Hsc physics study notes

1.

1 Universal Law of GravityNewton showed that all bodies attract one another by a force of gravity given by: F= Gxm1m2/r^2M1 and m2 are the masses in kgR is the separation between the objects centre??™sG= 6. 67×10^-11 Nm^2kg^-2, the universal constant of gravityAcceleration due to gravityNear the surface of the planet the acceleration due to gravity is by equating the radius of the planet and the gravity on it. W= FgravityMg= Gm1m2/r^2.:. g= Gm/Rp^2Acceleration 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 earths larger radius there 3. The rotation of the earth causes ??? g??™ to be lower on the equator beause some centripetal force is needed therePRAC: Projectile MotionAim: 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: KEbottom= PEtop/2 or v= 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 crrect distance and compare the balls calculated range to its experimental (measured) range. 1. 2 Projectile MotionGalileo 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= 1/2gt^2 +UyTVy= gt+ UyVy^2= 2Gy+ Uy^2Horizontal: Ux= VxX(displacement)= UxTThe maxium 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/Ux hence y= 1/2g(x/U)^2 + Vy (x/mx)Y=(G/2mx)^x^2+ x(Uy/mx)This is the equation of a parabola that passes through the origin. Hence projectiles move in parabolic pathsPrac: Acceleration due to gravityT = 2pivh/gAim: to measure ??? g??™ using a simple pendulumMethod: 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 errorsUse atleast 5 different lengthsOnly displace the pendulum by a small angle(<5degree) as the relationship is only correct for small displacements1. 4 General relationships in projectile motionFor projectiles that start and end at the same vertical hight, we can derive the following relationshipsTime of flight= 2usintheta/gMax range= u^2sin2theta/gMax height= u^2sin^2theta/2g1. 5 Absolute GPEIf 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= -GMeM1/rM1= objectMe= earthG= 6.

67×10^-11The negative sign reminds us that work must be done on the object to take it from??™r??™ to infinity. A a 1kg mass on the Earth??™s surface: GPE= 6. 2×10^7JKGThe 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 VelocityIf 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| 1/2mv^2= GM1Mp/RpV= v2GMp/Rp1. 7 Launching RocketsRockets 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(Newtom??™s third law)The thrust force on the rocket is equal to the change in momentum of the exhaust gases per unit timeThrust= f= deltaP/TEven with constant thrust , rockets accelerate as they move higher their mass is decreasing (G and air friction are also decreasing). WE measure the forces fel on an astronaut in ??? G??™s??™1. 81. 9 the Satellite EquationNewton derived Keplers laws by equating centripetal force and gravity. The law of periods can be derived as follows: Fc= FcMv^2/r= Gm1 m2/r^2.

:. v^2= Gm/r but v= 2pir/T for an object moving in a circle2pir/T= Gm/rT^2/R^3= 4pi^2/Gm= a constant1. 10 Satellite OrbitsLow Earth Orbits exist between 400km and several thousand km??™s above the surface. Satellites in LEO??™s 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. LEO??™s are used for remote sensing, spying , GPS and spacestations. 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. GSO??™s are slower then LEOs and all orbits have a radius of 42000km.

Geostationary satellites remain aboe 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 signalsPRAC: projectile motionAim: to verify projectile motion theoryMethod: determine Ux by measuring the time for the ball to travel dist ??? s??™. for each value of Ux find range of the projectileTable carbon paper and ball1.

11 newton??™s analysis of Satellite MotionNewton explained satellite motion by imagining a cannon on top of a mountain above the atmosphere 1. 12 Re-entry and LandingTo bring astronauts back to earth safely the spacecraft must enter the atmosphere between 5 and 7 degrees. If the spacecraft reenter at less then 5 degrees it bouces off if it enters at more then degrees it may burn up or decelerate to quickly n splatter 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 <1500decrees c.

The shuttle also uses ??? s??™ turns to help it wipe off kinetic energy as it moves through the atmosphere before laning like and aircraft1. 13 Gravitational assist Deep space probes can use eastic interactions with planets to increase their velocity with respect to the sun. this slingshot effect is similar to n 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 systemInertial frame is a frame in which Newton??™s laws are obeyed1. 14 Frames of ReferenceA frame of reference is a set of axis that??™s used to measure the position, velocity and acceleration of objects. We say the measurements are made wrt the axis. An inetial 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 an inertial frame, it ust also be an inertial. If a frame changes direction or accelerates wrt to an inertial frame, it must be in a non-inertial frame1. 15 Galilean/ Newtonian RelativityGalileo showed the velocity of an object is reative to a moving observer given by Vrelative= Vobject-VobserverGalileo 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 is first law of motion and stated that there was no mechanics experiment that ould be used to determine if you were in a moving frame or one at rest.

That is, the physics is identical in all inertial frames1. 16 the aetherIn the1800??™s electromagnetic waves were predicted theoretically by axwell and demonstrated experimentally by Hertz. Visibl 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 propertiesFluid 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 then steel1. 17 michelson morley experimentIn 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??? then across it.

Aray of light was split into 2 rays which travelled the same distance a long paths that were at 90 degrees to eah toher and then recombined to form an interference patternBy rotating the apparatus by 90 degrees , ray one wuld have change from a long path length (with nd 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 frine shift, but no significant change in the interference pattern was observed. This null result shocked scientists of the time1. 18 simultaneityEinstein 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 referenceA light beam emitted from x would reach a and b simultaneously according to and 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 first1. 19 time dilationIf 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 dilationEinstein 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 calculatedThe 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 dilationMass 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 restHence, the length contracts in the direction of motion, tie slows and mass increases for a moving object when measured by an observer at rest2.

1 the motor effectA current-carrying wire in a magnetic field experiences a force(called the motor force) given by F= BIL sinthetaB= magnetic field in teslaI= current in ampsL= length of wireTheta= angle between I and bCurrent maxium when perpendicular, zero when parallel2. 2 parallel current carrying wiresBecause all current-carrying wires are surrounded by a magnetic field (b= ki on r). if a second wire is placed parallel to the first a motor force will appear given byF= kIIL on rWhere I1 n 12 are the current in each wire in amps-l is the common length-r is the distance between the wires- k is a constant (2×10^-7 NA^-2)Same direction= attractionOpposite= repulsion2.

3 torqueTorque is a measurement of turning force. It is defined as the product of the applied force and the perpendicular distance between the lie of action of the force and the pivot(turning centre)T= fd_| _(f= ma, a=?? ™g??™)(d= radius in m!)2. 4 the dc electric motorA current carrying coil placed in a magnetic field experiences a torque (due to otor effect)T=

BANIcosthetaA= area of coilN= number of turnsTheta= angle between the plane of the coil and the magnetic fieldTo produce continualrotation the d. c electric motor uses a mechanical switch called the split ring comutator to reverse the direction in the coil each half cycle. One coil motors use a split ring comutator and a pair of graphite brushes to connect the split ring to the external circuitModern dc electric motors use profiled magnets and three coils rather then one to maxiise 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 rotorUses magnetic fields and current to make a copper wire rotate around a magnet in a sodium nitrate solution2. 5 other examples of the motor effecta) loud speakerthe 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 soundb)moving coil galvanometera 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 ROTATION OF THE COIL BEFORE IT COMES TO REST IS PROPORTIONAL TO THE CURRENT. Electromagnetic inductionWhat produces current Moving the magnet or coil or changing a bfield 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 byreversing 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 current2. 6 magnetic fluxManetic flux is the product of the agnetic field strength and the perpendicular area of the loop through which the b field passes throughMagnetic flux= BA_| _Magnetic flu is measured in Tm^2 or webers. The agnetic field strength is sometimes called the agnetic flux density (magnetic flux per square unit area BAona= B!) magnetic flux density would be easured in tesla2. 7 discovery of e/m inductionIn 1831 michael faraday disovered that when the magnetic field in a loop of wire was changed a voltage was induced in the loopFaraday found a voltage appeared on the coil b when the switch was turned on or offFurther experiments led faraday to conclude that a voltage was induced whenever the magnetic flu was changedEMF= -change of magneti flux on change in time2. 8 Lenz??™s lawLenz showed that for energy to be conserved when electromagnetic occurs: THE INDUCED CURRENT WILL ALWAYS BE IN A DIRECCTION THAT OPPOSES THE CHANGE THAT CAUSED IT! 2.

9 Eddy currentsThe 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 cane be useful aswell as problematic A) Induction cooktopEddy 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 saucepanb) electromagnetic

brakean electromagnet placed near a rotating aluminium disc will induce eddycurrents in the disk 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 currentsc) transformereddy currents indiced ion 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 andrejoining it with insulated materials between. 2. 10 deonstrating an AC generatorTurning a peranent magnet above a coil of wire induces an ac current in the coil2. 11 electromagnetic generatorsA generator has the same structures as an electric motor, but a different function.

A motor changes electrical energy into mechanical energy, while gernators do the opposite. When the generator is connected to an eternal load ore current flows through thewindings 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 transformerStepuup 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 A.

c 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 coilsNp= VpNs VsIpVp= IsVsTransformers 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= lowresistance= high efficiency2. 13 the battle of the currentsInn the 1880s dc generator/distribution systems copeted with newly developed a systems. Edison designed and built D.

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

Ploss= I^2 RBy the 1890s ac had won the battle of the currents due to its ability tobe transformed to other voltages, the higher efficiency of ac generators and its ability to be transmitted over long distances. High vioItage 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 of the insulator so soe of its dry. An emitting line is connected directly to the support poles and placed above the high voltage lines, to protect the lines from lightning strikes. DEMONSTRATIONThe principle of the ac induction motor can be shown by moving a magnet near a copper or aluinium plate or canSpinning a magnet under a can causes the an to rotate in the same directionMoving the magnet causes the copper sheet to move2.

14 ac induction motorThe ac induction motor is now the ost commonly used motor in the world. It does not have a comutator, requires very little maintenance and is very efficient. Th only advantage dc motors has over the ac motor is that it produces more torque at low speeds. An ac motor consists

of a conducting squirrel cage rotor surrounding by a series of stator coils. The phase of the ac on the statorcoils is adjusted to produce a north pole that rotates from one coil to the next around the squirrel cage. This opponent motion of the magnet around the rotor induces currents in the motorThese 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= Fonq)*force on a charge ??? q??™ in and 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= workonq= deltaPEonq*when a charge moves from one charged plate to another it does an amount of work given byw= fd=(qe)d. v= ed for charged parallel plates3.

2 CHARGES IN MAGNETIC FIELDS Only charges that move with soe component of their velocity perpendicular to a magneti 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= qvbsinthetaR= mvonqbRadius of the curvature of a charge moving perpendicular to a magnetic field. Hence charges that ove perpendicular to magnetic field move with uniform constant speed circular motion. 3. 3GAS DISCHARGE TUBESPlucker1858At about 5% atmo pressure- thin reddish streamers between the electrodes1% of atm pressure a uniform glow filles the tubeAs 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 green3.

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 particlesEvidence for wave nature-exposed photographic plate-fluoresced some crystals-passed through thin metal films-not deflected by electric fields, later shown to be wrongEvidence of particle nature-deflected by magnetic fields-could turn a paddle wheel-travelled in straight linesThese properties were independent of the type of cathode material and the type od gas which initially filled the tube3. 5 END OF CATHODE RAY DEBATEThe French physists showed negative charges were emitted from the cathode in the early 1890s and then J. J Thomson in 1896 ended the debate bu measuring their q/mThomson measured the speed using a velocity filter, which balanced electric and magnetic forces on the particle. He found that particles move uch slower then 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 fieldFb= FcqvB= mv^2/r.:. q/m= v/rBHe confirmed this value by using reflection in a magnetic field and showed it was 1836 times bigger then 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 electron3. 6 APPLICATIONS OF THE CRTa)Cathode ray Oscilloscopea CRO displays a graph of how a voltage changes over tie.

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. Asaw saw-tooth voltage on the vertical plates drives a the bea across the screen and the signal to be examined is placed on the horizontal plates. Electric fields can be changed faster then magnetic fields and this is why they??™re usedb) 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 anoded) thermionic valvesCRT 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 current3. 7intrinsic and extrinsic semiconductorsIntrinsic- 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 bandp-type- coped with group 3 atoms to leave positive holes in the conduction band3. 9 PROPERTIES OF SEMICONDUCTORS-resistance dereases 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 SEMICONDUCTORSa) variation of resistance used to measure intensity of light and tempb) p/n junctions can be used to make solar cels which convert light energy to electrical energy by exciting electrons with photonsc)p/n junctions can also be used to allow current to flow in only one directiond)p/n/p and n/p/n junctions can be used as switches or amplifiers3. 11 THE TRANSISTORThe transistor was developed after WWII at Bell??™s labs.

Therionic devices ahd been used up until then for electronics, but were expensive, fragile, ineffiecient and could not be miniturised. Solid state rectifiers were used for radars during ww11 and the scientists at bells lads 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 emitor collector currentThe first transistor used germanium because of the higher melting point and reactivity of silicon ade it difficult to purify.

Eventually silicon prevailed as it is cheaper, ore 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- ed to computers and communications and information revolutions. 3. 12 XRAY DIFFRACTION1912 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)Braggs lawNl = 2dsintheta3. 13 superconductivity1911 mercury is discovered to have no resistance at 4. 2 kelvin3. 14 BCS theoryBardeen, cooper and shrieffer show that electrons travel in cooper pairs wen a lattice is at a low enough temp, high and the pair splits3.

15 MEISNER EFFECTZero resistance allows superconductors to exclude agnetic fields. Currents in the superconductor can be used to levitate a magnet above a superconductor3. 16 Hertz and Electromagnetic wavesHertz zhowed the theoretical work of James clark Maxwell experimentally. Hertz used and induction coil to produce sparks that radiated e/m waves. He detected wavesby using a ring with a small gap that sarked when e/m waves induce a current through it.

He showed they could be reflected, refracted, diffractd and polarized. He also set up a standing wave and measured the wavelength of waves. He then use wave equation v= flander to show the wave travelled at 3×10^83. 17effect 3. 18 the photoelectric effectHertz 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 haraterstis. Lenard showed that electrons were only emitted when the inident frequency was greater then a specific threshold frequency (Fo) That as character istic pof the type of metal used. He also found that the kineti energy of the ejeted eetrons increased when the light frequency was increased. Neither of these ould be explained bu the lassial electromagnetic theory. In 1905, Einstein showed that by extendinding planck??™s quanta to light, he could explain the P/E effet by assuming one light quanta (photon) would interact with one atom to release an electron using conservation of energy he rote hf= 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