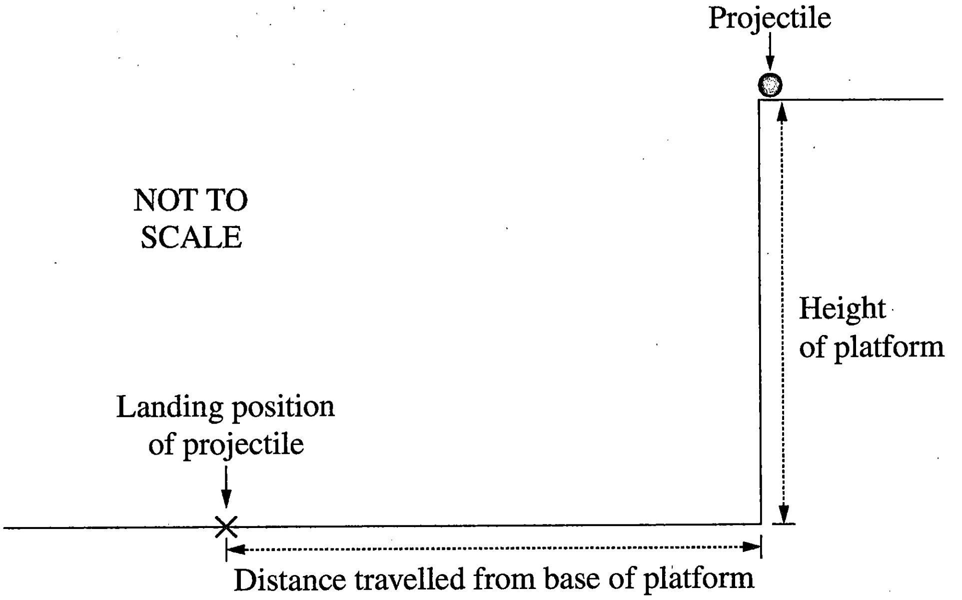
Question 21 (4 marks)

A projectile is fired horizontally from a platform.



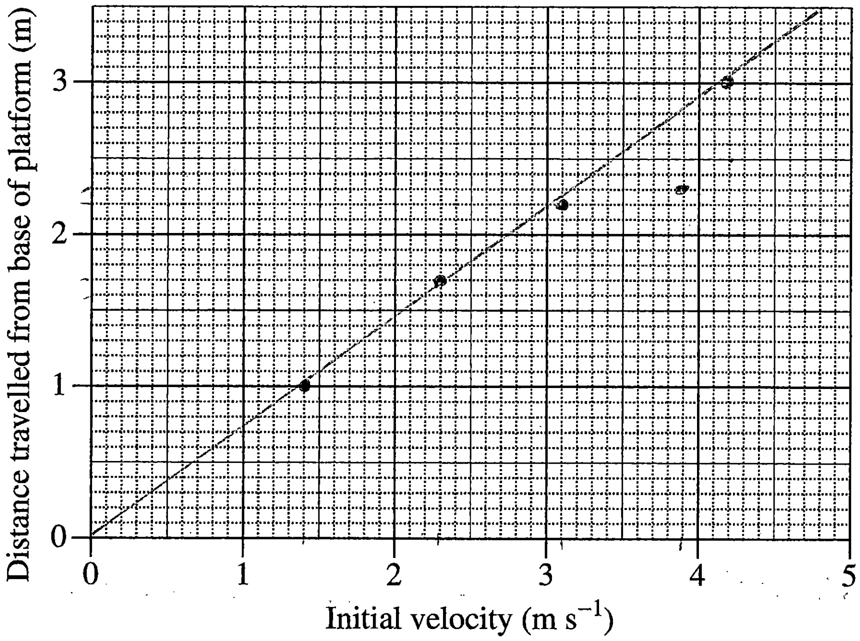
Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

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**

$t = \frac{\Delta x}{V_x} = \frac{\text{rise}}{\text{run}}$ (using point: (4.2, 3))

$t = \frac{3}{4.2} = \frac{5}{7}$

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

$u_y = 0$

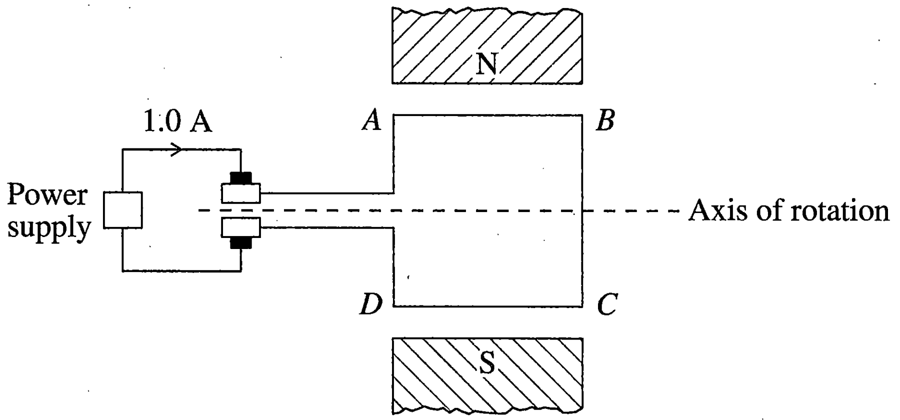
$t = \frac{5}{7}$

$\Delta y = 4.9 \times \left(\frac{5}{7}\right)^2 = 2.5\text{ m}$

End of Question 21

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**

AB: $F = BIl\sin\theta$
$B = .01$
$I = 1$
$l = .05$
$\theta = 90$
$\therefore F = .01 \times 1 \times .05$
$= 5 \times 10^{-4}$ N

BC: current in direction of magnetic field lines.
= 0 N

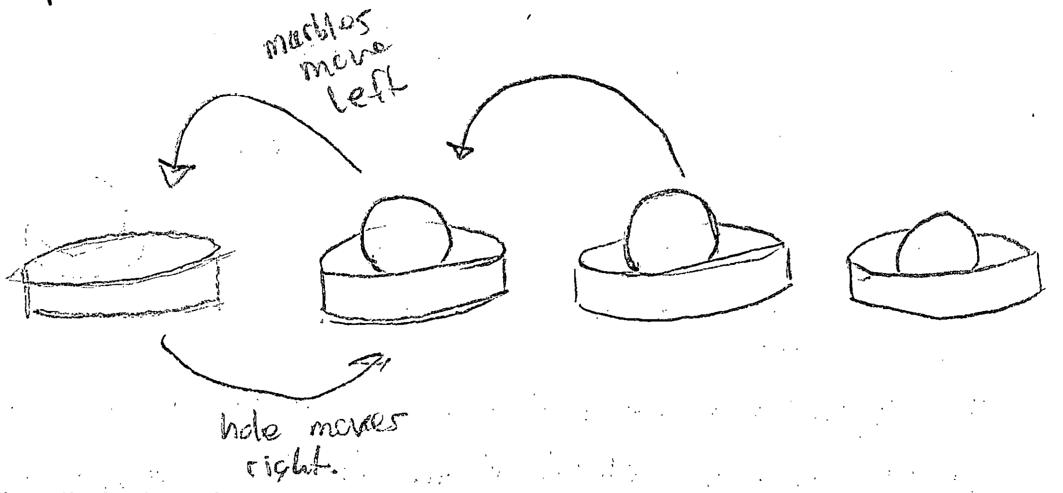
(b) How is the direction of the torque maintained as the loop rotates 360° from the position shown? **2**

As the motor rotates 90°, the magnetic field will tend to force AB and DC in the same direction, meaning the motor will move in reverse. To counteract this, a split-ring commutator reverses the direction of the current every half-cycle, maintaining torque in a constant direction.

Question 23 (5 marks)

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

A series of bottle tops are lined up, with marbles placed in all but one. A marble is moved to fill the hole, leaving an empty bottle top. The next marble fills this hole, and so on. The moving marbles represent electrons. The moving hole represents a positive hole in the superconductor lattice.

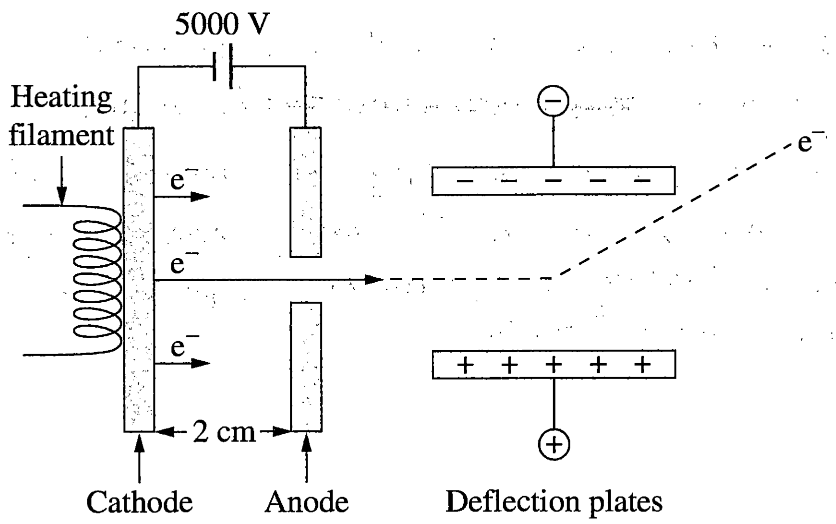


(b) Explain a limitation of the model outlined in part (a). **2**

The model above is very simplistic, and can not truly describe the electrical conduction in a semiconductor. In reality, there are millions of holes and electrons travelling very fast, and this model cannot depict the true scale of the electrical current. Also this model has no way of distinguishing between the valence and conduction bands of the semiconductor.

Question 24 (7 marks)

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

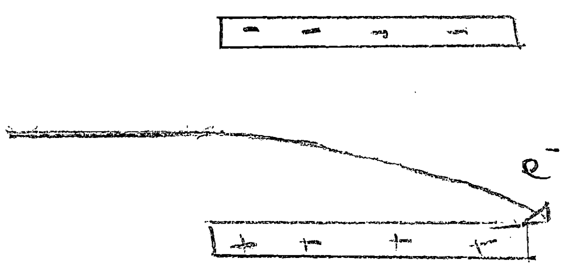


Electrons leave the cathode and are accelerated towards the anode.

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

The diagram shows the electron being deflected on a linear pathway, from the midpoint of the field. In reality, the electron would experience a constant force from the moment it entered the field until the moment it left. This constant force would produce a parabolic pathway, as shown. Furthermore, the electron is accelerated in the wrong direction. As a negative charge, it would be repelled from the negative plate and attracted to positive plate.

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**

$F = qE$

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

$\therefore F = \frac{qV}{d}$

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

$d = .02\,m$

$V = 5000$

$F = \frac{1.602 \times 10^{-19} \times 5000}{.002}$

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

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

$F = ma$

$F = 4.005 \times 10^{-19}$ (part b)

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

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

$= \frac{4.005 \times 10^{-14}}{9.109 \times 10^{-31}}$

$a = 4.3967 \times 10^{16}$

$E = qV$

$= 5000 \times 1.602 \times 10^{-19}$ Ev

$E = \frac{1}{2}mv^2$ $\therefore V = \sqrt{\frac{2E}{m}}$

$= \sqrt{\frac{2 \times 5000 \times 1.602 \times 10^{-19}}{9.109 \times 10^{-31}}}$

$= 41.9 \times 10^{6}$ m/s

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**

Devices like cooktops and heaters use electro-magnetic induction to convert electrical energy into thermal energy, producing heat. Devices like fans and blenders use the motor effect to convert electrical energy into kinetic energy, ie spinning motion.

(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.

Since the input is 240V and output is 2000V, it appears that this is a step-up transformer, with a coil turn ratio of 240:2000. If the voltage is stepped up, then the current must be stepped down accordingly. However, this is not the case. The power in the primary coil is 240×5 = 1200 W. The power in the secondary coil is 2000×1 = 2000W. This means that the output has more power than the input. This is impossible. Either the output has less current than depicted or less voltage.

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: $G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ $r_{\text{Earth}} = 6.38 \times 10^6\ \text{m}$ $r_{\text{orbit}} = 6.58 \times 10^6\ \text{m}$ $M = 6.0 \times 10^{24}\ \text{kg}$ $m = 300\ \text{kg}$ $W = \Delta E_p$ $\Delta E_p = E_{p\ \text{final}} - E_{p\ \text{initial}}$ $= -\frac{GMm}{r_{\text{orbit}}} - \left(-\frac{GMm}{r_{\text{Earth}}}\right)$ $= -1.824 \times 10^{10} - (-1.881 \times 10^{10})$ $= 5.7 \times 10^8\ \text{J}$

(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, it is assumed that gravity remains constant even at an altitude of 200km. In reality, it varies according to $\frac{GMm}{r^2}$. Model Y uses this more complex formula to produce a more accurate result.

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

Applying $a = \frac{Gm}{d^2}$ with $d_1 = 6.38 \times 10^6$ and $d_2 = 6.38 \times 10^6 + 200 \times 10^3$. Results: $g_1 = 9.83$, $g_2 = 9.24$

∴ The difference in gravity is very minimal, only $0.6\ \text{m/s}^2$ less in orbit.

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**

$V = \sqrt{\frac{Gm}{r}}$

$G = 6.67 \times 10^{-11}$

$m = 6 \times 10^{24}$

$r = 6.58 \times 10^{6}$

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

$v = 7798.76$ m/s

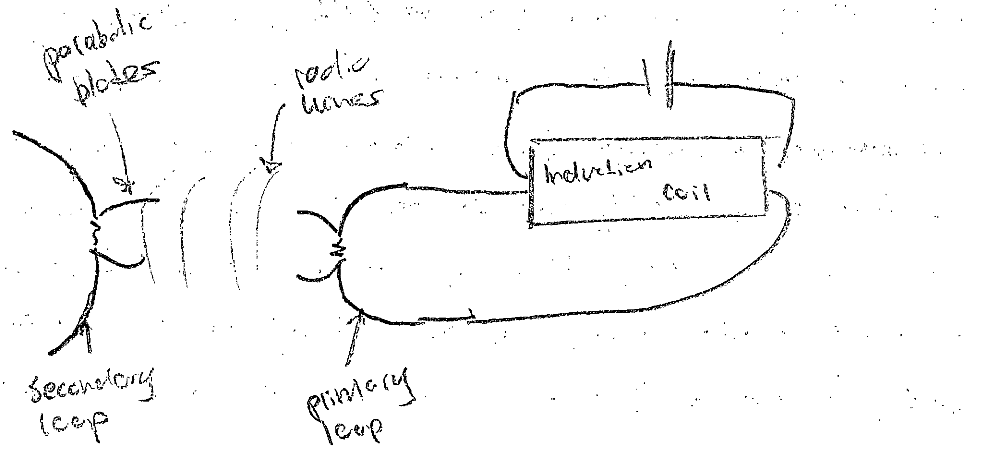
End of Question 26

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**

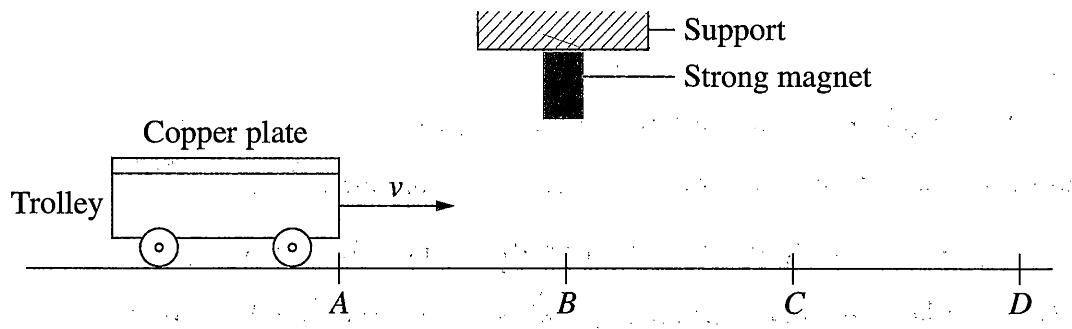
How did Hertz test and validate Maxwell's theory?

Heinrich Hertz conducted an experiment in which he observed the production of radio waves. He used an induction coil to produce a high-voltage spark in a primary loop. This created radio waves according to the frequency of the spark. These waves were focused by parabolic plates towards the secondary loop, where they generated a second spark. Hertz used an interference pattern to determine the wavelength and velocity of these waves. The results were seen to concur with maxwell's equations, proving the existance of electromagnetic waves of lower frequency than visible light. Furthermore, Hertz observed that these waves had the same properties of light in terms of reflection, refraction and polarization. By increasing the frequency, Hertz was able to observe the properties of a range of different waves, validating Maxwell's theory and proving the existance of IR radiowaves.



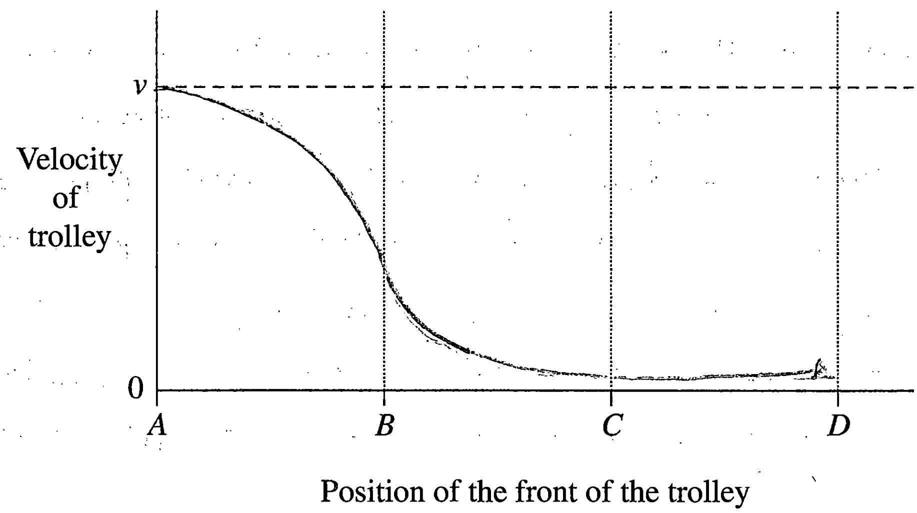
Question 28 (5 marks)

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 moves towards the magnet, the field induces eddy currents in the copper plate, this creates a field that resists and opposes motion, according to lenz law. This opposing force increases until the trolley reaches B. After B, the eddy currents reverse direction, as the trolley begins to move away from the magnet. This new field tries to reduce relative velocity between the trolley and the magnet, slowing it further. this force decreases as the trolley approaches D.

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**

Because superconductors have zero resistance below critical temperature, they are able to produce very powerful magnetic fields with very little energy loss. These strong fields are required to accelerate particles to very high speeds, ie .9999 c.

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

As the protons approach speeds nearing c, they experience mass dilation. This makes them harder to accelerate and so calculations must be applied to cause them to reach desired speeds. They also undergo time dilation, which means their time is slowed when viewed from a stationary frame of reference. Finally, they undergo length contraction, meaning that their observed lengths must be applied using Einsteins' equations of special relativity

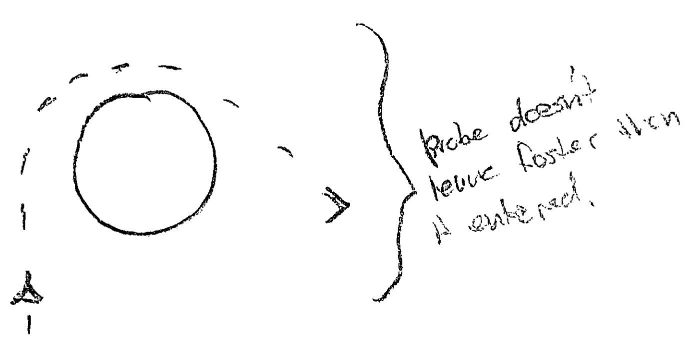
Question 30 (6 marks)

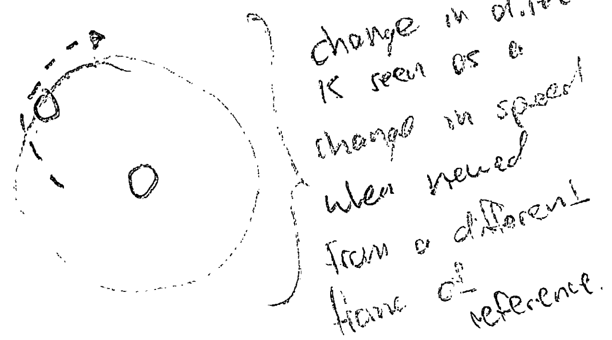
The following is a timeline for the Cassini space probe mission to Saturn. **6**

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.

During the launch, the rocket propels gasses downwards, which creates an equal and opposite force on the rocket, according to Newtons third law. Once in space, the Cassini probe underwent attraction to bodies in space according to Newtons' universal law of Gravitation $F = \frac{GMm}{r^2}$. Scientists took advantage of this via the slingshot effect. As the probe passed venus, Earth and Jupiter, the probe had some of the angular momentum of the planets added to it, resulting in an increase in velocity when viewed from an external frame of reference (see diagram). Using the slingshot effect meant that the probe could reach its destination in less time, and expending less fuel.





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