ForwardThinking

HELPING STUDENTS RE-ENGAGE WITH SCIENCE

Higher Physics Learning Outcomes

Unit 1 – Our Dynamic Universe

Equations of Motion

- Can I calculate the equivalent vector by scale diagram or otherwise for vectors in a non-right angled triangle?

- Can I carry out calculations to find the horizontal and vertical components of vectors using the relationships:
- $V_H = V\cos\Theta$ $V_v = V\sin\Theta$?

- Can I carry out calculations using the kinematic relationships:
- $v = u + at,$ $s = ut + \frac{1}{2}at^2,$ $v^2 = u^2 + 2as,$ $s = \frac{(u + v)}{2}t$
- for objects moving with a constant acceleration in a straight line?

- Can I interpret displacement–time graphs? e.g. gradient is velocity

- Can I interpret velocity–time graphs including:
- a) area under graph is displacement
- b) gradient is acceleration
- c) objects in freefall taking into account air resistance and changing surface area (covered in 1.2 Forces)?

- Can I interpret velocity–time graphs including:
- a) area under graph is displacement
- b) gradient is acceleration
- c) objects in freefall taking into account air resistance and changing surface area (covered in 1.2 Forces)?

- Can I draw and interpret acceleration – time graphs using information obtained from a velocity – time graph for motion with a constant acceleration?

- Can I identify and interpret motion – time graphs of:
- a) bouncing objects and
- b) objects thrown vertically upwards?

Forces, Energy and Power

- Can I analyse the motion of an object using free body diagrams and Newton's first and second laws?

- Can I carry out calculations using Newton's second law (F=ma) in one direction only?

- How does the direction of frictional forces compare to the direction of motion of an object?

- Can I carry out calculations using Newton's second Law (F=ma) when a number of opposing forces act on an object in the horizontal direction?

- Can I analyse and carry out calculations using Newton's second law (F=ma) and W=mg when a number of opposing forces act on an object in the vertical direction? e.g rockets, lifts etc

- Can I carry out calculations using Newton's second law (F=ma) when investigating internal forces (Tension exerted by a string or cable) e.g. car pulling a caravan etc?

- Can I carry out calculations using Newton's second law (F=ma) when an object is on an incline (slope)?
- *(components of weight = mgsinΘ & mgcosΘ)*

- Can I analyse and calculate the horizontal and vertical component of vectors (including forces)?

- Can I carry out energy calculations involving work done, potential energy, kinetic energy and power in
- a) familiar situations
- b) unfamiliar situations?

- Can I carry out calculations and analyse situations involving the conservation of energy?

Collisions, Explosions and Impulse

- Can I carry out calculations using the equation $p=mv$?
- Can I state the law of conservation of momentum?
- Can I carry out calculations using *p before = p after* for collisions between objects moving in the same direction?
- Can I carry out calculations using *p before = p after* for collisions between objects moving in opposite directions?
- What is meant by an:
- a) elastic collision
- b) inelastic collision?
- Can I use the equation $E_k = ½ mv^2$ to establish whether a collision is elastic or inelastic?
- Can I carry out calculations using *p before = p after* for explosions in one dimension?
- Can I apply the law of conservation of momentum to the interaction of two objects moving in one dimension to show that the forces acting on each object are equal in size and opposite in direction.
- Can I carry out calculations using the equation *Impulse = Force x time of contact*?
- How does Impulse and change in momentum compare in size during a collision in one dimension?
- Can I carry out calculations using the equation $Ft = mv-mu$?
- Can I identify the shape of a force – time graph of a collision in one dimension?
- Can I interpret force – time graphs including:
- a) area under graph is impulse
- b) changing the time of impact to see the effect on the
- average force and impulse e.g. use of crumple zones
- and air bags

Gravitation

- How does the vertical motion of a dropped object compare with an object which has been projected horizontally?

- Can I describe the vertical motion of an object which has been projected
- a) horizontally
- b) upwards at an angle (oblique)?

- Can I describe the horizontal motion of an object which has been projected
- a) horizontally
- b) upwards at an angle?

- Can I carry out calculations using
- $d = vt$ *(horizontal component)*
- $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
- *(vertical component)*

- for objects projected horizontally?

- Can I carry out calculations using
- $d = vt$ *(horizontal component)*
- $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $s = (u + v)\ t$
- *(vertical component)*
- for objects projected upwards at an angle?

- Using Newton's thought experiment, can I explain how satellites remain in orbit?

- What does the magnitude of the gravitational field depend upon?

- How do scientists believe stars were formed?

- Can I carry out calculations using the equation

$$F = \frac{Gm_1m_2}{r^2}$$

- Can I state an application of gravitational force?

Special relativity

- Do I know that the speed of light in a vacuum is the same for all observers in all reference frames?
- Can I describe the motion of an object in terms of an observer's frame of reference, using time dilation and length contraction?
- **Can I carry out calculations involving time dilation, I.e.**
- **Can I carry out calculations involving length contraction, I.e.**
- Do I know the minimum speed at which relativistic effects are observed?

The Expanding Universe

- Can I explain what is meant by the Doppler effect?
- Can I state which types of waves undergo the Doppler effect?
- **Can I calculate the apparent frequency detected by a stationary observer relative to a moving source of sound waves?, i.e.**
- Can I explain what is meant by redshift?
- **Can I carry out calculations using**
-
- **to calculate the redshift of a galaxy?**
-
- **Can I carry out calculations using**
-
- **to calculate the redshift of a galaxy at non-relativistic speeds?**
- Can I explain what is meant by Hubble's Law?
- **Can I carry out calculations using Hubble's Law, i.e.**
- Can I explain how Hubble's Law allows us to estimate the age of the universe?
- Can I describe the evidence which has lead to the theory that the universe is expanding?
- Can I explain how the rate of expansion of the universe is changing and name the force responsible for this?

- Can I describe how observations can be used to estimate the mass of our galaxy?
- Do I know what is meant by the term dark matter?
- Can I describe the evidence for dark matter?
- Do I know what is meant by the term dark energy?
- Can I describe the evidence for dark energy?

The Big Bang

- Can I describe the relationship between the temperature of a stellar object and the wavelength distribution of radiation it emits?
- Do I know how the peak wavelength of emitted radiation is related to the object's wavelength?
- Do I know how the intensity of radiation is related to the temperature of the star?
- Do I know what is meant by the cosmic microwave background radiation?
- Can I describe evidence to justify the Big Bang as a theory for the beginning and evolution of the Universe?

Unit 2 – Particles and Waves

Orders of Magnitude

- To be able to discuss the range of orders of magnitude of length from the very small (sub-nuclear) to the very large (distance to furthest known celestial objects).

The Standard Model

- To be able to discuss the evidence for the sub-nuclear particles and the existence of antimatter.
- State that Fermions, the matter particles, consist of Quarks (6 types) and the 6 Leptons (Electron, Muon and Tau, together with their neutrinos).
- State that Hadrons are composite particles made of Quarks
- State that Baryons are made of three Quarks and Mesons are made of two Quarks.
- To be able to describe beta decay as the first evidence for the neutrino
- State that the force mediating particles are bosons (Photons, W and Z Bosons and Gluons)
- Describe how a PET scanner works

Electric Fields

- State that, in an electric field, an electric charge experiences a force
- State that an electric field applied to a conductor causes the free electric charges in it to move

Movement of Charge

- State that work, W, is done when a charge, Q, is moved in an electric field.
- State that the potential difference (V) between two points is a measure of the work done in moving one coulomb of charge between the two points
- State that if one joule of work is done moving one coulomb of charge between two points, the potential difference between the points is one volt.
- State the relationship $V = W/Q$.
- Carry out calculations involving the relationship $V = W/Q$
- Calculate the speed of a charged particle accelerated in an electric field using the relationship $QV = ½ mv2$.

Charged Particles in a Magnetic Field

- State that a moving charge produces a magnetic field
- Describe the force acting on a charged particle in a magnetic field.

Particle Accelerators

- State the three types of particle accelerator
- Describe the basic operation of particle accelerators in terms of acceleration, deflection and collision of charged particles

Fission and Fusion

- Explain what is meant by alpha, beta and gamma decay of radionuclides
- Identify the processes occurring in nuclear reactions written in symbolic form

- State that in fission a nucleus of large mass number splits into two nuclei of smaller mass numbers, usually along with several neutrons
- State that fission may be spontaneous or induced by neutron bombardment
- State that in fusion two nuclei combine to form a nucleus of larger mass number
- Explain, using E = mc2, how the products of fission and fusion acquire large amounts of kinetic energy
- Carry out calculations using E = mc2 for fission and fusion reactions.
- Describe the principles of the operation of a nuclear fission reactor in terms of fuel rods, moderator, control rods, coolant and containment vessel
- Describe the coolant and containment issues in nuclear fusion reactors.

The Photoelectric Effect and Wave Particle Duality

- State that photoelectric emission from a surface occurs only if the frequency of the incident radiation is greater than some threshold frequency, fo, which depends on the nature of the surface
- State that a beam of radiation can be regarded as a stream of individual energy bundles called photons, each having an energy
- E = hf, where h is Planck's constant and f is the frequency of the radiation.
- Carry out calculations involving the relationship E = hf
- State that photoelectrons are ejected with a maximum kinetic energy, Ek, which is given by the difference between the energy of the incident photon hf and the work function hfo of the surface:
- Ek = hf – hfo.
- State that for frequencies smaller than the threshold value, an increase in the irradiance of the radiation at the surface will not cause photoelectric emission.
- State that for frequencies greater than the threshold value, the photoelectric current produced by monochromatic radiation is directly proportional to the irradiance of the radiation at the surface.

- Explain that if N photons per second are incident per unit area on a surface, the irradiance at the surface I = Nhf.

Conditions for Constructive and Destructive Interference

- Use correctly in context the terms: 'in phase', 'out of phase' and 'coherent', when applied to waves
- Explain the meaning of: 'constructive interference' and 'destructive interference' in terms of superposition of waves.
- State that interference is the test for a wave

Interference of Waves using two Coherent Sources

- State the conditions for maxima and minima in an interference pattern formed by two coherent sources in the form:
- Path difference = $n\lambda$ for maxima and
- Path difference = $(n + ½)\ \lambda$ for minima, where n is an integer
- Carry out calculations using the above relationships

Gratings

- Describe the effect of a grating on a monochromatic light beam
- Carry out calculations using the grating equation ;
- $d\sin\theta = n\lambda$
- Describe the principles of a method for measuring the wavelength of a monochromatic light source, using a grating
- State approximate values for the wavelengths of red, green and blue light.
- Describe and compare the white light spectra produced by a grating and a prism

Refraction

- State that the ratio $\sin\theta_1 / \sin\theta_2$ is a constant when light passes obliquely from medium 1 to medium 2
- State the absolute refractive index, n, of a medium is the ratio
- $\sin\theta_1 / \sin\theta_2$, where θ_1 is in a vacuum (or air as an approximation) and θ_2 is in the medium
- Describe the principles of a method for measuring the absolute refractive index of glass for monochromatic light
- Carry out calculations using the relationship for refractive index
- State that the refractive index depends on the frequency of the incident light.
- State that the frequency of a wave is unaltered by a change in medium
- State the relationships for refraction of a wave from medium 1 to medium 2

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

- Carry out calculations using the above relationships

Critical Angle and Total Internal Reflection

- Explain what is meant by total internal reflection
- Explain what is meant by critical angle θ_c
- Describe the principles of a method for measuring a critical angle
- Derive the relationship $\sin\theta_c = 1/n$, where θ_c is the critical angle for a medium of absolute refractive index, n.
- Carry out calculations using the above relationship

Irradiance and the Inverse Square Law

- State that the irradiance I at a surface on which radiation is incident is the power per unit area.
- Describe the principles of a method for showing that the irradiance is inversely proportional to the square of the distance from a point

source.

- Carry out calculations involving the relationship I = k/d2
- Explain why a beam of laser light having a power even as low as 0.1 mW may cause eye damage

Spectra

- State that electrons in a free atom occupy discrete energy levels
- Draw a diagram which represents qualitatively the energy levels of a hydrogen atom
- Use the following terms correctly in context: ground state, excited state, ionisation level
- State that an emission line in a spectrum occurs when an electron makes a transition between an excited energy level W2 and a lower level W1, where W2 – W1 = hf
- State that an absorption line in a spectrum occurs when an electron in energy level W1 absorbs radiation of energy hf and is excited to energy level W2, where W2 = W1 + hf.
- Explain the occurrence of absorption lines in the spectrum of sunlight.

Unit 3 – Electricity

Electrons and Energy

Monitoring and measuring a.c.

- Describe a.c. electric current and voltage in terms of the movement of charges in a circuit.
- State that a.c. current and voltage can be measured using an oscilloscope.
- Describe how to measure the frequency and peak voltage of an alternating supply using an oscilloscope.
- State that the r.m.s. voltage is equivalent to a d.c. voltage that produces the same power.
- State the relationship between peak and r.m.s. values for a sinusoidally varying voltage and current.
- Carry out calculations involving peak and r.m.s. values of voltage and current.

Current, voltage, power and resistance

- State that voltage is defined as the energy transformed per unit of charge.
- State the relationship $V = Ew/Q$.
- Carry out calculations involving the relationship between energy, voltage and charge.
- State that the energy transformed from an external source to the circuit is known as the electromotive force (e.m.f.).
- Give examples of sources of e.m.f.
- State that the energy transformed into another form of energy by a circuit component is known as the potential difference (p.d.).

- Carry out calculations involving the relationships between resistances in potential dividers using the potential divider equation and Ohm's law.

Electrical sources and internal resistance

- State that a power supply is equivalent to a source of e.m.f. with a resistor in series, the internal resistance.
- Describe the principles of a method for measuring the e.m.f. and internal resistance of a source
- Explain why the e.m.f. of a source is equal to the open circuit p.d. across the terminals of a source.
- State that the closed circuit p.d. across the terminals of a source is equal to the t.p.d.
- State that the e.m.f. of a cell is equal to the sum of the t.p.d. and the lost volts.
- Carry out calculations involving the relationship between the e.m.f., t.p.d. and lost volts.
- Describe two methods of measuring e.m.f. and internal resistance by graphical methods.
- State the R = r for maximum transfer of energy between a source and a load.

Capacitors

- State that the capacitance of a capacitor is a measure of its ability to store charge.
- State that a simple capacitor consists of two parallel conducting plates separated by an air gap.
- Describe the circuit symbol for a capacitor.
- State that the charge Q stored on a capacitor is directly proportional to the p.d. V across it.
- Describe the principles of a method to show that the p.d. across a capacitor is directly proportional to the charge on the plates.
- State that capacitance is defined as the gradient of the charge against p.d. graph or the ratio of charge to p.d.

- State that the unit of capacitance is the farad and that one farad is one coulomb per volt.
- Carry out calculations involving the relationship between charge, capacitance and p.d.
- Explain why work must be done to charge a capacitor.
- State that the work done to charge a capacitor is given by the area under the graph of charge against p.d.
- State that the energy stored in a capacitor is given by ½ (charge × p.d.) and equivalent expressions.
- Carry out calculations using the relationship between energy, charge and p.d. or alternative expressions.
- Draw qualitative graphs of current against time and of voltage against time for the charge and discharge of a capacitor in a d.c. circuit containing a
- resistor and capacitor in series.
- Carry out calculations involving voltage and current in CR circuits.

Electrons at work

Conductors, semiconductors and insulators

- State that solids can be classified into three types according to their electrical properties as conductors, semiconductors and insulators.
- Give examples of conductors, semiconductors and insulators.
- State that the different electrical properties of conductors, semiconductors and insulators can be explained by Band Theory.
- State that in isolated atoms, the permitted energy levels consist of a series of sharply defined states.
- State that in solids, the permitted energy levels associated with each state of the isolated atom forms a continuous band.
- State that the two highest bands are known as the valence band and the conduction band, respectively.
- State that the valence band contains electrons that can be considered to be bound to the atom.
- State that the valence band is full in insulators and semiconductors.

- State that the conduction band contains electrons that are free to move.
- State that the conduction band is empty in insulators and semiconductors, but partially filled in conductors.
- State that only partially filled bands may permit conduction.
- State that there is an energy gap between the valence and conduction bands in insulators and semiconductors.
- State that an electron can absorb energy to move between the valence band and the conduction band.
- State that in insulators, the energy gap is normally too large for electrons to jump to the conduction band.
- State that in semiconductors, the energy gap is much smaller and electrons can jump to the conduction band as a result of thermal excitation.

Intrinsic and extrinsic semiconductors

- State that in semiconductors, conduction occurs by means of negative charge carriers, (electrons) or positive charge carriers (holes).
- State that in pure semiconductors there are very few electrons available to conduct which makes the resistance very large.
- State that in pure semiconductors more free electrons become available at higher temperatures, therefore the conductivity increases and the resistance
- decreases.
- State that these pure semiconductors are known as intrinsic semiconductors.
- State that the addition of impurity atoms to a pure semiconductor (a process called doping) increases its conductivity by adding either extra electrons or
- holes to the lattice.
- State that doped semiconductors now have a majority charge carrier present and are known as extrinsic semiconductors.
- State that group V doping agents result in n-type extrinsic semiconductors, which contain extra electrons.
- State that group III doping agents result in p-type extrinsic semiconductors, which contain extra holes.

- Explain how doping can form an n-type semiconductor in which the majority of the charge carriers are negative, or a p-type semiconductor in which
- the majority of the charge carriers are positive.

p – n junctions

- State that the interface between p-type and n-type material is called the p–n junction and it functions as a diode.
- State that the majority charge carriers diffuse towards the junction and electrons and holes combine to form ions.
- State that this results in a depletion zone across the p–n junction where the density of charge carriers is low, with positive ions on the n-type side and
- negative ions on the p-type side.
- State that when the p-type material is connected to the positive terminal of a supply and the n-type to the negative terminal, then the junction is
- forward biased.
- State that if the potential difference across the junction is sufficient to force electrons to cross the depletion zone, then the junction will conduct.
- State that when the terminals are reversed, the junction is reverse biased and cannot conduct.
- Describe the movement of the charge carriers in a forward/ reverse-biased p-n junction diode.
- State that in a light emitting diode a large forward bias is applied to the p-n junction enabling positive and negative charge carriers to recombine,
- thereby producing photons of light.
- State that the frequency of the emitted photons increases as the size of the energy gap between the conduction and valence bands increases.

- State the relationship $E = h f$.
- Carry out calculations involving the relationships between E, h, f and λ.
- State that in photovoltaic cells, absorbed photons can create electron-hole pairs to produce a potential difference.