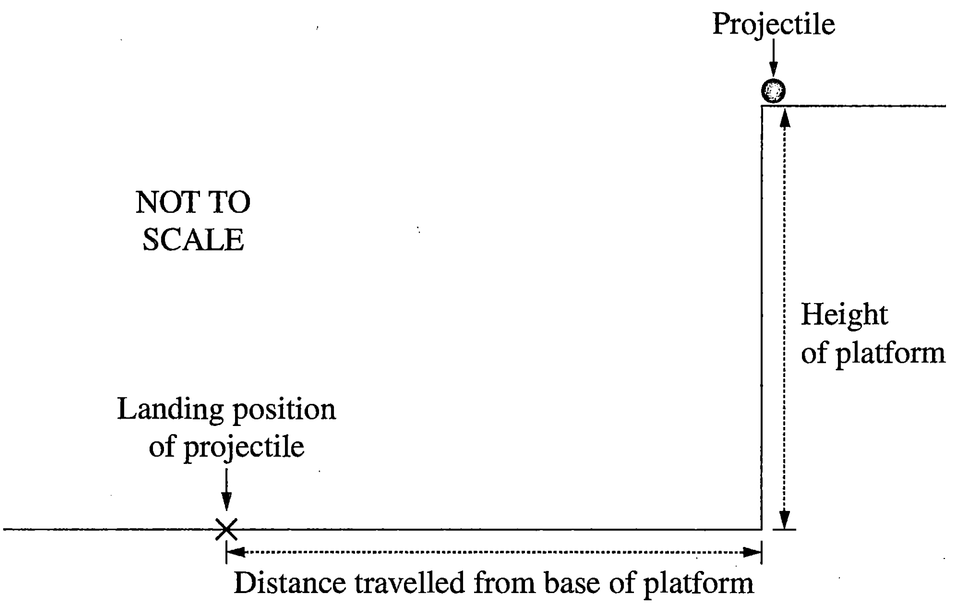
Question 21 (4 marks)

A projectile is fired horizontally from a platform.



Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

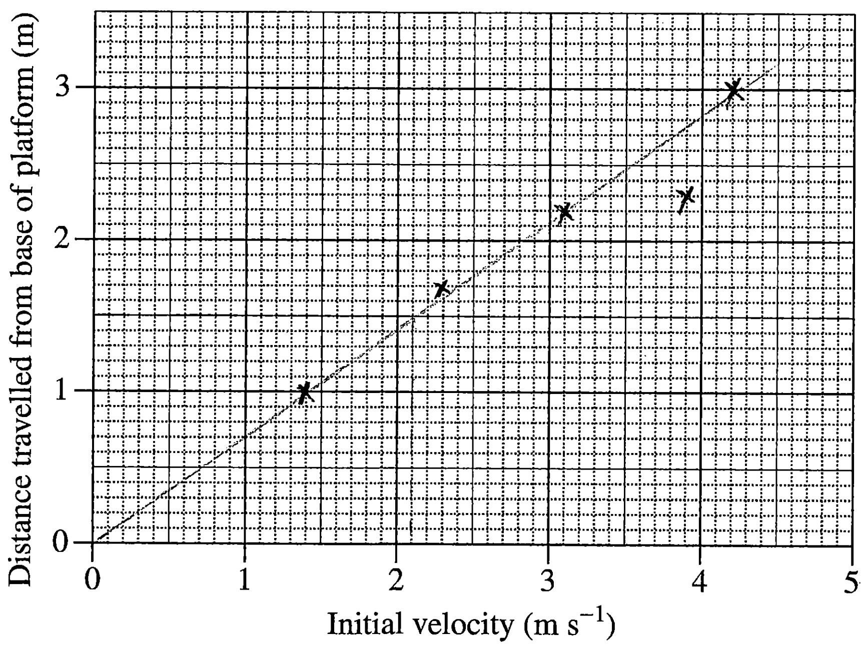
Initial velocity of projectile (m s^{-1})	*Distance travelled from base of platform* (m)
1.4	1.0
2.3	1.7
3.1	2.2
3.9	2.3
4.2	3.0

Question 21 continues on page 15

Question 21 (continued)

$s = \frac{d}{t}$ $t = \frac{d}{s}$

(a) Graph the data on the grid provided and draw the line of best fit. **2**



(b) Calculate the height of the platform. **2**

$U_y = V\sin\theta$

$U_y = 0$

as $t = \frac{d}{s}$

$\frac{3}{4.2} = 0.71$ sec $\therefore V_y = 0 + (-9.8)(0.71)$ $\therefore V_y = -6.958$ ms⁻¹

$V^2_y = u^2_y + 2a_y\Delta y$

$(-6.958)^2 = 0 + 2(-9.8)\Delta y$

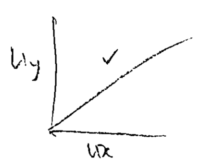
$\Delta y = 2.47$ m

$= 2.5$ m

End of Question 21

$\Delta y = u_y t + \frac{1}{2} a_y t^2$

$v^2_y = u^2_y + 2a_y \Delta y$



$u_x = v\cos\theta$

$u_y = v\sin\theta$

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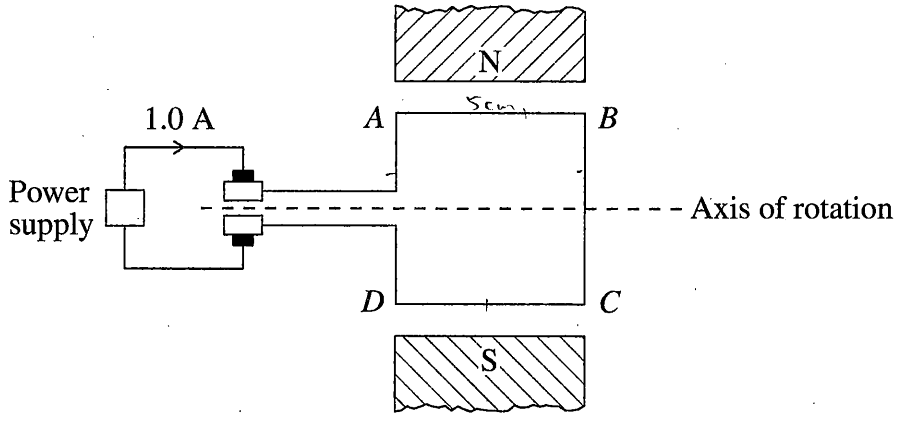
Question 22 (5 marks)

The diagram represents a simple DC motor. A current of 1.0 A flows through a square loop *ABCD* with 5 cm sides in a magnetic field of 0.01 T.



(a) Determine the force acting on section *AB* and the force acting on section *BC* due to the magnetic field, when the loop is in the position shown. **3**

$F = BIl \sin\theta$

Section AB: | Section BC

$0.01 \times 1 \times 0.05 \times \sin(90)$ | $0.01 \times 0.05 \times 1 \times \sin(0)$

$= 0.5 \times 10^{-3}$ N | $= 0$ N

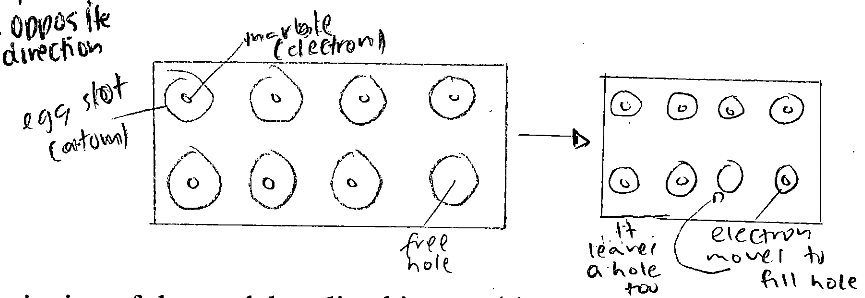
(b) How is the direction of the torque maintained as the loop rotates 360° from the position shown? **2**

Torque is maintained by the slip ring commutator that reverses direction of current every half cycle by changing contact of the brushes with each half commutator. This ensures torque is maintained.

Question 23 (5 marks)

(a) Outline a procedure that could be used to model electrical conduction in a semiconductor. **3**

An egg carton could be used, with a marble placed inside. The egg hole represents the atom. All egg holes can be filled, leaving only one empty. Moving a marble from a neighbouring atom, into the hole, fills the hole but leaves a hole where the marble left. Hence the next marble fills this hole, but it too leaves a hole. As this process continues, it can be seen to model p-type semiconductors and the electron-hole pair conduction, where movement of electrons in one direction constitute movement of holes in the opposite direction.

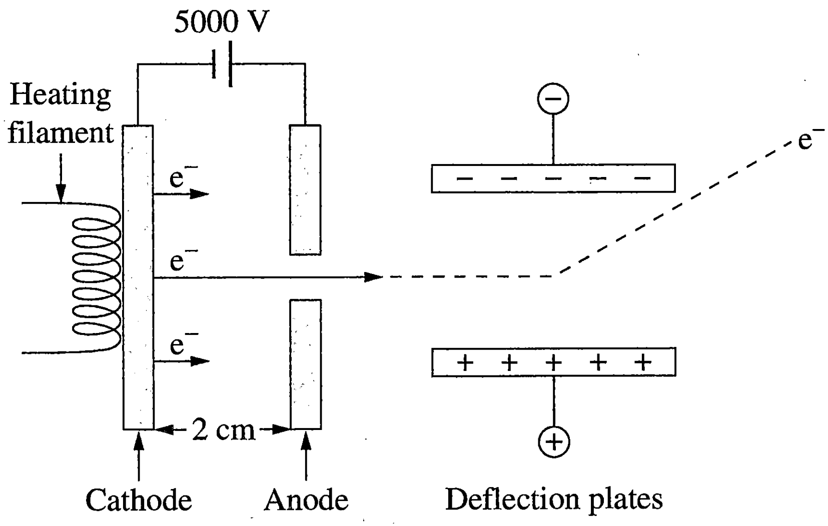


(b) Explain a limitation of the model outlined in part (a). **2**

One limitation of the model is that it does not take into account the relative sizes of atoms and electrons. Since the process is enlarged so it can be viewed, this eliminates certain properties, such as the negative potential of electrons, or the bonds that hold the atoms together - covalent bonds.

Question 24 (7 marks)

A part of a cathode ray oscilloscope was represented on a website as shown.



Electrons leave the cathode and are accelerated towards the anode.

(a) Explain why the representation of the path of the electron between the deflection plates is inaccurate. **3**

Firstly, electrons are not attracted towards the negative plate, as they are negative themselves. They should be attracted to the positive plate. Furthermore an electron does not take a sudden drop when deflected by electric fields, but rather they curve in a smooth direction once entering the field - in this case, downwards.

Question 24 continues on page 19

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Question 24 (continued)

(b) Calculate the force on an electron due to the electric field between the cathode and the anode. **2**

$E = \frac{F}{q}$ and $E = \frac{V}{d}$

$E = \frac{5000}{0.02}$

$= 250 \times 10^{3}\ Vm^{-1}$

$\therefore F = (250 \times 10^{3}) \times (1.602 \times 10^{-19})$

$= 4.005 \times 10^{-14}\ N$

(c) Calculate the velocity of an electron as it reaches the anode. **2**

$F = ma$

$4.005 \times 10^{-14} = (9.109 \times 10^{-31}) \times a$

$\therefore a = 4.40 \times 10^{16}\ ms^{-1}$ to the right

End of Question 24

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Question 25 (6 marks)

(a) Outline the conversion of electrical energy by devices in the home into TWO other forms of energy. **3**

1. A toaster
 - convert electrical energy into heat energy
 - used to heat and toast bread

~~[illegible] energy~~

2. A fan
 - convert electrical energy int mechanical energy
 - used to cool the area down.

(b) The diagram shows a label on a transformer used in an appliance. **3**

Input:	240 V AC	5.0 A
Output:	2 kV AC	1.0 A

Explain why the information provided on the label is not correct. Support your answer with calculations.

The transformer is a step up transformer where $\frac{V_p}{V_s} = \frac{I_s}{I_p}$. Since $\frac{V_p}{V_s} = \frac{240}{2000} = \frac{3}{25}$ ∴

$\frac{I_s}{I_p}$ should also equal $= \frac{3}{25}$ However in this case,

$\frac{I_s}{I_p} = \frac{1}{5}$. Hence, because they are not equal, the information can be deemed incorrect.

$\frac{V_p}{V_s} = \frac{n_p}{n_s} = \frac{I_s}{I_p}$

$\frac{240}{240 \times 10^3} = \frac{1}{5}$

Question 26 (6 marks)

Consider the following two models used to calculate the work done when a 300 kg satellite is taken from Earth's surface to an altitude of 200 km.

You may assume that the calculations are correct.

Model X	*Model Y*
Data: $g = 9.8\ \text{m s}^{-2}$ $m = 300$ kg $\Delta h = 200$ km $W = Fs$ $= mg\Delta h$ $= 3 \times 10^2 \times 9.8 \times 2.0 \times 10^5$ $= 5.9 \times 10^8$ J	Data: $G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ $r_{\text{Earth}} = 6.38 \times 10^6$ m $r_{\text{orbit}} = 6.58 \times 10^6$ m $M = 6.0 \times 10^{24}$ kg $m = 300$ kg $W = \Delta E_p$ $\Delta E_p = E_{p\ \text{final}} - E_{p\ \text{initial}}$ $= -\frac{GMm}{r_{\text{orbit}}} - \left(-\frac{GMm}{r_{\text{Earth}}}\right)$ $= -1.824 \times 10^{10} - (-1.881 \times 10^{10})$ $= 5.7 \times 10^8$ J

(a) What assumptions are made about Earth's gravitational field in models *X* and *Y* that lead to the different results shown? 2

In model X, the assumption ^taken is that Earth's gravitational field remains constant with altitude. This is not the case as $g = \frac{GM}{d^2}$, where the square of the distance is inversely proportional to the 'g' value. Hence, this is why there are different results.

(b) Why do models *X* and *Y* produce results that, although different, are close in value? 1

Since both models are finding the gravitational potential energy, they both utilise the same values except for 'g' which differs.

Question 26 continues on page 22

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Question 26 (continued)

(c) Calculate the orbital velocity of the satellite in a circular orbit at the altitude of 200 km. **3**

$v = \sqrt{\frac{GM}{r}}$

$= \sqrt{\frac{(6.67\times10^{-11})(6\times10^{24})}{6.58\times10^{6}}}$

$= 7798.8\ ms^{-1}$

$\frac{Gm_1m_2}{r^2} = \frac{mv^2}{r}$

$v^2 = \frac{Gm_2}{r}$

$v = \sqrt{\frac{Gm_2}{r}}$

End of Question 26

$\frac{Gm_1m_2}{r^2} = \frac{mv^2}{r} \quad v^2 = \frac{Gm_2}{r}$

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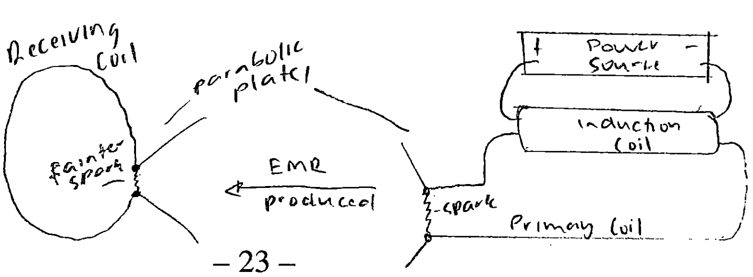
Question 27 (6 marks)

In 1865, James Clerk Maxwell developed the theory of electromagnetism. This theory explained the nature of light. It also predicted the existence of other electromagnetic waves. **6**

How did Hertz test and validate Maxwell's theory?

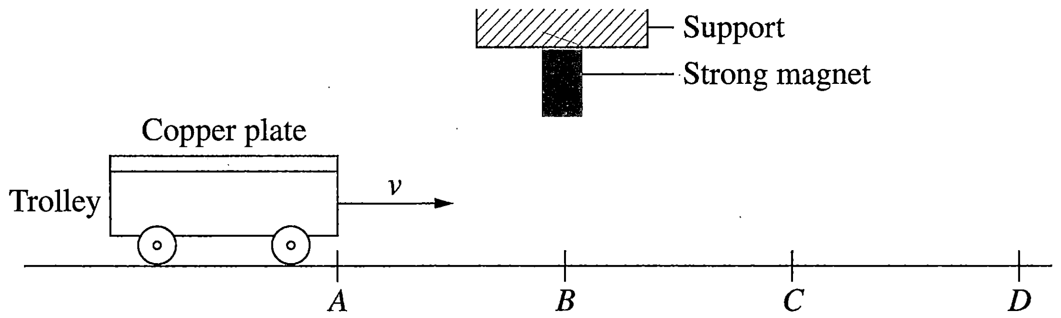
Hertz aimed to test Maxwell's theory of EMR that were self-propagating and that there was an entire ~~re~~ range of EMR. He tested his theory through his experiment to produce an EMR other than visible light. His experiment can be broken into 3 main steps:

1. Production of EMR: A voltage was fed into the primary coil via the induction coil, one of a high enough voltage that oscillated and accelerated. This oscillation of charges produced an EMR (in this case, radio waves), that flowed in the loop.
2. Transmission of EMR: Hertz used parabolic plates to focus the EMR and allow it to travel to the receiving coil, where again it was focused. He also noticed a spark in primary coil.
3. Reception of EMR: The EMR in the receiving coil oscillated again, regaining the electric charge present in primary coil, though much weaker. He also noticed a spark on ~~[illegible]~~ receiving coil, though it was much fainter. Hertz found the frequency of the EMR by measuring frequency of ~~osc~~ oscillations and found wavelength by measuring interference pattern produced when the newly formed wave was allowed to take 2 seperate pathways and be combined. He found that the EMR had the speed of light, and could be polarised, deflected, reflected, diffracted etc. Thus Hertz tested and validated Maxwell's theory.



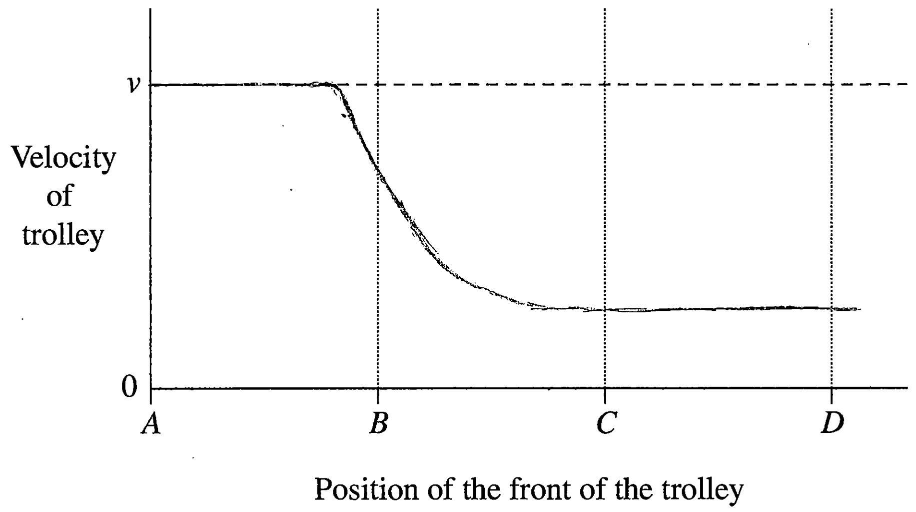
Question 28 (5 marks)

A copper plate is attached to a lightweight trolley. The trolley moves at an initial velocity, v, towards a strong magnet fixed to a support. **5**



The dashed line on the graph shows the velocity of the trolley when the magnet is not present.

On the axes, sketch the graph of the velocity of the trolley as it travels from A to D under the magnet, and justify your graph.



When the trolley reaches towards the magnet, its magnetic field will interact with the copper plate, thus reducing the velocity. The copper plate, being a solid conductor, will, according to Lenz's Law, develop eddy currents. These eddy currents slow the velocity of the trolley, as the copper plate cuts the magnetic flux of the magnet, one according to Faraday induces EMF.

Question 29 (5 marks)

In the Large Hadron Collider (LHC), protons travel in a circular path at a speed greater than 0.9999 c.

(a) What are the advantages of using superconductors to produce the magnetic fields used to guide protons around the LHC? **2**

Since superconductors have zero resistance, they can be used to produce very strong, powerful and efficient magnetic fields, with no energy loss, as they have no resistance, and have perfect flow of current.

(b) Discuss the application of special relativity to the protons in the LHC. **3**

Since special relativity has its effect on relativistic speeds, the protons in the LHC will be subject mass dilation, time dilation, and length contraction. As the proton increases in speed, its mass increases till eventually it reaches infinity, where acceleration is zero. Because of this, it cannot exceed speed of light. Also, the protons time will be dilated, running slower in its frame of reference, allowing it to live longer. It also would undergo length contraction, where the space in front of it would seem to contract, reducing the length of the 'circular path'.

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Question 30 (6 marks)

The following is a timeline for the Cassini space probe mission to Saturn. **6**

Earth	Venus	Venus	Earth	Jupiter	Saturn
Launch	Slingshot	Slingshot	Slingshot	Slingshot	Orbit
15/10/1997	26/4/1998	24/6/1999	18/8/1999	30/12/2000	1/7/2004

Explain how Newton's Laws of Motion and Universal Gravitation were applied to the Cassini mission.

The major application applied was the Slingshot Effect. This is where a space probe utilises a planet's gravitational field to help it increase in velocity, saving it on fuel. Newton's Law of Gravitation states that all objects have a gravitational field that exerts an attraction force. Hence a space probe can use this gravitational field to its advantage. Since the planet (Venus eg) orbits Sun, when space probe enters Venus's gravitational field, it would have the velocity of Venus orbiting the Sun added onto it. Hence the velocity of the probe increases relative to the Sun. Furthermore, because of Newton's Third Law states every force has equal and opposite force, this is applied when the extra velocity gained by probe must be lost as momentum by the planet, so as to not violate Newton's Laws. Hence by utilising Newton's Laws, it can be seen how the Cassini space probe utilised the slingshot effect of major planets to reach its orbit in Saturn, a process that reduced cost and fuel.