

Hsc physics study notes



**ASSIGN
BUSTER**

1. 1 Universal Law of Gravity Newton showed that all bodies attract one another by a force of gravity given by: $F = G \frac{m_1 m_2}{r^2}$ m_1 and m_2 are the masses in kg R is the separation between the objects centre $G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$, the universal constant of gravity Acceleration due to gravity Near the surface of the planet the acceleration due to gravity is by equating the radius of the planet and the gravity on it.

$W = F_{\text{gravity}} = Mg = \frac{Gm_1 m_2}{r^2} \therefore g = \frac{Gm}{R^2}$ Acceleration due to gravity is different at different locations on Earth due to: 1. Local changes in density of the earth's crust 2. The earth is not a sphere, causing g to be less at the equator because of the earth's larger radius there 3. The rotation of the earth causes g to be lower on the equator because some centripetal force is needed there
 PRAC: Projectile Motion Aim: To verify the equations of projectile motion and Galileo's assumption that the vertical and horizontal components of motion can be treated independently. Method ptA: Set up an inclined plane and roll a ball down it. For a rolling ball: $KE_{\text{bottom}} = PE_{\text{top}}/2$ or $v = \sqrt{vgh}$ (check that eqn gives the correct velocity of the ball) ptB: Using three different heights for the inclined plane, calculate the velocity of the ball then use this velocity to find how far from the end of the table it would have landed (the range).

Place a cup the correct distance and compare the balls calculated range to its experimental (measured) range. 1. 2 Projectile Motion Galileo showed that projectile motion could be described fully if the vertical and horizontal components of the motion were treated independently. The initial velocity can be separated into vertical and horizontal components by treating it as the sum of vector components. We can then use the equations of motion to

describe each component of motion as follows: Vertical: $y = \frac{1}{2}gt^2$

$+U_y$ $V_y = gt + U_y$ $V_y^2 = 2Gy + U_y^2$ Horizontal: $U_x = V_x$ (displacement) =

$U_x T$ The maximum horizontal displacement is called the range of the projectile.

It is also useful to remember that the vertical component of the velocity is zero at the top of the motion. We can remove time from the equation as

follows: $T = x/U_x$ hence $y = \frac{1}{2}g(x/U)^2 + V_y(x/U)$ $Y = (G/2m_x)x^2 +$

$x(U_y/m_x)$ This is the equation of a parabola that passes through the origin.

Hence projectiles move in parabolic paths Prac: Acceleration due to gravity T

$= 2\pi v/h/g$ Aim: to measure g using a simple pendulum Method:

measure the period of a simple pendulum as a function of length. To ensure

the experiment is reliable and valid: Time for 10 oscillations and divide by 10

to minimize errors Use at least 5 different lengths Only displace the pendulum

by a small angle ($< 5^\circ$) as the relationship is only correct for small

displacements 1. 4 General relationships in projectile motion For projectiles

that start and end at the same vertical height, we can derive the following

relationships Time of flight = $2u \sin \theta / g$ Max range = $u^2 \sin 2\theta / g$ Max

height = $u^2 \sin^2 \theta / 2g$ 1. 5 Absolute GPE If we define the absolute GPE to

be zero a very long way away (infinity) from the Earth, the GPE at a

distance r from the centre of the earth is given by: $GPE =$

$-G M_e M / r$ = object M_e = earth $G = 6.67 \times 10^{-11}$ The negative sign reminds

us that work must be done on the object to take it from r to infinity.

A 1kg mass on the Earth's surface: $GPE = 6.2 \times 10^7$ J/kg The GPE for

other planets could be calculated by replacing the mass of earth with the

mass of the planet and r with the distance to the centre of the

planets. 1. 6 Escape Velocity If we give an object a Kinetic energy equal to its

absolute GPE it will continue moving upwards and will never fall down /9it will goto infinity) $KE = |PE| \frac{1}{2}mv^2 = \frac{GM_1M_p}{R_p} V = v^2 \frac{GM_p}{R_p} 1.7$

Launching Rockets Rockets are powered by oxidizing fuel. The energetic gas released is directed out the back of the rocket and the rocket moves due to conservation of momentum (Newton's third law) The thrust force on the rocket is equal to the change in momentum of the exhaust gases per unit time $Thrust = f = \frac{\Delta p}{T}$ Even with constant thrust, rockets accelerate as they move higher their mass is decreasing (G and air friction are also decreasing).

WE measure the forces felt on an astronaut in $1.81.9$ the Satellite Equation Newton derived Keplers laws by equating centripetal force and gravity. The law of periods can be derived as follows: $F_c = \frac{Mv^2}{r} = \frac{Gm_1 m_2}{r^2} \therefore v^2 = \frac{Gm}{r}$ but $v = \frac{2\pi r}{T}$ for an object moving in a circle $\frac{2\pi r}{T} = \sqrt{\frac{Gm}{r}} \Rightarrow \frac{4\pi^2 r^3}{T^2} = Gm = \text{a constant} 1.10$ Satellite Orbits Low Earth Orbits exist between 400km and several thousand km above the surface. Satellites in LEO move very rapidly, have short period, 1.

5-6hrs and have a short life span (degenerate). They don't last long because they collide with gas particles in the outer atmosphere. LEOs are used for remote sensing, spying, GPS and space stations. All LEOs orbits around the centre of the earth, but their orbits can be at any orientation from equatorial to polar orbits.

Polar orbits have ground orbits that cover the whole earth. Geostationary Orbits- period of 24 hours and orbit above the equator. GSOs are slower than LEOs and all orbits have a radius of 42000km. Geostationary satellites

remain above the one point of the equator and are so far above the earth that they are not slowed by collisions with atmospheric gases, so they don't degenerate like LEOs. GSOs are used for communications, receiving and retransmitting microwave signals

PRAC: projectile motion
 Aim: to verify projectile motion theory
 Method: determine U_x by measuring the time for the ball to travel dist s . for each value of U_x find range of the projectile

Table carbon paper and ball

1. 11 Newton's analysis of Satellite Motion
 Newton explained satellite motion by imagining a cannon on top of a mountain above the atmosphere

1. 12 Re-entry and Landing
 To bring astronauts back to earth safely the spacecraft must enter the atmosphere between 5 and 7 degrees.

If the spacecraft reenter at less than 5 degrees it bounces off if it enters at more than 7 degrees it may burn up or decelerate to quickly splash the astronauts. Ballistic pods are protected from heat of re-entry by an Ablative heat shield which melts to carry the heat. The spacecraft uses silica tiles to protect it from the heat of reentry <1500 degrees c. The shuttle also uses $???$ turns to help it wipe off kinetic energy as it moves through the atmosphere before landing like an aircraft

1. 13 Gravitational assist
 Deep space probes can use elastic interactions with planets to increase their velocity with respect to the sun. this slingshot effect is similar to an elastic collision between a light and very massive object moving in opposite directions. The planet loses a small amount of momentum (and KE) and the probe gains this momentum and KE. The voyager probe used the slingshot effect to escape the solar system

Inertial frame is a frame in which Newton's laws are obeyed

14 Frames of Reference A frame of reference is a set of axes that's used to measure the position, velocity and acceleration of objects. We say the measurements are made wrt the axis. An inertial frame is a frame in which Newton's first law is obeyed. A Non-inertial frame is one in which it is not. If a frame moves in a straight line at constant velocity wrt an inertial frame, it must also be an inertial. If a frame changes direction or accelerates wrt to an inertial frame, it must be in a non-inertial frame.

15 Galilean/ Newtonian Relativity Galileo showed the velocity of an object is relative to a moving observer given by $v_{\text{relative}} = v_{\text{object}} - v_{\text{observer}}$. Galileo also showed that the laws of mechanics were the same if an observer was at rest or moving with constant velocity. Newton generalized this result in his first law of motion and stated that there was no mechanics experiment that could be used to determine if you were in a moving frame or one at rest. That is, the physics is identical in all inertial frames.

16 the aether In the 1800's electromagnetic waves were predicted theoretically by Maxwell and demonstrated experimentally by Hertz. Visible light is part of the electromagnetic spectrum with wavelengths between 400 and 700 nm.

Electromagnetic waves were believed to move through a medium called the aether. The aether was thought to have the following properties: Fluid that filled all space, invisible, zero velocity (planets could move through it without slowing down, it was incompressible, it was 100s of times more rigid than steel).

17 Michelson Morley experiment In the late 1880's, Michelson and Morley designed and conducted an experiment to measure the speed of the earth through the aether. It was on the idea that light would take longer to traverse a path with and against the aether wind than across it. Aray

of light was split into 2 rays which travelled the same distance a long paths that were at 90 degrees to each other and then recombined to form an interference pattern. By rotating the apparatus by 90 degrees, ray one would have change from a long path length (with wind against the wind) to a short path length (across the wind). This would cause a fringe shift (change in interference patterns). The set-up was sensitive enough to see the expected fringe shift, but no significant change in the interference pattern was observed.

This null result shocked scientists of the time.

1.18 simultaneity Einstein showed (using thought experiment) that if the speed of light was constant for all observers, events that were simultaneous in frame of reference would not be simultaneous from another frame of reference. A light beam emitted from x would reach a and b simultaneously according to an observer on the train, but would not appear to reach a and b simultaneously when observed from outside the train. Observer would see it reach the back of the train first.

1.19 time dilation If the speed of light is an absolute constant time must pass different rates in different frames of reference. This means that if a clock is moving wrt to your clock the moving clock will run slow wrt your clock. The moving observer will also (as if you are moving in its frame of reference).

1.20 Length dilation Einstein showed that for the speed of light to be an absolute constant, the length of objects moving wrt a stationary observer must contract in the direction of their motion. The length of a moving object can be calculated. The moving observer see length (and space) contracted in the direction of their motion, while the stationary observer see the length of the moving object contracted.

1. 21 mass dilation Mass also depends on relative velocity. The mass of a moving object is greater as measured by an observer at rest, than it is when the object is at rest Hence, the length contracts in the direction of motion, time slows and mass increases for a moving object when measured by an observer at rest

2. 1 the motor effect A current-carrying wire in a magnetic field experiences a force (called the motor force) given by $F = BIL \sin \theta$ $B =$ magnetic field in tesla $I =$ current in amps $L =$ length of wire $\theta =$ angle between I and b Current maximum when perpendicular, zero when parallel

2. 2 parallel current carrying wires Because all current-carrying wires are surrounded by a magnetic field ($b = \frac{\mu_0 I}{2\pi r}$). if a second wire is placed parallel to the first a motor force will appear given by $F = \frac{\mu_0 I_1 I_2 L}{2\pi r}$ Where I_1 and I_2 are the current in each wire in amps - L is the common length - r is the distance between the wires - μ_0 is a constant ($2 \times 10^{-7} \text{ NA}^{-2}$) Same direction = attraction Opposite = repulsion

3 torque Torque is a measurement of turning force. It is defined as the product of the applied force and the perpendicular distance between the line of action of the force and the pivot (turning centre) $T = fd_{\perp}$ ($f = ma$, $a = \omega^2 r$) ($d =$ radius in m)

2. 4 the dc electric motor A current carrying coil placed in a magnetic field experiences a torque (due to motor effect) $T = BANl \cos \theta$ $A =$ area of coil $N =$ number of turns $\theta =$ angle between the plane of the coil and the magnetic field To produce continual rotation the d.c. electric motor uses a mechanical switch called the split ring commutator to reverse the direction in the coil each half cycle. One coil motors use a split ring commutator and a pair of graphite brushes to connect the split ring to the external circuit Modern dc electric motors use profiled magnets and three

coils rather than one to maximize torque during rotation. D. c motors produce max torque from zero rpm.

The rotor coils (armature) of an efficient d. c motor also have laminated iron core. This reduces electrical loss to heat due to eddy currents.

Faraday's rotor Uses magnetic fields and current to make a copper wire rotate around a magnet in a sodium nitrate solution.

2. 5 other examples of the motor effect

a) loud speaker the voice coil of the loud speaker is connected to a paper diaphragm that vibrates when the coil moves up and down, converting the motion of the coil to sound

b) moving coil galvanometer a moving coil galvanometer is similar to a simple, one coil d. c motor BUT DOESN'T HAVE A SPLIT RING COMMUTATOR. THE TORQUE IN THE COIL IS BALANCED BY A COIL SPRING. THE ANGLE OF ROTATION OF THE COIL BEFORE IT COMES TO REST IS PROPORTIONAL TO THE CURRENT.

Electromagnetic induction What produces current Moving the magnet or coil or changing a field in the coil. Motion of either is irrelevant, it's the relative motion that is important.

Current is proportional to velocity, so the faster the motion the more current. Right hand rule can be used to determine the direction of the current. The direction of current can be reversed by reversing the relative motion or reversing the poles of the magnet. Doubling the power of the magnet/magnetic field will result in double current being induced.

Current is also proportional to turns, more turns = more current

2. 6 magnetic flux Magnetic flux is the product of the magnetic field strength and the perpendicular area of the loop through which the field passes

through Magnetic flux = BA | Magnetic flux is measured in Tm^2 or webers.

The magnetic field strength is sometimes called the magnetic flux density (magnetic flux per square unit area $BA_{\text{area}} = B!$) magnetic flux density would be measured in tesla².

7 discovery of e/m induction In 1831 Michael Faraday discovered that when the magnetic field in a loop of wire was changed a voltage was induced in the loop Faraday found a voltage appeared on the coil b when the switch was turned on or off Further experiments led Faraday to conclude that a voltage was induced whenever the magnetic flux was changed $EMF = -\text{change of magnetic flux on change in time}^2$.

8 Lenz's law Lenz showed that for energy to be conserved when electromagnetic occurs: THE INDUCED CURRENT WILL ALWAYS BE IN A DIRECTION THAT OPPOSES THE CHANGE THAT CAUSED IT!

2. 9 Eddy currents The magnetic field with respect to a conductor or charges near conductor, small loops of currents called eddy currents will be induced in the conductor. Eddy currents can be useful as well as problematic

A) Induction cooktop Eddy currents induced in saucepan heats saucepan to cook meals. In an induction cooktop an AC induction current is fed into an electromagnet which induces eddy currents in saucepan

b) electromagnetic brake an electromagnet placed near a rotating aluminium disc will induce eddy currents in the disc that will be in a direction that will oppose the motion of the disc. the KE of the disc is converted into heat by resistance heating due to the induced eddy currents

c) transformer eddy currents induced in the core of transformers reduces the efficiency of the transformer.

The eddy currents are reduced in the transformers by using laminated iron cores. The core is laminated by cutting it into slices and rejoining it with insulated materials between.

2. 10 demonstrating an AC generator
Turning a permanent magnet above a coil of wire induces an AC current in the coil.

2. 11 electromagnetic generators
A generator has the same structures as an electric motor, but a different function.

A motor changes electrical energy into mechanical energy, while generators do the opposite. When the generator is connected to an external load, current flows through the windings and it is harder to turn. This can be understood in terms of conservation of energy, as more energy must be put in, more electrical power is being used.

2. 12 the transformer
Step-up transformer increase the voltage while step-down decreases. The transformer consists of a primary (input) coil and a secondary (output) coil, wrapped around a common laminated core. The AC

on the primary produces a changing magnetic field in the core, which causes AC voltage to be induced on the secondary coil. The change in voltage produced is related to the ratio of turns in the primary and secondary coils.

$$N_p = V_p \quad N_s = V_s \quad I_p V_p = I_s V_s$$

Transformers can be 98% efficient, losses are due to eddy currents in the core and the resistance of the windings. Efficiency is increased by laminating the core and/or oil cooling of the core (low temp = low resistance = high efficiency).

2. 13 the battle of the currents
In the 1880s DC generator/distribution systems competed with newly developed AC systems. Edison designed and built DC.

ac systems in the USA first, but his systems were limited because dc could only be transmitted for a few kilometers (due to line losses). Westinghouse bought the patent to the transformer and with Tesla designed AC systems which used very high voltage and low currents to minimize line losses.

$P_{loss} = I^2 R$ By the 1890s AC had won the battle of the currents due to its ability to be transformed to other voltages, the higher efficiency of AC generators and its ability to be transmitted over long distances. High voltage lines are insulated from the poles that carry them by glass or ceramic insulators.

Insulators are designed to have a ribbed structure to increase surface area and reduce surface loading. And to let water drip off the insulator so it stays dry. An earthing line is connected directly to the support poles and placed above the high voltage lines, to protect the lines from lightning strikes.

DEMONSTRATION The principle of the AC induction motor can be shown by moving a magnet near a copper or aluminium plate or can. Spinning a magnet under a can causes the can to rotate in the same direction. Moving the magnet causes the copper sheet to move.

AC induction motor The AC induction motor is now the most commonly used motor in the world. It does not have a commutator, requires very little maintenance and is very efficient. The only advantage DC motors have over the AC motor is that it produces more torque at low speeds. An AC motor consists of a conducting squirrel cage rotor surrounded by a series of stator coils. The phase of the AC on the stator coils is adjusted to produce a north pole that rotates from one coil to the next around the squirrel cage. This opposite motion of the magnet around the rotor induces currents in the

motor These currents will be in a direction that opposes the change that created them due to Lenz's law, causing the squirrel cage to rotate in the same direction as the rotating magnet.

4. 1 REVIEW OF ELECTRIC FIELDS *electric field is defined as the force on a +1c charge at that point ($E = F/q$) *force on a charge q in an electric field $f = qE$ *the voltage difference between two points in an electric field is defined as the work done when a +1c charge moves between the point. Hence $v = \text{work}/q = \Delta PE/q$ *when a charge moves from one charged plate to another it does an amount of work given by $w = fd = (qe)d$.

$v = ed$ for charged parallel plates 3. 2 CHARGES IN MAGNETIC FIELDS Only charges that move with some component of their velocity perpendicular to a magnetic field experience a force. The force is perpendicular to the velocity and the magnetic field in the right hand rule sense and is given by $F = qv \sin \theta$ $R = mv/qb$ Radius of the curvature of a charge moving perpendicular to a magnetic field. Hence charges that move perpendicular to magnetic field move with uniform constant speed circular motion. 3. 3 GAS DISCHARGE TUBES Plucker 1858 At about 5% atm pressure - thin reddish streamers between the electrodes 1% of atm pressure a uniform glow fills the tube As pressure is further reduced striations appear in the tube and dark space occurs at the cathode <0.01 atm pressure the dark space fills the tube and the glass near anode glows green 3.

4 CATHODE RAY DEBATE - 20 year debate between English and German scientists over nature - Germans believed they were an undulation of the aether, waves - English believed they were made up of particles Evidence for

wave nature-exposed photographic plate-fluoresced some crystals-passed through thin metal films-not deflected by electric fields, later shown to be wrong Evidence of particle nature-deflected by magnetic fields-could turn a paddle wheel-travelled in straight lines These properties were independent of the type of cathode material and the type of gas which initially filled the tube.

3.5 END OF CATHODE RAY DEBATE

The French physicists showed negative charges were emitted from the cathode in the early 1890s and then J. J Thomson in 1896 ended the debate by measuring their q/m . Thomson measured the speed using a velocity filter, which balanced electric and magnetic forces on the particle. He found that particles move much slower than e/m waves.

Knowing the velocity, Thomson was then able to measure q/m by measuring the radius of curvature of the beam in the magnetic field $F_b = F_{qv} = mv^2/r$. $q/m = v/rB$. He confirmed this value by using reflection in a magnetic field and showed it was 1836 times bigger than q/m of a hydrogen atom. He then showed this value was the same for different cathode materials and proposed these negative particles were tiny and contained by all atoms.

Thomson discovered the electron

3.6 APPLICATIONS OF THE CRT

a) Cathode ray Oscilloscope
A CRO displays a graph of how a voltage changes over time. As any physical quantity can be changed to a voltage the CRO can be used to examine any physical transient. Over the past century the CRO has been an important tool in science, engineering and medicine.

A saw-tooth voltage on the vertical plates drives the beam across the screen and the signal to be examined is placed on the horizontal plates. Electric fields can be changed faster than magnetic fields and this is why

they??™ re used b) tvs-magnetic fields instead, greater bending/deflection of cathode rays= flatter boxes/tubes-the broadcast signal is placed on the grid determines brightness at eachn point on the screenc)xray tubesvery high, large voltages and heavy metal cathodes are used to produce xrays when electrons collide with the anode d) thermionic valves CRT tubes can be designed to act as rectifiers or amplifiers and these tubes led to electronics revolution. Small change in grid voltage produces a large change in cathode > anode current

3. 7 intrinsic and extrinsic semiconductors Intrinsic- undoped, equal, no holes. Works by exciting electrons to conduction band. Very few free charge carriers, poor conductors. Extrinsic- made by doping a semiconductor with a group 3 or 5 element to 1 part in 10^6 .

n-type- doped with group 5 elements to add electrons to the conduction band p-type- doped with group 3 atoms to leave positive holes in the conduction band

3. 9 PROPERTIES OF SEMICONDUCTORS-resistance decreases with heat due to more free charge carriers being created by lattice vibrations-resistance decreases when light shines on a semiconductor, photons of light excite the electrons into a higher state

p-n-type semiconductors brought together form a junction which has a voltage. THIS JUNCTION STOPS ANY FURTHER DRIFT OF CHARGES AND PRODUCES A DEPLETION ZONE NEAR THE JUNCTION THAT HAS NO FREE CHARGE CARRIERS.

3. 10 APPLICATIONS OF SEMICONDUCTORS a) variation of resistance used to measure intensity of light and temp b) p/n junctions can be used to make solar cells which convert light energy to electrical energy by exciting electrons with photons c) p/n junctions can also be used to allow current to flow in only one direction d) p/n/p and n/p/n junctions can be used

as switches or amplifiers. 3. 11 THE TRANSISTOR The transistor was developed after WWII at Bell's labs. Thermionic devices had been used up until then for electronics, but were expensive, fragile, inefficient and could not be miniaturised. Solid state rectifiers were used for radars during WW1 and the scientists at Bell's labs set about using the technology as an amplifier.

1948 Bardeen, Brattain and Shockley created the first junction amplifier, called the transistor. A small change in the base resulted in a large change in the emitter collector current. The first transistor used germanium because of the higher melting point and reactivity of silicon made it difficult to purify.

Eventually silicon prevailed as it is cheaper, more readily available and has larger band gaps which allow it to work at higher temps. Strongly adhering insulator at high temps, allowed for ICs to be developed in the 60s - led to computers and communications and information revolutions. 3. 12 XRAY

DIFFRACTION 1912 Max Von Laue showed that x-rays were diffracted by heavy metals and formed interference patterns. This was used to determine lattice structures by the Bragg father son team by showing the max angle of interference is related to the crystal plane spacing (d) Bragg's law $n\lambda = 2d \sin \theta$.

13 superconductivity 1911 mercury is discovered to have no resistance at 4.

2 kelvin. 3. 14 BCS theory Bardeen, Cooper and Schrieffer show that electrons travel in Cooper pairs when a lattice is at a low enough temp, high and the pair splits. 3. 15 MEISSNER EFFECT Zero resistance allows superconductors to

exclude magnetic fields. Currents in the superconductor can be used to

levitate a magnet above a superconductor. 3. 16 Hertz and Electromagnetic waves Hertz showed the theoretical work of James Clark Maxwell

experimentally. Hertz used an induction coil to produce sparks that radiated e/m waves.

He detected waves by using a ring with a small gap that sparked when e/m waves induce a current through it. He showed they could be reflected, refracted, diffracted and polarized. He also set up a standing wave and measured the wavelength of waves. He then used the wave equation $v = f\lambda$ to show the wave travelled at 3×10^8 m/s. Hertz discovered the photoelectric effect while he was studying electromagnetic waves.

He found UV light caused electrons to be ejected from metal surfaces. One of his students, Lenard, found that the photoelectric produced some unexpected characteristics. Lenard showed that electrons were only emitted when the incident frequency was greater than a specific threshold frequency (f_0) that is characteristic of the type of metal used. He also found that the kinetic energy of the ejected electrons increased when the light frequency was increased. Neither of these could be explained by the classical electromagnetic theory. In 1905, Einstein showed that by extending Planck's quanta to light, he could explain the P/E effect by assuming one light quanta (photon) would interact with one atom to release an electron using conservation of energy. He wrote $hf = \phi + KE$. Einstein predicted an experiment to measure the KE of the ejected electrons as a function of the incident light frequency would produce a graph with a gradient equal to Planck's constant.