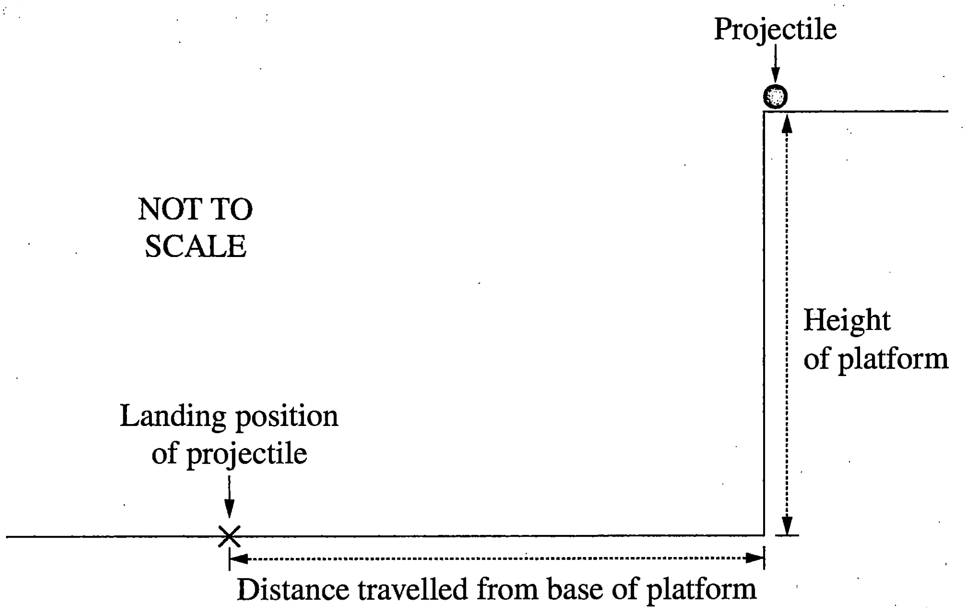
Question 21 (4 marks)

A projectile is fired horizontally from a platform.



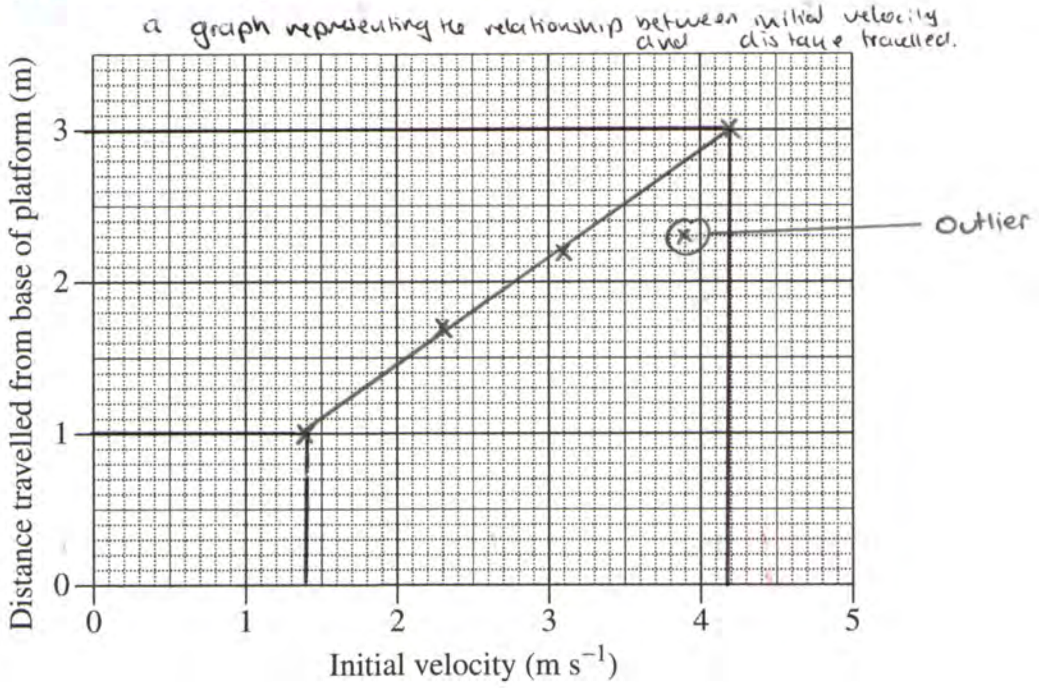
Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

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)

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



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

gradient = $\frac{\text{range}}{\text{initial } v}$ = $\frac{\Delta x}{u_x}$ = t

$\therefore t = \frac{3.0 - 1.0}{4.2 - 1.4}$

= 0.7142857143 seconds

∴ ~~$\Delta y = u_y^2 + 2 a_y t$~~

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

$= (0).(0.71...) + \frac{1}{2}(-9.8)(0.714...)^2$

= −2.5

∴ height of platform is 2.5 m (2 s.f)

End of Question 21

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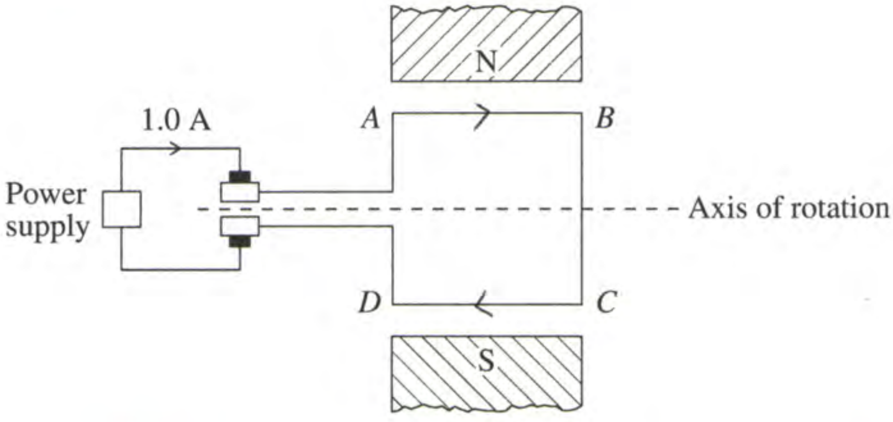
Question 22 (5 marks)

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**

Force on AB: $F = BIl\sin\theta$

$= (0.01) \times (0.05) \times (1) \times \sin 90$

$= 0.0005$

$\therefore$ Force on AB is 5.0×10^{-4} N (2s.f.) into the page.

Force on BC = $F = BIl\sin\theta$

$= (0.01) \times (0.05) \times (1) \times \sin(0)$

$= 0$

$\therefore$ no force on BC

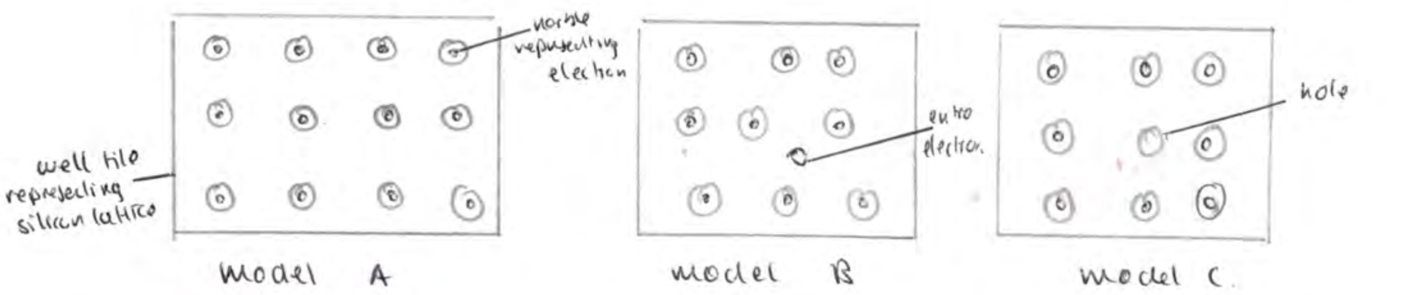
(b) How is the direction of the torque maintained as the loop rotates 360° from the position shown? **2**

As the diagram represents a simple DC motor, a split ring commutator is utilised. Hence, as the loop rotates ~~to~~ 180° (half turn), there ~~comm~~ is no contact with the motor and external circuit, hence inertia causes the motor to continue rotating. The split ring commutator alternates the polarity of current every half turn such that a unidirectional torque is ensured.

Question 23 (5 marks)

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

Electrical conduction in a semiconductor may be modelled via the use of an ~~atomic model kit~~ wells tiles. Construct ~~two~~ 3 separate lattices, as depicted through wells shown below using a ~~Silicon atom~~ tile representing silicon tile. For model A, no changes are imposed and all marbles are placed in all holes. However, for model B, an extra marble is ~~splatted~~ placed (representing the addition of group V element). Hence there are mobile charge carriers present (extra marbles/electron) and it can conduct. For Model C, a marble is taken out (representing the addition of a group III element). Hence, mobile charge carriers are introduced (lack of marble/hole) and it may conduct.



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

Despite its advantages, the above model does have associated limitations. As the generated model ~~simplif~~ represents the process of conduction in semiconductors on a wells tile, it may oversimplify the complex process. Furthermore, as it presents information on a macroscopic level, it may prevent an individual in exploring the microscopic properties of conduction in semi-conductors

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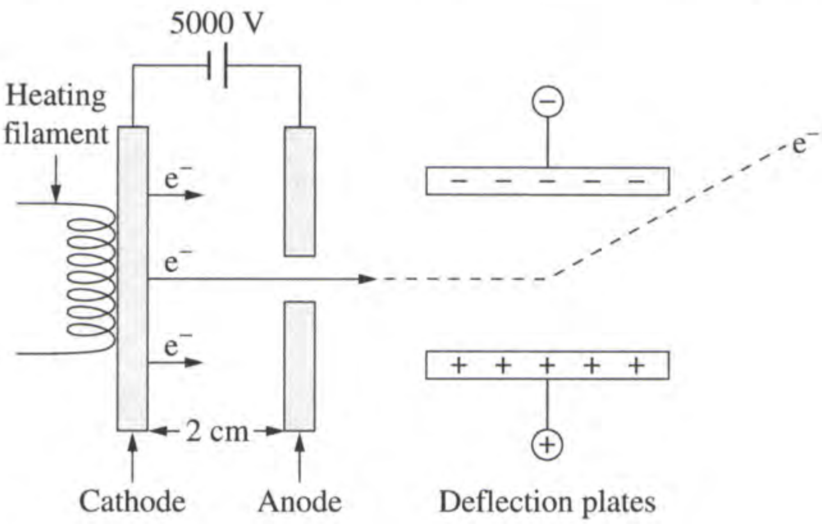
Question 24 (7 marks)

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**

The represented path of the electron as it travels through the deflection plates is false as an electron is a negatively charged particle, thus, by electrostatic repulsion it would not be attracted to the negatively charged plate (as depicted above), rather, it would accelerate towards the positive deflection plate (via electrostatic attraction). Further, the presented path depicts a sharper change in direction whereas it would usually appear as a curved trajectory.

Question 24 continues on page 19

Question 24 (continued)

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

$F = qE$

for $E = \frac{V}{d}$

$= \frac{5000}{(0.02)}$

$\therefore F = (1.602 \times 10^{-19}) \times \frac{5000}{0.02}$

$= 4.005000 \times 10^{-14}$

$\therefore$ Force on electron is 4.0×10^{-14} N (towards the anode)

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

$F = ma \qquad F = qE$

$a = \frac{qE}{m}$

$= \frac{(1.602 \times 10^{-19}) \times \left(\frac{5000}{0.02}\right)}{(9.109 \times 10^{-31})}$

$\therefore a =$

$d = 0.02$ m

$V = 5000$ V

$q = 1.602 \times 10^{-19}$

$m = 9.109 \times 10^{-31}$

$E_k = \frac{1}{2}mv^2$

End of Question 24

Volts = $\frac{\text{coulomb}}{\text{second}}$

$\therefore$ F = $q\frac{V}{d}$

= $q \times \frac{5000}{2}$

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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**

In a hairdryer, electrical energy is utilised to spin the motor in the hairdryer. Thus, electrical energy is converted to kinetic energy and sound energy. This kinetic energy ~~is the~~ of air particles is passed over a heating filament thus kinetic energy is also converted to heat energy.

(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 above label is not correct as by the conservation of power $P_{input} = P_{output}$

$V_p \cdot I_p = V_s \cdot I_s$

hence $\frac{V_p}{V_s} = \frac{I_s}{I_p}$

but: $\frac{240}{2000} \neq \frac{1}{5}$, as by the voltages the ratio should be ~~$\frac{1}{5}$~~ 3 : 25 for current. Thus, it indicates an creation of energy which defies the law of conservation.

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

(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 assumptions made that the gravitational field of the Earth (g) is constant (at 9.8ms⁻²) for all altitudes. However in Model Y, it accounts for the change in the Earth's gravitational field through the use of the Universal gravitational constant (G).

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

Despite produce slightly different results, the values for the work done on a satellite are quite similar as the value for g will not ~~alter~~ vary too much at such a relatively low altitude (~200km).

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**

to derive orbital velocity: $F_c = F_G$

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

$V_{orb} = \sqrt{\frac{GM}{r}}$

$= \sqrt{\frac{(6.67 \times 10^{-11}) \times (6.0 \times 10^{24})}{6.58 \times 10^6}}$

$= 7.79876072 \times 10^3$

∴ orbital velocity of satellite is 7.8×10^3 ms^{-1} (2 s.f.) tangential to it's orbit

End of Question 26

Maxwell's theory's did do

- he measured the speed calculated 3×10^8 → matched Maxwell validate

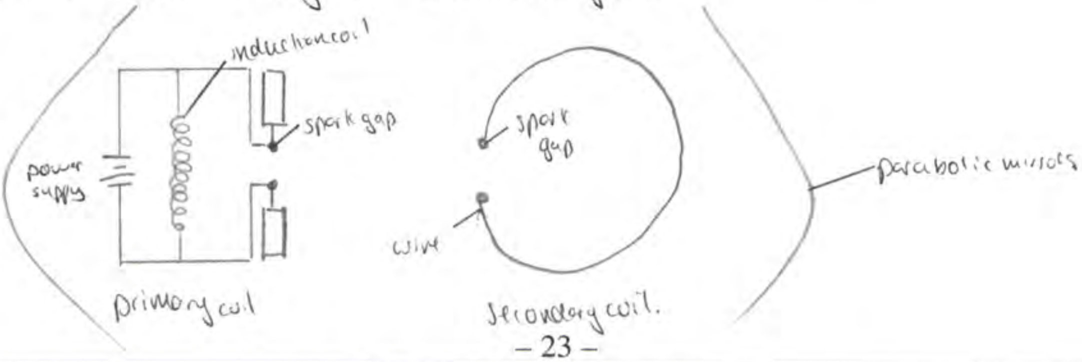
Small amount of polarisation

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?

In the late 19th century, James Clerk Maxwell developed the theory that EMR existed and they were waves propagate from self generated and self-sustaining mutual oscillations of magnetic and electric fields. To investigate this, Hertz set up the apparatus as shown below. He developed a voltage which was amplified through the induction coil to generate a spark in between the spark gap (due to the high charge build up). This spark, as it would produce light, had also emitted other ~~by~~ forms of electromagnetic radiation (i.e. radio waves). Almost instantaneously, Hertz observed that a second spark would be induced at the secondary coil, which must have been subsequent to radio wave emission. He further explored the nature of these radio waves according to Maxwell's theories by demonstrating that it ~~also~~ displayed properties like light (e.g. reflection & polarisation). To measure the speed of these radio waves, Hertz would set up an interference pattern: he would move the receiver coil back and forth until a maximum intensity was reached. He would continue to move it until another peak was detected. Thus, as he could physically measure the wavelength, and he controlled the frequency of oscillation, hence by $v = f\lambda$, he proved that the waves travelled at 3×10^8 ms^{-1} (i.e. speed of light) and thus validated Maxwell's equations, and theory of electromagnetism.



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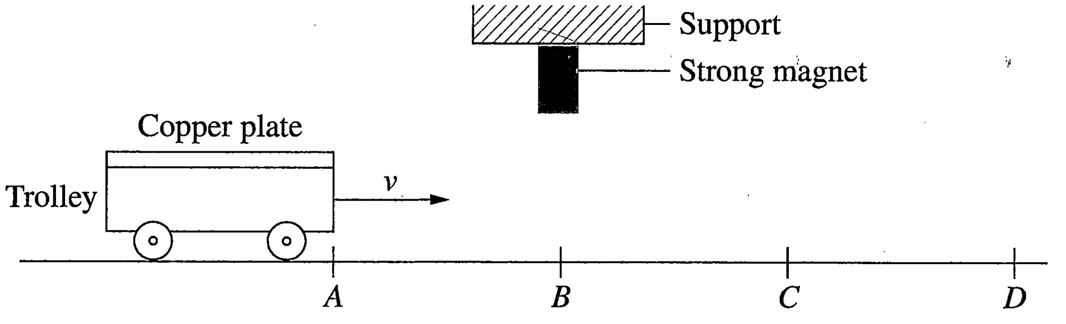
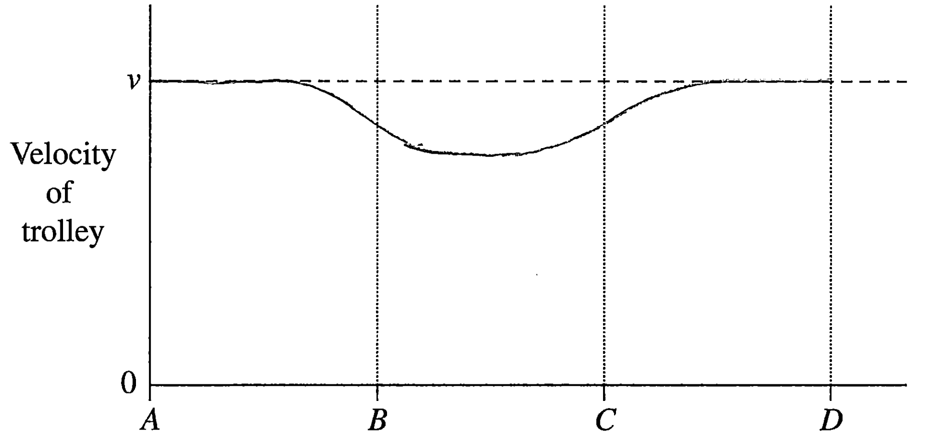
Question 28 (5 marks)

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.



Initially, at A, there is no interaction with the strong magnet and ~~electric~~ ~~the~~ copper plate. However, as it approaches the magnets (at B), it will be experiencing a change in flux, thus an emf will be induced (Faraday's Law). This emf would generate eddy currents on the copper plate to oppose this change in flux (Lenz's Law). Thus it will slow down, however, as it leaves the magnetic field of magnet (at C), it is experiencing another change in flux, thus by Faraday's law, an emf will be induced, these eddy currents will flow to oppose the change in flux (by Lenz's law), ~~but~~ (i.e. attracting it to magnet), thus a lower velocity is present. At D, there is no interaction between magnetic field and copper plate, so no change in velocity

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**

Below their critical temperature (T_c), superconductors will experience superconducting properties (experience zero resistance). Hence, it can carry large currents with no energy loss [$P_{loss} = I^2R$]. Thus, due to this large current, there can be a large associated magnetic field to guide the protons around the LHC.

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

The Large Hadron Collider (LHC) accelerates light particles (protons) to extreme speeds (> 0.9999c), here, the protons will experience the consequences of special relativity. By length contraction [$L_v = L_0\sqrt{1-v^2/c^2}$], the protons will not have to travel that far a distance, compared to a stationary observer. Thus, less energy will be required to accelerate these protons to ~~the~~ its target. Furthermore, by time dilation, as the protons experience proper time ~~to an observer, the~~ process of collision will occur much faster [$t_v = \frac{t_0}{\sqrt{1-v^2/c^2}}$]. Hence a more efficient process results.

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

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

To assist the Cassini mission from Earth to Saturn, Newtons Laws of Motion and Universal gravitation were used. Newton's First Law of Motion states that an object travelling in uniform circular motion will continue to travel tangentially to orbit unless acted upon by some force. This force can be justified through Newtons Laws of Universal gravitation $[F = \frac{GMm}{r^2}]$, as it demonstrates that it is the gravitational pull of the central body which allows a constant orbit to be maintained. Hence, these principions could be utilised in the Cassini space probe mission to commute from Earth to Saturn via a gravitational assist (or slingshot effect). In the slingshot effect, the space craft will be attracted to a central body (e.g. Jupiter) via its gravitational pull. [Newtons law of motion and universal gravitation]. It will have an elastic collision with planet and thus energy and momentum are transfered. This loss of energy by the planet can be negligible due to its sheer size but the gain in energy by the spacecraft provides a significant velocity boost. As seen above, the Cassini spaceprobe mission used 4 gravitational assists in its mission to mars to increse the velocity without the consumption of fuel.