Higher Physics

ODU definitions / reminders

Our Dynamic Universe

- **Acceleration** is the rate of change of velocity ie an acceleration of 5 ms^{-2} means the velocity is increasing by 5 ms^{-1} every second.
- **suvat**:
  - 'from rest' means u = 0
  - a = 9.8 ms^{-2} *down* on Earth
  - If the object changes direction then use negative for down.
- **Motion-time graphs** … think gradients!
  - Gradient of displacement-time graph = velocity
  - Gradient of velocity-time graph = acceleration
  - When an object changes direction the velocity-time graph must CROSS the time axis (x-axis)
  - Area under velocity-time graph = displacement
- **Satellites** are in freefall around a planet or star. They are constantly accelerating but not changing speed – this is because the direction, not the magnitude, of their velocity is changing. The surface of the planet or star curves away from the satellite at the same rate that the satellite curves towards it hence the satellite remains in orbit at a constant altitude.
- **Projectiles** have independent horizontal and vertical motions
  - The first job is usually to resolve the initial velocity into components ($u_{horizontal}$ = u cosθ and $u_{vertical}$ = u sinθ where θ is the angle to the *horizontal)*
  - From now on *only* use the components u_h and u_v
  - Horizontal velocity is constant (use $s_h = v_h t$)
  - Vertical *acceleration* is constant due to gravity (use s_v u_v v_v a_v t and watch your negatives).

- **Newton's First Law** states that an object will remain at rest or move with a constant speed in a straight line (constant velocity) *unless* acted upon by an unbalanced force.
- **Balanced Forces** have the same size but act in opposite directions on *one object*.
- Link it: constant velocity = balanced forces
- **Newton's Second Law:** F_{un} = m a.
- **Newton's Third Law** states that for every action (force) there is an equal and opposite reaction (force). *Two objects* - swap their names: the force of the foot on the ball is equal and opposite to the force of the ball on the foot.
- **Friction** is a force which always acts in the *opposite* direction to an object's motion.
- **Tension** is a pulling force exerted by a string, cable or coupling on another object. It acts both ways at the same time.
- **Air resistance** increases with speed. This is why, even though the weight of an object in freefall is constant, air resistance can eventually balance weight and the object will reach **terminal velocity**.
- **Rockets**: Draw a diagram of *all* the forces (free body diagram) – don't forget weight!
- **Lifts**: Remember that a set of scales/balance actually measures the *upwards* force on the person and that weight (acting *downwards*) is constant.
- **Slopes**: The *component of weight* acting down a slope = m g sinθ where θ is the angle of the slope to the *horizontal*.

- **The law of conservation of linear momentum** states that the total momentum before a collision/explosion is equal to the total momentum after the collision/explosion as long as no external forces are acting.
- **Momentum** questions: Draw before and after diagrams. Remember that objects going backwards have negative velocities.
- **Elastic collision**: Kinetic energy is conserved. **Inelastic collision**: Kinetic energy is NOT conserved.
- **Impulse** = change in momentum = area under a force-time graph. This takes place when there *is* a net external force.
- **Airbags**, crumple zones and rubber matting in playgrounds reduce the force (and therefore injury) on a person by increasing the time the force acts. Change in momentum would be constant.
- When using **Newton's Universal Law of Gravitation** remember to measure the distance from the *centre* of one mass to the *centre* of the other.
- **The speed of light** in a vacuum is *the same* for all observers.

- **Time dilation** is the increase in an observed time interval for an object moving relative to an observer compared to that measured when they are in the stationary frame of reference.

- **Length contraction** is the decrease in the observed length (in the direction of motion) of an object moving relative to an observer compared to that measured when they are in the stationary frame of reference.
- **t** and **l** are when the observer and object are stationary relative to each other, ie they are in the same location, and **t'** and **l'** are when there is relative motion, ie things are observed in more than one location.
- **Doppler**: When a source of waves is *coming towards* an observer a *higher frequency* of wave than that actually emitted will be observed because the waves become 'bunched up' in front of the source leading to a smaller wavelength. Going away → lower frequency.
- **Redshift** is when the Doppler effect is observed with light from galaxies. The light reaching earth has a smaller frequency and longer wavelength (ie is shifted towards the red end of the spectrum) than that actually emitted by the galaxy. This shows that the galaxy must be moving away from us. Blueshift → coming towards.
- Evidence supporting the **Big Bang/expanding universe** theory:
    - Cosmic Microwave Background Radiation
    - the abundance of hydrogen and helium
    - the darkness of the sky (Olbers' paradox)
    - the large number of galaxies showing redshift rather than blueshift.
- **Dark Matter**:
    - The mass of a galaxy can be estimated by using *the orbital speed of stars* within it
    - Masses measured are bigger than those predicted by looking at the *number* of stars present
    - Conclusion? There must be matter there that we can't see – Dark Matter.
- The existence of **Dark Energy** is supported by the accelerating rate of expansion of the universe ie something appears to be opposing gravity.
- The **hotter a star** is
    - the shorter the *peak* wavelength of the emitted radiation (more blue) *and*
    - the more energy it emits per second per square metre.

Higher Physics

P&W definitions / reminders

Particles and Waves

- **Order of Magnitude** is the power of ten ie $4x10^{16}$ is 4 orders of magnitude greater than $6x10^{12}$.
- **Standard Model**:
  - 12 Fermions (matter particles)
    - 6 Quarks – up, down, charm, strange, top, bottom
    - 6 Leptons – electron, electron neutrino, muon, muon neutrino, tau, tau neutrino
  - 4 Gauge Bosons (force carriers)
    - photon (electromagnetic force)
    - Z and $W^{\pm}$ bosons (weak nuclear force)
    - gluon (strong nuclear force).
- **Hadrons** are made up of quarks
  - Baryons are made of 3 quarks eg protons, neutrons
  - Mesons are made of 2 quarks (a quark and an anti-quark) eg pions, kaons.
- **Strong force** holds quarks together and also holds protons and neutrons together in the nucleus.
- **Beta decay** is caused by the **weak force** and is evidence of the **Neutrino**.
- **Anti-matter** particles are identical to their corresponding matter particles except charge.
- Matter + corresponding anti-matter = **annihilation**.
- **Electric field** lines point from positive to negative.
- A charged particle will accelerate in an electric field because it experiences an unbalanced force.
- Gain in kinetic energy = work done by electric field.
- Like charges repel, opposite charges attract.
- **Potential difference** (voltage) is the number of joules of energy per coulomb of charge.
- **Moving charged particle** will produce a magnetic field.
- **Magnetic field** lines point from North to South.
- Expressive dance …
- In a **particle accelerator** an electric field is used to change the particle's speed (SQA: accelerate) while it is most common to use a magnetic field to change the particle's direction (SQA: deflect).
- Nuclear **Fission** (must spell it correctly) – big nucleus splitting into smaller parts
  - **Induced/Stimulated** Fission: usually caused by neutron bombardment
  - **Spontaneous** Fission: random event, no external trigger.
- Nuclear **Fusion** (must spell it correctly) – smaller parts combining to make a more massive nucleus.
- The products of a nuclear reaction have less mass than the particles did before. The difference in **mass is converted into energy** ($E = m c^2$).
- The very high temperatures required in a **fusion reactor** lead to coolant and containment issues.
- **Wave particle duality**:
  - The photoelectric effect is proof that light is a particle
  - Interference is the proof that light is a wave.

- **Photoelectric effect**:
    - Minimum energy required to cause photoemission (ie eject an electron from a metal) is the **work function** of the metal
    - Minimum frequency of incident photon required to cause photoemission is the **threshold frequency**
    - Only one photon per electron and only negatively charged metals will discharge
    - Any extra energy is converted to kinetic energy of the electron.

- **Constructive interference**: when two coherent waves meet in phase (ie crest meets crest and trough meets trough) they combine to produce a *maximum*.

- **Destructive interference**: when two coherent waves meet exactly out of phase (ie crest meets trough and trough meets crest) they cancel out producing a *minimum*.
- **Path difference** is what it says – it is the difference in the length of the two paths the waves take.
    - 0, 1, 2, 3 … wavelengths difference – maxima / constructive interference
    - ½, 1½, 2½ … wavelengths difference – minima / destructive interference.
- **Diffraction grating**:
    - d is *spacing* between consecutive lines ie 300 lines per mm means d = $\frac{1}{300\ 000}$ m
    - θ is the angle between the *centre* maximum and the maximum you are considering.

- **Absolute refractive index** of a medium is the ratio of the speed of light in a vacuum to the speed of light in the medium.
- Going from a vacuum (air) into water/glass/Perspex etc the speed, wavelength and angle will all decrease. Glass →air etc and they all increase again.
- The frequency of light is not altered by refraction but refractive index varies with frequency.

- The **critical angle** of a medium is the angle of incidence *inside* the medium which results in a refracted angle of 90° in a vacuum.
- **Total internal reflection** occurs when the angle of incidence *inside* the medium is *greater* than the critical angle.
- **Irradience** of radiation is the power per unit area ie the number of watts per square metre *incident* on a surface.
- From a **point source**, irradience follows the inverse square law ie if the distance is doubled (x2) then the irradience will quarter (x$\frac{1}{2^2}$).
- **Bohr model of the atom**:
    - E_0 is the **ground state** and is the lowest energy level
    - The **ionisation level** is the highest energy level and is given an energy of zero
    - E_0, E_1, E_2 etc have negative energy levels in comparison to the ionisation level
    - Electrons can only exist in these discrete energy levels and fill the lower levels first
    - When an electron gains energy it can move up energy level(s)
    - When an electron *falls* from a higher to a lower energy level the energy is released in the form of a photon of light.
- **Line emission spectra** are produced as each electron that falls from a high energy level to a lower level will result in a specific energy and therefore frequency/wavelength/colour of photon.
- **Absorption spectra** occur when the atoms absorb specific energies of photons and the electrons move up to the relevant energy levels. Although the electrons will usually fall back down again and re-release the same mix of energies of photons, these new photons will be emitted in all directions and so an observer will see dark lines in a **continuous emission spectrum**.

Higher Physics

Elec. definitions / reminders

Electricity

- An **alternating current** is one which changes direction and instantaneous value with time ie the charges are *continually changing direction*.
- The **peak** value is always bigger than the **r.m.s.** value. R.m.s. is the d.c. equivalent value.
- Match when using V = I R ie $V_{peak} = I_{peak} \times R$ but $V_{rms} = I_{rms} \times R$
- You *must* use rms values for power calculations.
- Use the correct words:
  - Voltage or potential difference – **across**
  - Current – **in / through**
  - Resistance – **of**
- **Simple circuit rules**:
  - Current in series is the same (CISS), current in parallel branches add up to supply current
  - Voltage in parallel is the same, voltage in across series components add up to supply voltage (VIPs use VISA …)

- The **e.m.f.** is the number of joules of energy given to every coulomb of charge as it passes through a power supply / battery.
- The **t.p.d.** is the voltage across the terminals of the supply. This is the same as the voltage across the load resistor.
- The **internal resistance** is the inherent resistance of the supply itself.
- An **ideal supply** is one which has zero internal resistance.
- When a supply is **open circuit** it has an 'infinite' load resistance ie there is nothing connected across its terminals.
- The **open circuit voltage** of a supply is equal to the e.m.f..
- When a supply is **short circuited** it has a load resistance of zero ie a wire is connected directly from the positive terminal to the negative terminal.
- The **short circuit current** is the maximum current that can be drawn from the supply.
- Internal resistance is the negative gradient of a t.p.d. against current graph.
- If there is more than one supply in a circuit then combine the internal resistances and e.m.f.s separately using the standard circuit rules.
- **Capacitance** is the number of coulombs of charge stored per volt.
- **Charge against potential difference graph**:
  - Gradient = capacitance
  - Area under graph = work done charging capacitor = energy stored on capacitor.
- Don't forget the *half* term in E = ½ Q V.
- When a capacitor is **fully charged** the voltage across it will be equal to the supply voltage and there will be zero volts across the series resistor and thus zero current.
- When a capacitor is **fully discharged** the voltage across it will be zero and the full supply voltage will be across the series resistor thus maximum current ($I_{max} = \frac{V}{R}$).
- The *current* starts big and decreases in magnitude for both charging *and* discharging.
- Increasing R or C increases the time for the capacitor to charge/discharge.

- Increasing R *also* decreases the magnitude of I_{max}.
- Increasing C *also* increases the maximum energy stored. This can also be increased by increasing V_s.
- When atoms combine to form a solid, the electrons align themselves into energy bands rather than discrete energy levels.
- The highest filled band is called the **valence band**. The next band up is called the **conduction band**.
- Electrons are held tightly in the valence band but are able to move freely in the conduction band.
- A **conductor** has an overlapping conduction and valence band. This means that the conduction band contains electrons which are free to move and so the solid conducts.
- An **insulator** has a full valence band and an empty conduction band. The energy gap (band gap) between the valence and conduction bands is too large for electrons to jump up and so the solid does not conduct.
- A **semiconductor** is like an insulator with a much smaller band gap. The gap is small enough that room temperature is enough to give some electrons the energy to jump up from the valence to conduction band and increase the conductivity of the solid. Conductivity increases (ie resistance decreases) with increasing temperature.
- Semiconductors can be **doped** by adding impurity atoms to reduce their resistance.
- An **n-type** semiconductor has had an impurity with extra electrons added. As these are not used for valency (holding the solid together) they are added to the conduction band and so it conducts more. The majority charge carriers are negative electrons.
- A **p-type** semiconductor has had an impurity with 'missing' electrons added. There are gaps in the valence band. This also increases conductivity. The majority charge carriers are 'positive holes'.
- A **p-n junction** is when p-type and n-type semiconductor materials are side by side. A **depletion layer** forms which has virtually no free charge carriers.
- **Forward biased** means that the p-type side of a p-n junction is connected to the positive terminal of a power supply and the n-type side is connected to the negative terminal.
- **Reverse biased** means p-type to negative and n-type to positive.
- A **solar cell** is an unbiased p-n junction. Photons of light enter the depletion layer and give electrons enough energy to move from the valence band of the p-type into the conduction band of the p-type. The potential barrier of the depletion layer provides the electric field needed to move across to the conduction band of the n-type and a voltage is produced. This is the **photovoltaic effect**.
- An **LED** is a forward biased p-n junction. Electrons cross from the conduction band of the n-type to the conduction band of the p-type where they release energy as a photon of light as they 'fall' into the valence band of the p-type.