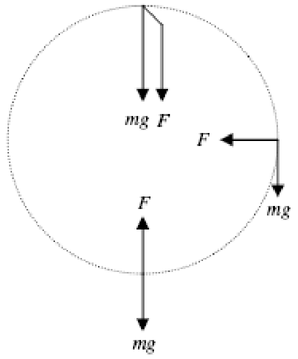
Circular Motion & Oscillations

- Angular speed, $\omega = \Delta\theta / \Delta t = 2\pi f$ (assuming angle is a complete revolution, in radians)
- Centripetal Force, $F = \frac{mv^2}{r}$

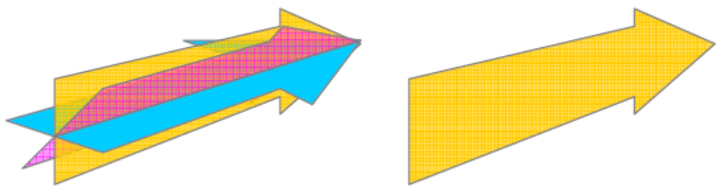


As the item moves around the circle the resultant force differs. When at the top of the circle the only forces are acting downwards, which can result in a feeling of weightlessness.

- Simple Harmonic Motion is a variation of displacement, velocity and acceleration with time. It occurs when acceleration is proportional to displacement from a fixed point and in the opposition direction.
  - $a = -\omega^2 x = -(2\pi f)^2 x$ (assuming angle is a complete revolution, in radians)
  - $x = x_0 \cos\theta$ (displacement at any point in the revolution)
- Period of a pendulum, $T = 2\pi\sqrt{\frac{l}{g}}$
- Period of a mass on a string, $T = 2\pi\sqrt{\frac{m}{k}}$
- These models assume a frictionless environment, which would allow perpetual motion. In reality damping will cause a loss of energy to the system which will over time reduce the maximum amplitudes. If the damping is too heavy there will be no oscillations at all. (Example: Shock Absorbers)
- A force can be used to put this energy back into the system, this is known as forced oscillations. If the applied frequency of oscillation matches the natural frequency, then resonance will occur – where a large amount of energy is put into the system – which can be problematic for structural engineering, etc.

Waves

- Waves may be transverse (displacement is perpendicular to direction of wave) or longitudinal (displacement is in the same direction as the wave). The E-M spectrum is transverse waves, whilst sound and water waves are longitudinal.
- Waves may be superimposed upon one another (addition or subtraction of amplitude usually if the frequency is the same).
- Travelling/Progressive waves transmit energy from one place to another – no particles actually move apart from their displacement about a fixed point – but there is transfer of energy (the wave seemingly *goes* somewhere)
- Standing/Stationary waves are the result of superposition of waves in such a way that the resultant wave does not transfer energy anywhere – there is no net displacement.
  - In a standing wave there are nodes (points of which there is no amplitude) and anti-nodes (points at which amplitude is at its peak).
  - Nodes and antinodes are always equidistant and located at half wavelength distances.
- Wave speed, $v = f\lambda$
- For the E-M spectrum, wavespeed = speed of light, c.
  - Radio Waves (wavelength in metres)
  - Microwaves (wavelength in centimetres)
  - Infra Red (wavelength in micrometers)
  - Light (Visible) (wavelength from $7\times10^{-7} \Rightarrow 4\times10^{-7}$ m)
  - Ultraviolet (wavelength in nanometres)
  - X-Rays (wavelength around 10×10^{-10} m)
  - Gamma Rays (wavelength in picometers)
  - (*Randy Max's Intercourse Leaves Utterly Exhausted Girls)*
- Transverse waves may be polarised or unpolarised. Polarised waves move only in one plane about the axis along which the wave is directed. Unpolarised waves moves in all planes. Waves can be polarised with Polaroid filter or by using a fine grill which only certain planes of the wave can move through. Similarly polarised waves can be blocked with a grill.



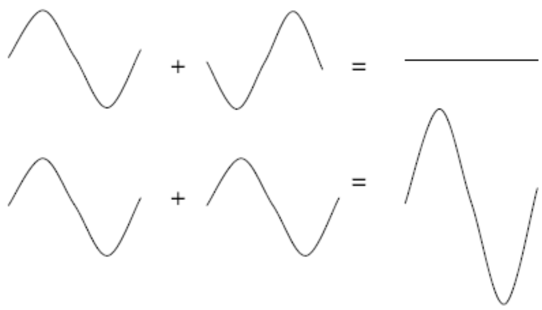
This wave is not polarised, since particles are being displaced in three different planes.

This wave is polarised, since particles are being displaced in only one plane.

- Intensity, $I = \dfrac{P}{4\pi r^2}$ (power per unit area, inverse square law)

Superposition of Waves

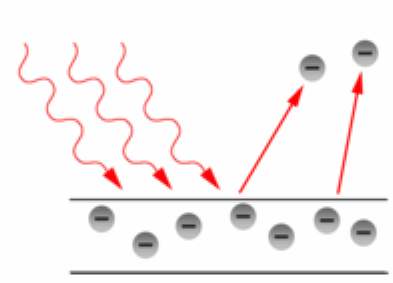
- Graphical Superposition



- A wavefront is a line whereby all the points on it are in phase.
- Single slit interference occurs when a wave travels through a slit and then spreads out. We can observe interference patterns, showing different parts of the wave are interacting with each other.
- With double slit experiments, we see multiple sets of fringes in the interference pattern – due to superposition between the different beams of waves. The brightest points, *maxima*, are positioned equal distances apart.
  - Formula, $\lambda = \frac{xs}{D}$ (*x* is maxima spacing, *s* is slit spacing, *D* is distance to screen)

Quantum Phenomena

- Energy of a Photon, $E = hf$ (h is Plank constant)
- The electron volt, the energy to move one coulomb across one volt.
- Photoelectric effect… when photons hit a metal surface they provide an energy which can be used to release electrons from the material.



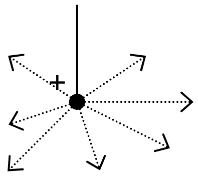
  - There are discrete energy states an electron may reside at
  - If the correct amount of energy is provided by a photon, an electron may move up an energy level (or more than one). If sufficient energy is provided to overcome the work function (the minimum energy required to release an electron from the surface of a material) a photoelectron may be emitted.
  - Threshold Frequency is the minimum wavelength required to cause the photoelectric effect.
  - The absorption/emission spectra of a material are related to the energy levels it has – since for each change in energy level a different energy photon must be absorbed.
  - Maximum energy of a photoelectron, $QV = E = hf - \varphi$ where q is charge on electron and V is stopping potential.
  - The photoelectric effect can be observed since the emission of electrons results in a change in charge (or if in a circuit, a current albeit a very small one).
- Electrons can be diffracted (using a vacuum tube).
- All objects have a wave-particle duality, which means we all have a wavelength. (de Broglie).
  - Wavelength, $\lambda = \dfrac{h}{p}$ (where p is momentum and h is the Plank constant)

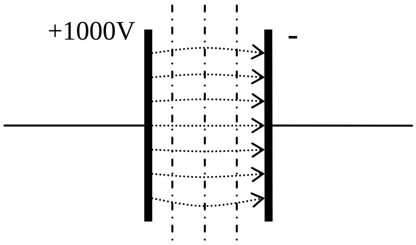
The Expanding Universe

- Stars have emission spectra which relates to their chemical composition.
- A light year is the distance light will travel in one year.
- The Doppler shift is where we observe spectral lines shifting depending whether an object is moving towards or away from us.
  - $\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} = \frac{v}{c}$ where v is the speed at which the object is moving
  - By measuring the observed frequency of light, and comparing this to the light given off by the same chemical the star is made of – in a lab environment – we can work out the shift in wavelength and thus use this to calculate the speed at which the galaxy is moving.
  - Note usually applied to galaxies not stars.
  - We can observe a red shift when we look at a galaxy, which indicates that most galaxies are moving away from, us. The balloon model shows us that this means the universe is expanding (but does not mean we are at its centre).
- Hubble plots the distance a galaxy is from Earth against its velocity, the gradient of this curve is the hubble constant, H where $v = Hd$.
  - The inverse of the hubble constant is an approximate age of the universe.
- There are three key possibilities for the future of the universe.
  - Open Universe → The universe continues expanding indefinitely
  - Stable Universe → The universe will reach a maximum size then ceases to expand.
  - Closed Universe → The universe will eventually start collapsing in on itself.
  - These depend on the critical density of the universe, as to whether there is sufficient gravitational force to hold the universe together.

Gravitational and Electric Fields

- An electric field is a region where a charged particle experiences a force; similarly a gravitational field is a region where a particle with mass experiences a force.
- Radial and Linear fields:





- Lines of equipotential are where the potential difference is the same in an electric field. In a uniform field the distance between lines of equipotential should be regular, so half way across the plate separation there will be half the voltage.
- Comparing Electric and Gravitational Fields:

	Electric Fields	***Gravitational Fields***
Force in a Radial Field	$F = \frac{kQ_1Q_2}{r^2}$ $k = \frac{1}{4\pi\varepsilon_0}$	$F = \frac{Gm_1m_2}{r^2}$
Force in a Uniform Field	$F = EQ$ *where* $E = \frac{V}{d}$	$F = mg$ *Although the field of the Earth is not uniform, the curvature is so slight we model it as being so.*
Field Strength	E measured in Vm^{-1} or NC^{-1}	g in ms^{-2} or Nkg^{-1}
Nature	Can be attractive or repulsive.	Always attractive (although there may be such thing as anti-mass as yet undiscovered)
Shieldin g	Can be shielded against (for example Faraday Cage).	Cannot be shielded against.

- A Volt is defined as the energy required to move one Coulomb of charge. Thus $E = QV$

Capacitance

- Capacitance in Farads, $Q = CV$
- Energy stored in a capacitor, $E = \frac{1}{2}CV^2$
- Equivalent capacitance
  - In series, $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ (since voltages add and charge is equal)
  - In parallel, $C_T = C_1 + C_2 + C_3$ (since charges add and voltage is equal)
- There is exponential decay when discharging a capacitor though a resistor.
- The area under a Current-Time graph is charge.

Magnetic Fields & Electromagnetic Induction

- Magnets have field lines too. A magnetic field is a region where a certain type of object experiences a force.
- The flux density (field strength)(in Tesla) is defined, $B = \frac{\phi}{A}$ where ϕ is magnetic flux
- Force due to magnetic field, $F = BIl$
  - The direction is B is given by the left hand rule.
  - This can be re-arranged to $F = BeV$ for a single electron.
- Magnetic field can be measured with a Hall Probe.
- In a solenoid (coil), $B = \mu_0 nI$ (n is number of coils)
- About a single wire, $B = \frac{\mu_0 I}{2\pi r}$ (r is perpendicular distance from wire)
- An e.m.f. can be induced in a circuit by a changing the flux.
- Induced e.m.f., $\varepsilon = -N\frac{\Delta\phi}{\Delta t}$
- With a transformer, the flux is linked about a single coil, which makes a relationship between the emf on one side and emf on the other.
  - $\frac{V_p}{V_S} = \frac{N_p}{N_S}$