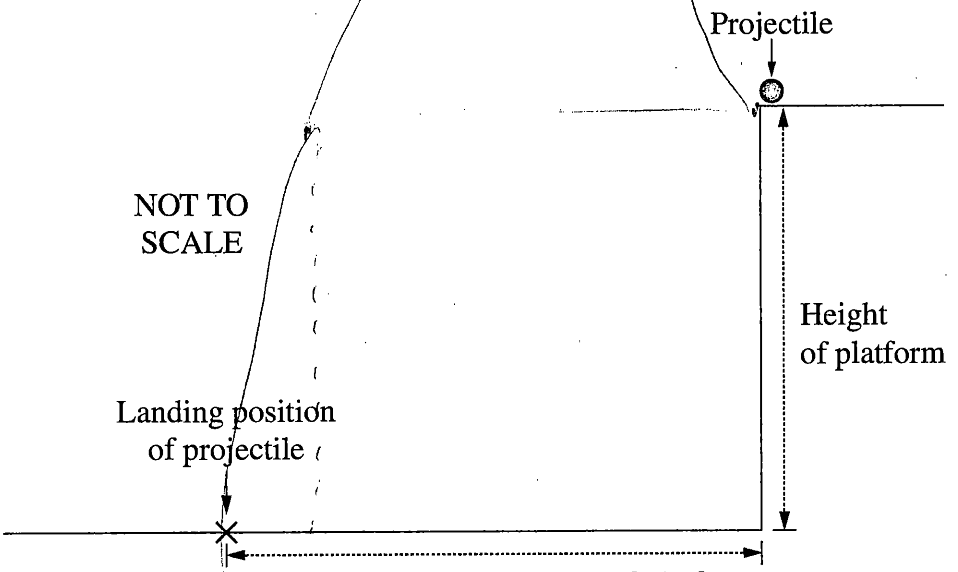
Question 21 (4 marks)

A projectile is fired horizontally from a platform.



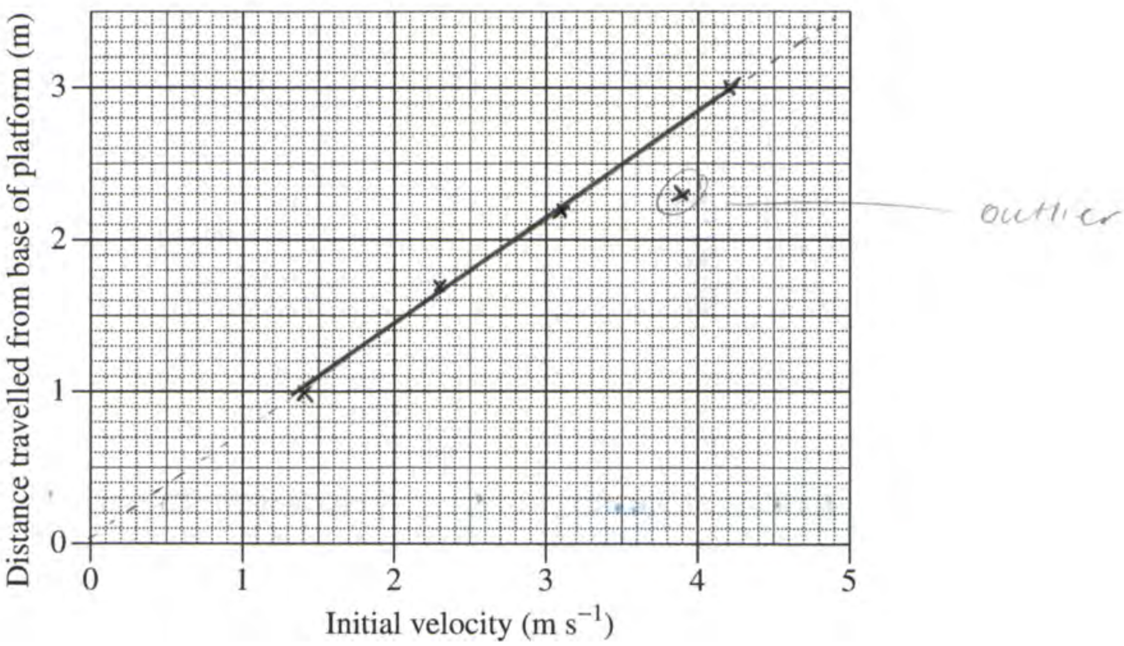
Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

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. Δy **2**

$u = 4.2$ m/s $\qquad v = u + at \qquad v_y^2 = u_y^2 + 2a_y \Delta y$

$\Delta x = 3.0$ m $\qquad$ at apogee, $v = 0$ $\qquad$ at apogee $v = 0$

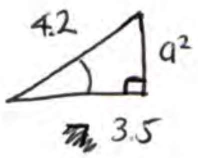
$\Delta x = u_x t \qquad 0 = 4.2 + 9.8t \qquad 0^2 = 2.32^2 + 2.9.8\,\Delta y$

$3 = u_x \times 0.857 \qquad \therefore t = 0.428571$ s $\qquad \therefore \Delta y = \frac{2.32^2}{2 \times 9.8}$

$\therefore u_x = 3.5 \qquad \approx 0.43 s \times 2$

$= 0.857$ s $\qquad = 0.275$ m

End of Question 21



$\cos\theta = \frac{3.5}{4.2}$ $\qquad c^2 = a^2 + b^2$

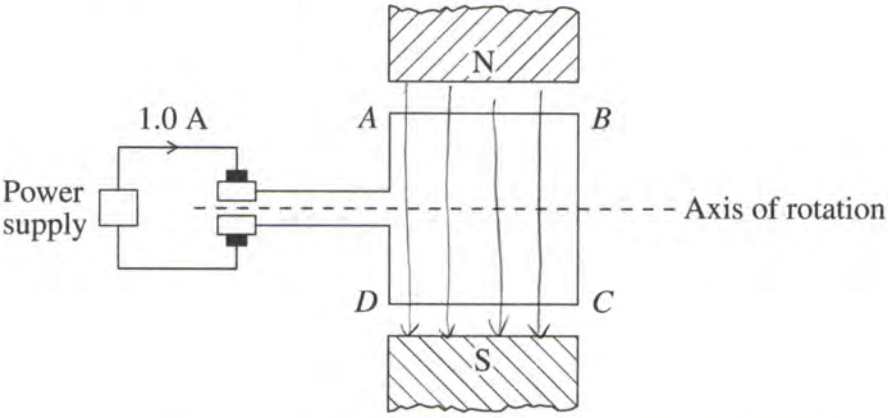
$4.2^2 = a^2 + 3.5^2$

$\therefore \theta =$ $\qquad u_y = \sqrt{4.2^2 - 3.5^2}$

$= 2.32$

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**

$F = BlI\sin\theta$

$= 0.01 \times 1 \times 0.05 \times \sin 90°$

$= 0.0005$ N

Force on AB = 0.0005N downwards

Force on BC = 0N (parallel to magnetic field, ∴ ~~sin~~ θ = 0, ∴ sin θ = 0, hence F = 0)

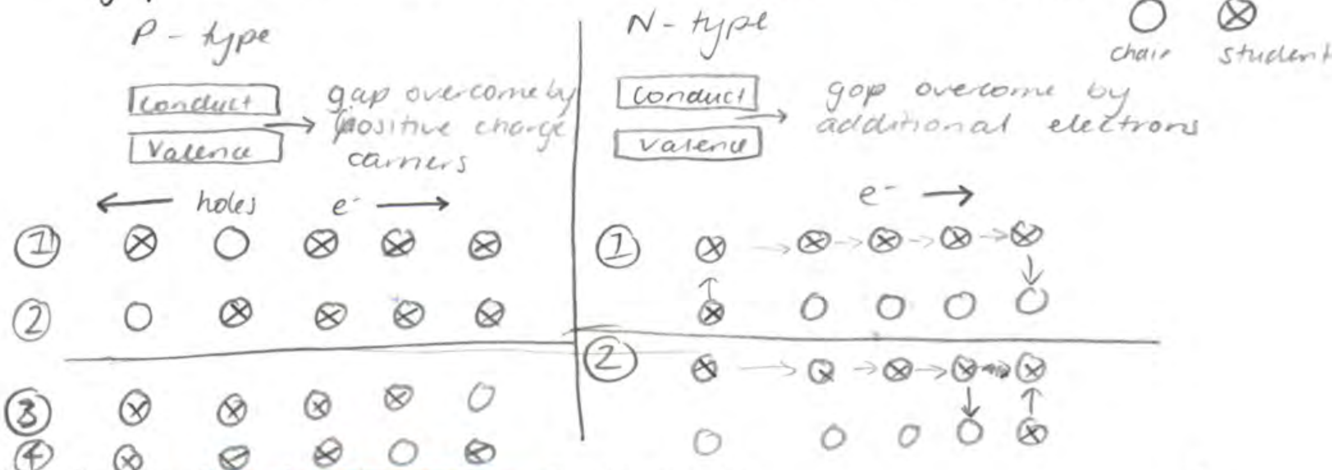
(b) How is the direction of the torque maintained as the loop rotates 360° from the position shown? **2**

Split ring commutators "reverse" the current every 180°, so the torque is maintained in the same direction (otherwise, they square ~~magnet~~ loop ~~not~~ would stop turning). Radial magnets may be used to maintain an even force and thus ~~an~~ maintain torque.

Question 23 (5 marks)

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

Using students to represent electrons and chairs to represent positive 'holes', both p-type (positive holes - doped with boron) and n-type (extra electrons - doped with phosphorous) may be modelled. Semiconductor has a very small gap between valence and conduction bands.

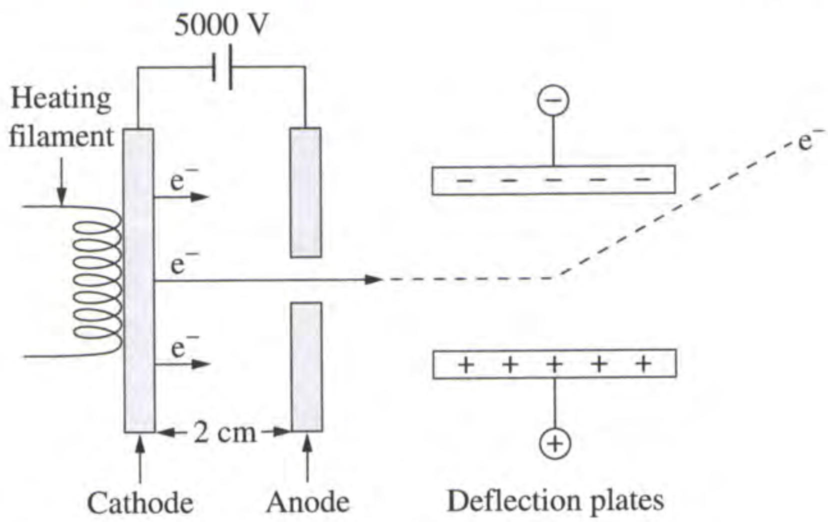


(b) Explain a limitation of the model outlined in part (a). **2**

The model does not show the relative "speed" of conduction, nor the differing conductivity as heat increases. N-type semiconductors are much 'faster' than P-type, as the additional electrons can move more quickly than the positive 'holes' (or charge carriers.)

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**

Deflection plates are used to alter the path of the electron beam. As electrons are negative, they should be attracted to the positive plate (not to the negative plate, as shown in the diagram). Thus, the diagram is inaccurate.

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**

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

$= \frac{5000}{0.02}$

$= 250000$

$E = \frac{F}{q}$

$250\,000 = \frac{F}{-1.602\times10^{-19}}$

$\therefore F = 4.005\times10^{-14}\ N$ towards anode.

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

$W = Fs$

$= 4.005\times10^{-14}\times 0.02$

$= 8.01\times10^{-16}$

$\therefore E_k = 8.01\times10^{-16}$ required

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

$8.01\times10^{-16} = \frac{1}{2}\times 9.109\times10^{-31}\ v^2$

$\therefore v^2 = 1.7587\times10^{15}$

$\therefore v = 4.1937\times10^{7}\ ms^{-1}$

$= 4.2\times10^{7}\ ms^{-1}$

End of Question 24

Question 25 (6 marks)

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

Electrical energy to heat: through the use of a filament, heat is produced through the high resistance (e.g in a kettle)

Electrical energy to kinetic energy: ~~pow~~ by powering a motor (eigther the electromagnets or current in coils) ~~cr~~ to drive motion (e.g. in a fan)

(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.

$P_1 = V_1 I_1$ $\qquad$ $P_2 = V_2 I_2$

$= 240 \times 5$ $\qquad$ $= 2\,000 \times 1$

$= 1200$ W $\qquad$ $= 2\,000$ W

∴ The information is incorrect, as Power must remain the same in a transformer. Additional power cannot be produced in a transformer. If V was to increase to 2kV, then I should decrease to 0.6A, in order to remain with P=1200W.

$P = VI$

$1200 = 2000 \cdot I$

$\therefore I = 0.6$A

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: $g = 9.8\text{ m s}^{-2}$ $m = 300\text{ kg}$ $\Delta h = 200\text{ km}$ $W = Fs$ $= mg\Delta h$ $= 3\times10^2 \times 9.8 \times 2.0 \times 10^5$ $= 5.9 \times 10^8\text{ J}$	Data: $G = 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2}$ $r_{\text{Earth}} = 6.38 \times 10^6\text{ m}$ $r_{\text{orbit}} = 6.58 \times 10^6\text{ m}$ $M = 6.0 \times 10^{24}\text{ kg}$ $m = 300\text{ kg}$ $W = \Delta E_p$ $\Delta E_p = E_{p\text{ final}} - E_{p\text{ initial}}$ $= -\frac{GMm}{r_{\text{orbit}}} - \left(\frac{GMm}{r_{\text{Earth}}}\right)$ $= -1.824\times10^{10} - \left(-1.881\times10^{10}\right)$ $= 5.7\times10^8\text{ J}$

(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, it is assumed that $g = 9.8\text{ ms}^{-2}$ is constant in all areas, whereas in model Y, g is not used – instead it is calculated using ~~more exact values~~ ~~for the~~ $g = -\frac{Gm}{\Delta h \times r}$. ~~where the mass~~

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

They are using the same ~~data~~ main source of data (e.g. $F = mg$ ∴ $W = mgh$ $E_p = W$ ∴ $E_p = mgh = -\frac{Gm_1 m_2}{r}$ $gh = -\frac{Gm}{r}$ ∴ $g = \frac{-Gm}{\Delta h \times r}$

Question 26 continues on page 22

Question 26 (continued)

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

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

$3\times10^2 \times 9.8 = \frac{3\times10^2 \times v^2}{6.58\times10^6}$

$2940 = \frac{3\times10^2 v^2}{6.58\times10^6}$

$\therefore v^2 = \frac{2940 \times 6.58\times10^6}{3\times10^2}$

$= 6.4484\times10^7$

$\therefore v = 8.03\times10^3 \text{ m s}^{-1}$

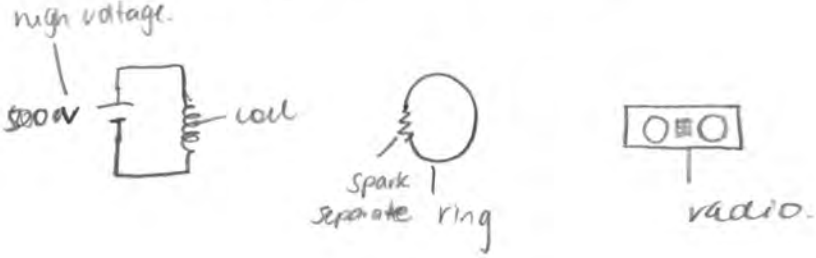
End of Question 26

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**

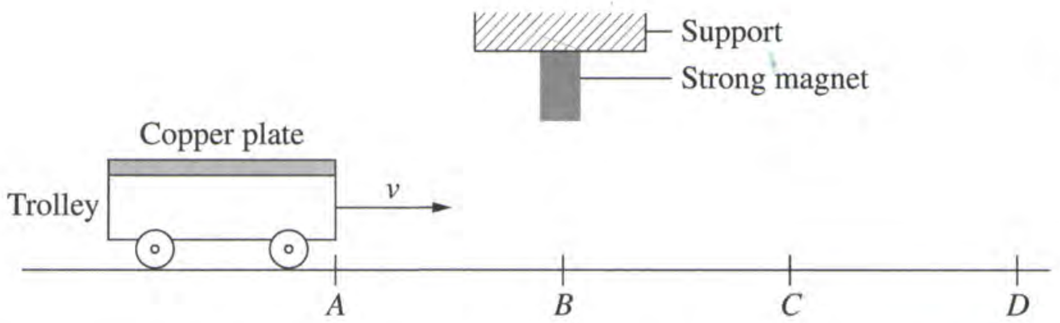
How did Hertz test and validate Maxwell's theory?

Hertz set up a circuit with an coil connected to a very high voltage power source. When connected, he observed a spark and current induced in a ~~disconnected~~ separate ring on the other side of the room. He hypothesised that radiowaves produced by the coil induced a current in the ring. He proved this by tuning a radio to a frequency with no station. When the circuit was on, the radio experienced 'buzzing' (interference), thus proving the presence of radio waves (another form of electro-magnetic waves). He also tested the effect of the presence of UV radiation (another form of EMR) and found that when the separate ring was under UV light, the spark was induced more quickly (known as the photoelectric effect), but he failed to investigate this further.



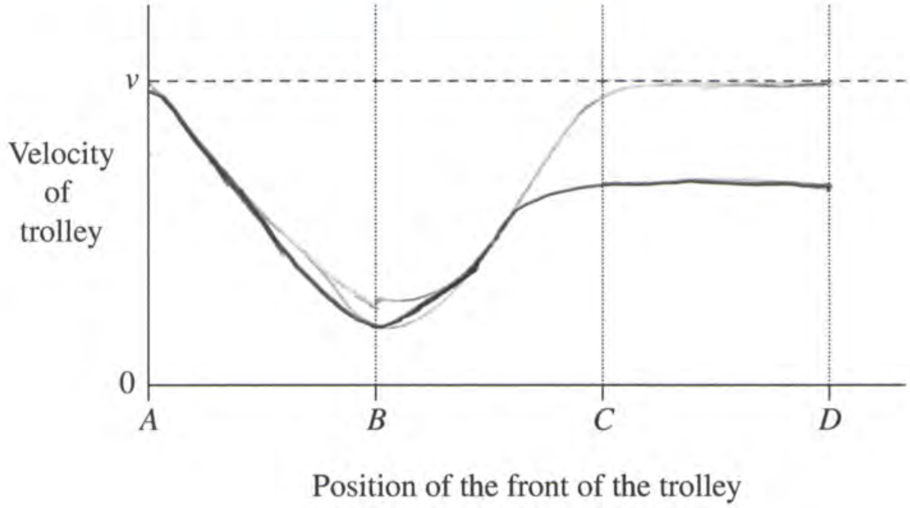
Question 28 (5 marks)

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.



As the trolley nears the magnet, eddy currents will be induced to oppose the magnetic field being experience by the copper. Thus it's velocity will decrease, being the least at B. [illegible] As the trolley moves away, eddy currents are reduced and the velocity increases again, but to a lower rate. (magnet acts as 'brakes').

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**

Superconductors can produce magnetic fields in all directions, thus they have greater accuracy and control in guiding protons around the LHC.

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

Special relativity states that at relativistic speeds (e.g. 0.9999c), objects in inertial frames of reference will undergo:

· Mass dilation: the protons will be much heavier than what they are measured to be at rest

· Time dilation: time will slow from the protons - they will be able to cover a greater distance in a ~~shorter~~ set. time

· Length contraction: the protons will ~~be~~ appear smaller and thus denser and ~~more abl~~ able to cover a set distance in a shorter time.

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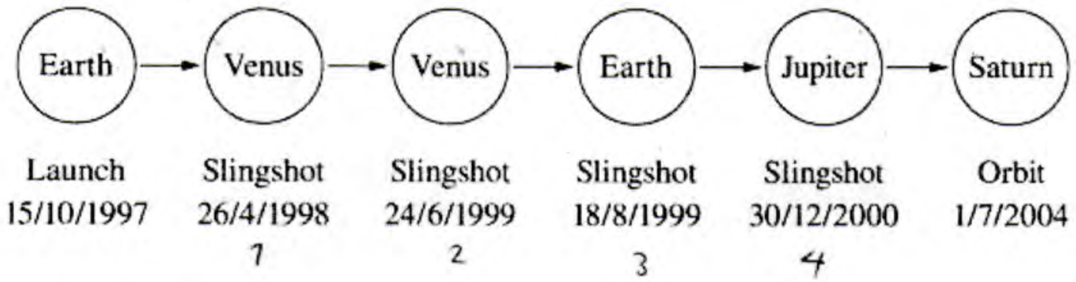
Question 30 (6 marks)

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



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

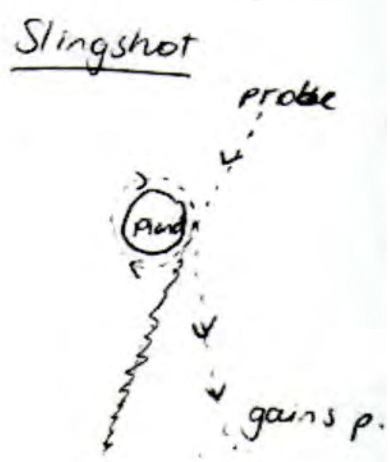
The Cassini mission used four slingshots to increase it's ~~acceleration~~ velocity and save fuel, allowing it to reach Saturn sooner. According the Newton's Laws of Motion and Universal Gravitation, momentum must be conserved. When the probe neared a planet (e.g. Venus), it experienced gravitational pull, causing it to accelerate towards the planet, as the planet accelerated towards the probe. This gave the probe momentum, as the planet lost some. (elastic interaction). While the loss of p is negligible to the planet, it is significant for the probe, gaining momentum and hence increasing velocity. This theory was applied to the Cassini mission to save fuel and reduce fight time (money).

Newtons laws of motion

① momentum conserved

② "inertia" - no change unless ΔF.

③ equal & opposite reaction



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