \times 10^{-19} V$ $V = 1550$ V

8aiv	Electrons may not be emitted horizontally from cathode (as shown in Fig.8.2). Electrons emitted may come from various positions below the surface of the cathode. Hence, they may collide with other atoms or electrons, losing some energy before emerging from the cathode with a range of speeds. As such, there would still be a range of speeds of electrons reaching the anode despite the same increase in KE.
8bi	$B = \frac{\mu_0 N I}{2r}$ $= \frac{4\pi \times 10^{-7} \times 120 \times 3.5}{0.30}$ $= 1.8 \times 10^{-3}$ T
8bii	From the top view, current is clockwise. By right hand grip rule, the magnetic flux will be pointing into the paper. Hence, on Fig 8.4, the magnetic flux will be pointing downwards (within the col). Outside the coil, the field lines should continue and hence loops are observed.  Note: 1) At least 5 lines with correct arrows 2) Lines must not cross. 3) Spacing of lines should be carefully considered while keeping symmetry.
8ci	The initial direction of motion of electrons is perpendicular to the uniform magnetic field out of the page. By Fleming's left hand rule, electrons will experience a magnetic force that is always perpendicular to velocity of the electrons. In this case, the magnetic force provides for the centripetal force that causes the electrons to move in a circular path.
8cii	Magnetic force provides for the centripetal force $Bqv = \frac{mv^2}{r}$ $r = \frac{mv}{Bq}$ $= \frac{9.11 \times 10^{-31} \times 2.40 \times 10^{7}}{1.43 \times 1.8 \times 10^{-3} \times 1.6 \times 10^{-19}}$ $= 0.0531$ m
8d	The component of the velocity (of the electrons) perpendicular to the field will result in the electron to move in circular path. The component of the velocity (of the electrons) parallel to the field will cause the electron to move (at constant speed) in the direction of the field. Hence, the net effect is that the electron will move in a helical path.

9a	1. This observation supports the particulate nature because radiation arrives as discrete bundles of energy (photons) with energy, $E = hf$. Each photon interacts with an electron in the metal surface on a one-to-one basis as each photon can transfer its energy to at most one electron. A higher intensity beam of radiation contains more photons but the maximum kinetic energy of the emitted electrons depends on the energy of each individual photon which depends on its frequency only. This observation does not support the wave nature as classical wave theory suggests that since intensity of a wave is its power per unit area, a higher intensity beam of radiation has more energy hence it will impact more kinetic energy to the electron, but this is not observed in reality. 2. This observation supports the particulate nature because radiation arrives as discrete bundle of energy (photons). Each photon interacts with an electron in the metal surface on a one-to-one basis, If the energy of the photon (frequency) is less than the work function (threshold frequency) of the metal then no electrons are emitted. A higher intensity of radiation contains more photons but the energy and hence the frequency of each individual photons remains the same. This observation does not support the wave nature as classical wave theory suggests that a higher intensity beam should accumulate sufficient energy over time to overcome the work function (threshold frequency) of the metal and cause the electrons to be emitted but this is not observed in reality. **note: need to cover both particulate and wave nature**
9b	Threshold frequency
9c	$\frac{hc}{\lambda} = \phi + E_{k\max}$ $E_{k\max} = \frac{hc}{\lambda} - \phi$ $= \frac{6.63\times10^{-34}(3.0\times10^{8})}{210\times10^{-9}} - (4.33\times1.6\times10^{-19})$ $= 2.54\times10^{-19}$ J
9d	$E_{k\max} = eV_s$ $V_s = \frac{E_{k\max}}{e}$ $= \frac{2.54\times10^{-19}}{1.6\times10^{-19}}$ $= 1.59$ V

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9eii
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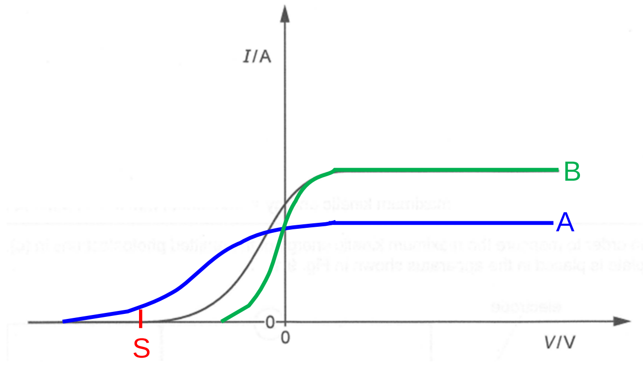

(e)(ii):

Photons of shorter wavelength will have greater energy, hence using $\frac{hc}{\lambda} = \phi + eV_s$, the stopping potential will increase.

When photon wavelength decreases, keeping the intensity constant, using $\text{Intensity} = \frac{N_p}{tA}\left(\frac{hc}{\lambda}\right)$, the number of incident photons per unit time will decrease, since number of incident photons per unit time is proportional to number of electrons emitted per unit time, hence the maximum current will decrease.

(e)(iii):
Since the metal has a greater work function, and the photon wavelength remains unchanged, using $\frac{hc}{\lambda} = \phi + eV_s$, the stopping potential will decrease.

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When the electrode is negative with respect to the zinc plate, as the photoelectrons move from zinc plate to the electrode, they lose kinetic energy and gain electric potential energy. When the potential difference between the zinc plate and the electrode is greater than the stopping potential, even the most energetic photoelectron has insufficient kinetic energy to reach the electrode as all its kinetic energy is already converted to electric potential energy before it reaches the electrode. Hence current is zero.

note: when V is equal to V_s or greater than V_s, there is <u>still emission of electrons</u> but these electrons are not able to reach the collector plate, hence zero current

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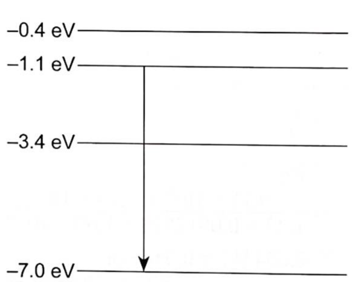
$$
\begin{aligned}
E &= \frac{hc}{\lambda} \\
&= \frac{6.63\times10^{-34}(3.0\times10^{8})}{210\times10^{-9}} \\
&= 9.47\times10^{-19}\ \text{J} \\
&= 5.9\ \text{eV}
\end{aligned}
$$

Electrons de-excite and a photon is emitted.



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9fii	$$\Delta E = \frac{hc}{\lambda}$$ $$[-0.4-(-1.1)]\times 1.6\times 10^{-19} = \frac{6.63\times 10^{-34}(3.0\times 10^{8})}{\lambda}$$ $$\lambda = 1.78\times 10^{-6}\ \text{m}$$ For a photon with the longest wavelength, its energy must be the smallest. Since the energy of the emitted photon is equal to the difference between the two energy levels, the energy difference between the two levels must be the smallest possible, hence the transition from -0.4 eV to -1.1 eV.