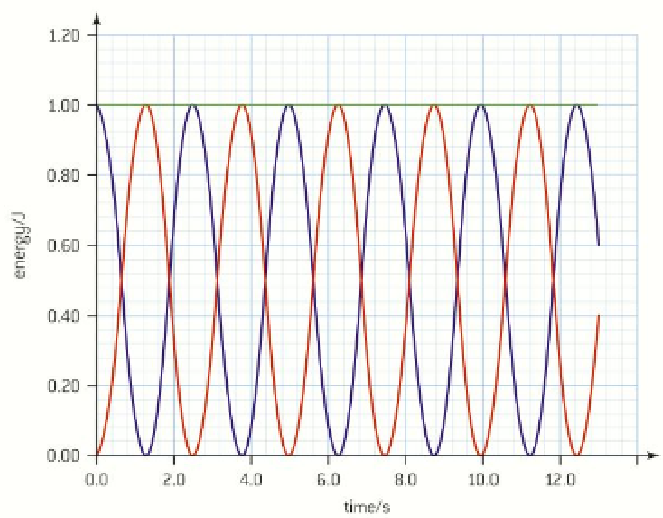
IB Physics Exam Definitions

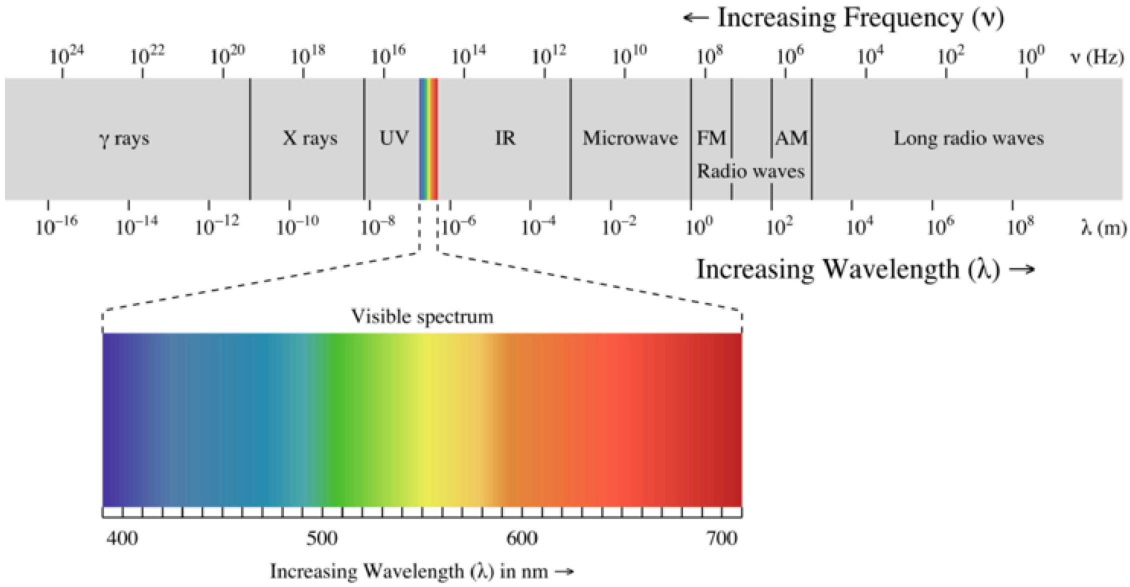
Fundamental Units and Magnitudes of stuff	
The 7 SI units	1. Distance: Metre; a. Nucleus of atom ≈10^{-15} m b. The universe ≈10^{25} m 2. Mass: Kilogram; a. Electron ≈10^{-30} kg b. Universe ≈10^{50} kg 3. Time: Second; a. Age of universe ≈10^{17}s b. Time for light to travel across H^+ ≈ 10^{-24} s 4. Temperature: Kelvin 5. Mol: Avogadro's number → the number of atoms in 12g of ^{12}C ≈ 6.02 x 10^{23}. 6. Electrical current: Ampere. 7. Luminous intensity: Candela.

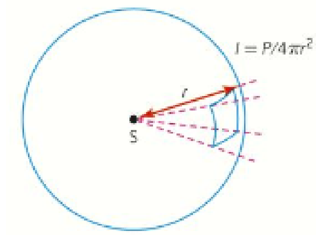
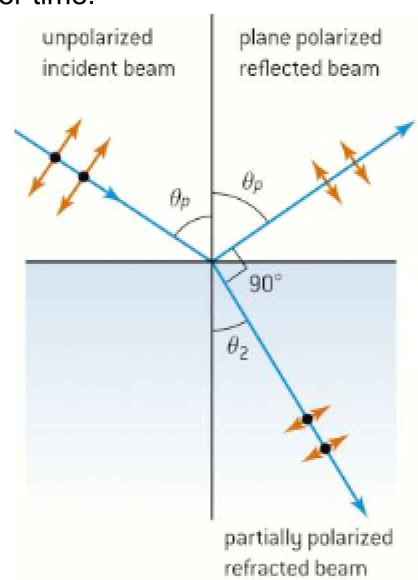
Mechanics (2)	
Translational equilibrium	The resultant force on the body in any direction is zero.
Newton's First Law of Motion	"An object continues to remain stationary or to move at a constant velocity unless an external force acts on it"
Newton's Second law of motion	The rate of change of momentum of a body is equal to the net external force acting on the body ($\Delta p/\Delta t=F$). ("Force = mass x acceleration")
Newton's Third Law of Motion	"Every action has an equal and opposite reaction"
Momentum	$p = mv$;always in direction of velocity.
Impulse	$I = F\Delta t$ where Δt is the time for which the force acts/ **The change in momentum**, where F is magnitude of the net force acting on a body.
Principle of conservation of momentum	total momentum of a system is constant, provided an external force does not act.
average speed vs instantaneous speed	average speed is the distance travelled divided by the time taken; instantaneous speed is the rate of change of distance at a given instant (in time);
Displacement vs Distance	Distance- total distance moved (scalar quantity) Displacement-object's overall change in position (vector quantity).
Work, Energy, & Power (2.3)	
Work (W)	Product of force and distance moved in the direction of the force. $W = Fcos\,\theta$
Power (P)	The rate of working OR work/time; units (Watts (W)) P=Fv P=$\frac{\Delta Work}{\Delta Time}$
Kinetic Energy (E_k)	Energy an object has due to its motion. $E_k= \frac{1}{2}mv^2$
Gravitational Potential Energy (E_p)	Energy an object has due to its position in a gravitational field. $E_p=mgh$
Principle of Conservation of Energy	The total energy of an isolated system remains constant.
Elastic Potential Energy	Energy associated with motion or position of an object
Efficiency (Eff)	The ratio of the useful energy (or power or work) output;

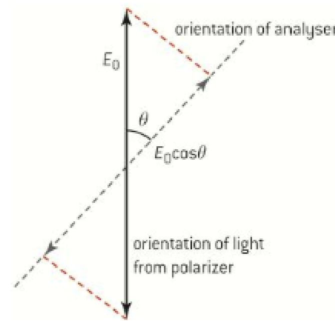
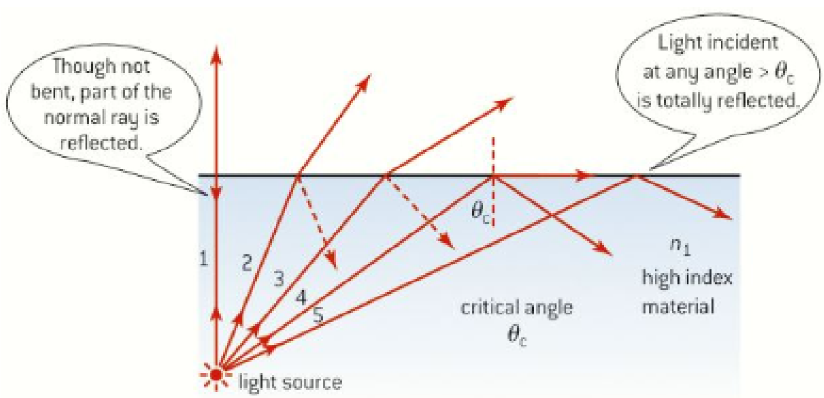
	to the total energy (or power or work) input. Eff = $\frac{Work\ out}{Work\ in} = \frac{Power\ out}{Power\ in}$
Elastic Collision	A collision in which kinetic energy is conserved; and momentum is conserved.
Inelastic Collision	A collision in which the kinetic energy is not conserved; but the **momentum is conserved.** Normal, everyday collisions are this.
Explosion	A single object that splits into two or more objects; momentum is conserved in this case.
Fields (5.1, 10.1, 10.2)	
Electric field strength	Force per unit charge on a small positive test charge placed at that point in the field.
Gravitational field strength	The force exerted per unit mass; on a point mass.
Gravitational Force (F_g)	The force exerted on a test mass.
E and G field shapes	Both electric and gravitational fields are 'Radial'.
Electrical potential	The work done in bringing a unit positive test charge from infinity to the point.
Gravitational potential	defined to be equal to the work done per unit mass (kilogram) in moving a test mass from infinity to the point in question.
Terminal velocity	When a falling object reaches a constant speed. F_d=mg.
Circular Motion (6)	
Properties of Circular Motion	● The force is always towards the centre and since F=ma, acceleration is also towards the centre. ● The velocity of the object undergoing circular motion is tangent to the circle. ○ (velocity changes because vector direction changes. Speed is scalar → constant) ● The centripetal force does not apply work on the object because it acts perpendicular to the direction of motion. (cos 90 = 0) ● Objects that undergo CM are never in equilibrium because a force is acting on them, they are changing direction and acceleration (towards centre) ○ → forces never cancel out
Angular displacement	The angle moved around the circle by an object from where its circular motion starts

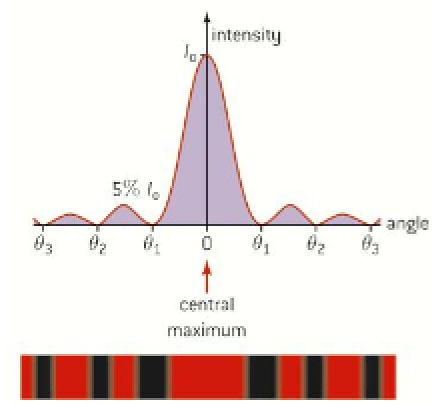
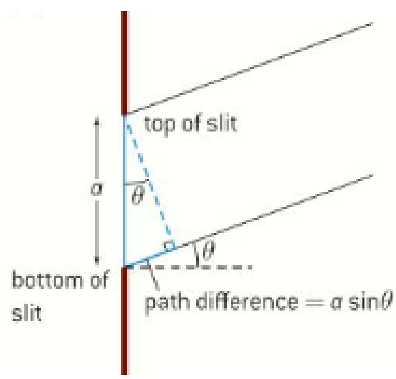
Thermal Physics (3)	
Specific heat capacity	The amount of energy/heat required to raise the temperature of 1 kg of a substance by 1K.
Mole	The amount of a substance that contains as many elementary entities as the number of atoms in 12g of the isotope carbon-12.
Assumptions of a kinetic model of an ideal gas	1. A gas consists of a large number of tiny molecules in constant random motion. 2. The number is large enough for statistical averages to be made. 3. Each molecule has negligible volume when compared with the volume of the gas as a whole. 4. At any instant as many molecules are moving in one direction as in any other. 5. The molecules undergo perfectly elastic collisions between themselves and their containers; during collisions each momentum of each molecule is reversed. 6. There are no intermolecular forces between the molecules between collisions (energy is entirely kinetic). 7. The duration of a collision is negligible compared with the time between collisions. 8. Each molecule produces a force on the wall of the container. 9. The forces of individual molecules will average out to produce a uniform pressure throughout the gas.
Heating	The non-mechanical transfer of energy.
Difference between boiling and evaporating	● Evaporation takes place at any temperature and boiling takes place at constant temperature; ● Evaporation takes place at the surface of the liquid and boiling takes place throughout the liquid.
Internal energy and thermal energy	Internal energy is the total kinetic and potential energy of the molecules of a body; thermal energy is a (net) amount of energy transferred between two bodies
Thermal energy transfer	The substance with the greater thermal energy will always transfer to the substance with a lower thermal energy through either conduction, convection, or radiation.
Specific latent heat of fusion	The energy required to change the phase of 1 kg of substance from a solid to a liquid without any temperature change. (known as melting)
Specific latent heat of vaporization.	The energy required to change the phase of 1 kg of liquid into a gas without any temperature change. (known as boiling)
Boyle's law	The pressure of a gas is inversely proportional to the volume. $p \, \alpha \, 1/V$
Charles's law	The volume of a gas is directly proportional to the absolute temperature. $V \, \alpha \, T$
"The third" gas law	For a gas of fixed mass and volume, the pressure is directly proportional to the absolute temperature. $p \, \alpha \, T$

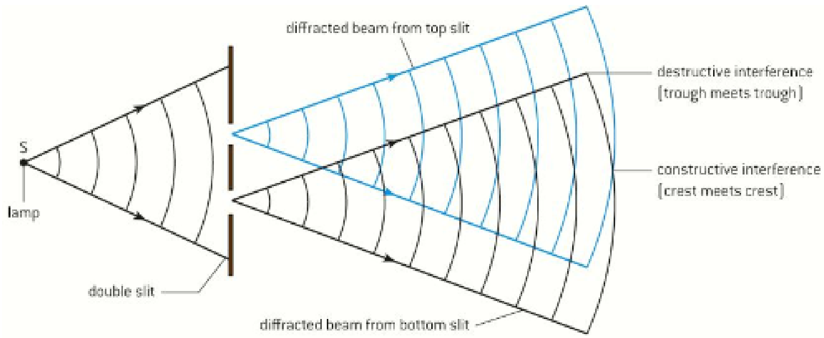
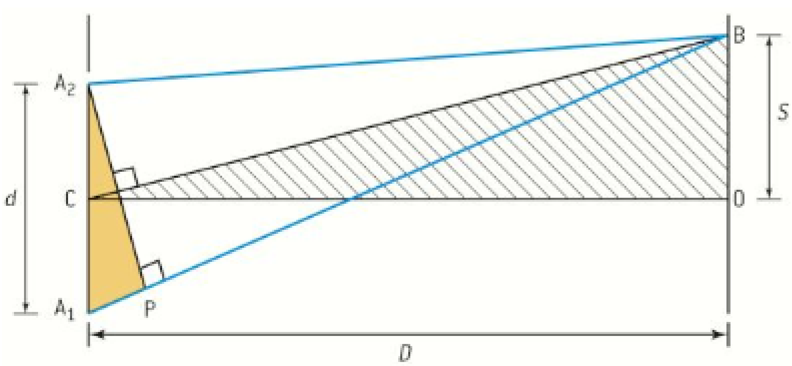
Oscillations, Waves, and Wave phenomena (4, 9)	
Simple Harmonic Motion	
Oscillation	The term used to describe the movement of a “particle” (can also be field) from a position “to and fro” back to its original position. Vibration is an alternative term
Displacement	Distance in a particular direction from its mean position;
Amplitude, x_0 [m]	Magnitude of the max displacement from the equilibrium position
Frequency, f [Hz]	Frequency: number of oscillations/vibrations per unit time;
Period, T [s]	Time taken for one complete oscillation
Hooke’s law	The tension on a spring is proportional and opposite to its extension; $F = kx$, where k is the spring constant, F is the force, and x is the displacement.
Phase difference	The fraction of an oscillation that one wave moves behind another. When the phase difference is 0 or T then two systems are said to be oscillating **in phase**.
Natural frequency	That frequency (or frequencies) at which a system oscillates when disturbed from its equilibrium state.
Resonance	A system resonates when a periodic force is applied to it and the frequency of the force is equal to the natural frequency of vibration of the system. ● maximum amplitude of oscillation
Damping	The process whereby energy is taken from the oscillating system (usually due to friction)
Total energy of an SHM system	The green line represents the total energy, the red curve the potential energy and the blue curve the kinetic energy. 

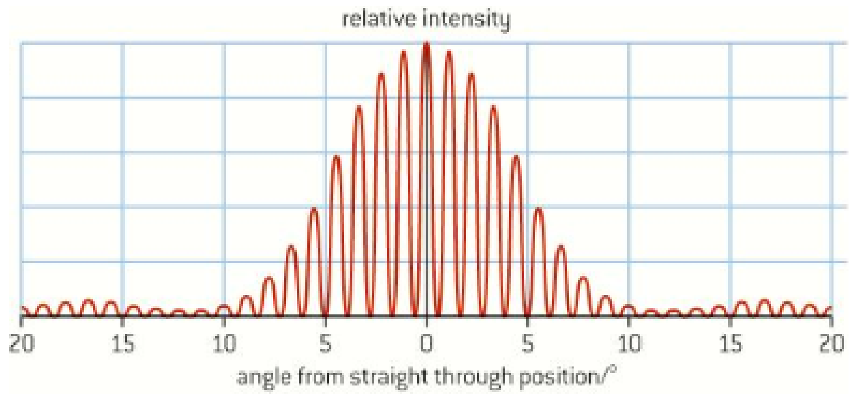
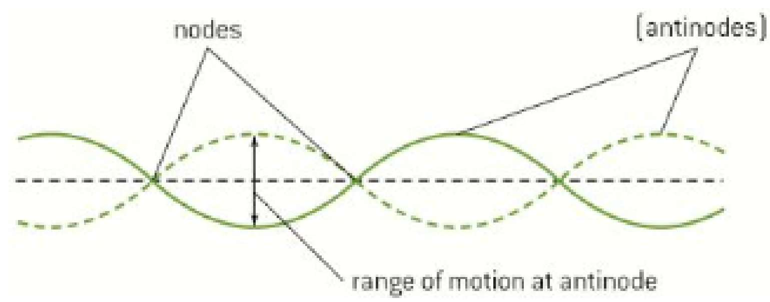
Travelling waves (4.2)	
Mechanical waves	Require a material medium through which to travel.
EM waves and spectrum	They are transverse waves that don't need a medium to travel, and are able to travel through a vacuum at *c*. (3×10^8 m/s) 
Transverse wave	Motion of both the particles and energy are **perpendicular** to direction of wave travel.
Longitudinal wave	Motion of the particles and energy is **parallel** to direction of wave travel.
	Characteristics of sound waves in air: ● Longitudinal. ● Displacement of oscillation is parallel to propagation of energy. ● Series of compressions and rarefactions.
Wave frequency	Number of vibrations per second by the source
Wave period	Time for one complete vibration performed by the source
Wavelength λ	Distance moved by wave during one oscillation of the source; Accept distance between successive crests or troughs.
Wave speed *c*	Distance travelled per unit time; by the energy of the wave / by a wavefront;
Compression and rarefaction	<u>Compressions:</u> Where particles are more **bunched up**. <u>Rarefactions:</u> Where the particles are more **spread out**.

Wave characteristics (4.3)	
Wavefront	Line joining (neighbouring) points that have the same phase / displacement. ● The distance between two wavefronts is λ.
Wave Ray	Direction in which wave (energy) is travelling
Wave behaviour	Waves can be reflected, refracted, and diffracted.
Wave intensity	Intensity is proportional to the square of the amplitude. ● Additionally, since $I = \frac{P}{4\pi r^2}$, Intensity is inversely proportional to the square of the distance. 
Superposition	When 2 or more waves of the same type meet, the total displacement at a point on a wave is the displacements of the individual waves added at that point.
Principle of superposition	When two (or more) waves meet; resultant displacement is the sum of the individual displacements;
Polarization	Polarization restricts the direction of oscillation to a plane perpendicular to the direction of propagation. ● Has no effect on longitudinal waves ● Most natural EM waves are unpolarized. ● The electric field and magnetic field vector vibrate in random directions (perpendicular to each other) Plane polarization: ● When the direction of vibration is constant over time. Partial polarization: ● When there is a restriction to direction of vibration but not 100%. 

Polarization filter (polaroid)	The electric field vibration components parallel to the direction of the alignment become absorbed. ● When two polaroids are held perpendicular to each other, no light is able to pass through. ○ The first polaroid is called the **polarizer** and the second is called the **analyser**.
Malus' law	In the polarization of light: $I = Io\ cos^2 \Theta$ *Remember that the light loses 50% intensity through passing the polarizer! 
Wave behaviour (4.4)	
Reflection and refraction	1. The reflected and refracted rays are in the same plane as the incident ray and the normal. 2. angle of incidence = angle of reflection 3. The ratio of the $\sin\Theta_i$ to $\sin\Theta_r$ is equal to the refractive index. (Snell's law) $\frac{\sin \theta_1}{\sin \theta_2} = {}_1n_2$
Refractive index	The absolute refractive index (*n*) of a medium is defined: $n = \frac{\text{speed of electromagnetic waves in a vacuum}}{\text{speed of electromagnetic waves in the medium}} = \frac{c}{v}$
	The ratio of the speed of light in vacuum to the speed of light in the medium / the ratio of the sine of the angle of incidence to the sine of the angle of refraction;
Total internal reflection	
Critical angle	The angle of incidence above which total internal reflection occurs. Calculating θ_C: $sin\theta c\ = \frac{1}{n1}$

	*When the less dense medium (medium 2) is a vacuum or air.
Diffraction and interference (4.4 and 9.2)	
Diffraction	The spreading out of a wave around the corners of an aperture into the region of geometrical shadow of the obstacle. ● The effect is most obvious when the slit width is approximately equal to the wavelength of the waves. ● The amplitude of the diffracted wave is less than the incident wave because energy is distributed over a larger area.
Coherent	Sources whose phase difference is constant and are of the same frequency.
Monochromatic	single frequency / single colour.
Single slit diffraction and equation	Pattern: ● The central maximum has twice the angular width of the secondary maxima. ● Intensity is proportional to square of amplitude.   $\theta = \frac{\lambda}{a}$ The position of other minima (shown in figure 1) will be given by $\theta = \frac{n\lambda}{a}$ (where $n = 2, 3, 4, \ldots$) but you will not be examined on this relationship. ● This is the equation of the first **minimum.**
Interference	When two waves meet, the resultant displacement is found by adding individual displacements. ● Constructive interference: ○ The amplitude is greater than that of an individual wave. ● Destructive interference:

	○ The amplitude is smaller than that of an individual wave.
Double-slit interference	When a coherent beam of light is incident on two narrow slits very close together, the beam is diffracted at each slit.  ● When a crest meets a crest (or a trough meets a trough) → constructive interference. ● A crest meets a trough → destructive interference.
Path difference And double-slit equation	 Rearranging gives $s = \frac{\lambda D}{d}$ For two coherent beams starting in phase: ● For constructive interference, path difference must $= n\lambda$ ● For destructive interference, path difference must $= (n + \frac{1}{2})\lambda$ ○ n is the order of the fringe.

Pattern of double-slit diffraction	
Standing waves (4.5)	
Standing wave	Formed when two travelling waves of **equal amplitude** and **equal frequency** travelling with the same speed in opposite directions are superposed. ● No energy is transferred ● Stays in the same position ● All particles vibrate with same frequency (other than stationary nodes)
Nodes and antinodes	
Dispersion	light (that is a combination of colors/wavelengths/frequencies) is divided/split into its component colours/wavelengths/frequencies;
	Optical dispersion: 1. The speed of light in a medium depends on frequency; 2. The refractive index depends on frequency; 3. Light of different frequencies refracted by different amounts.
Harmonics on strings	

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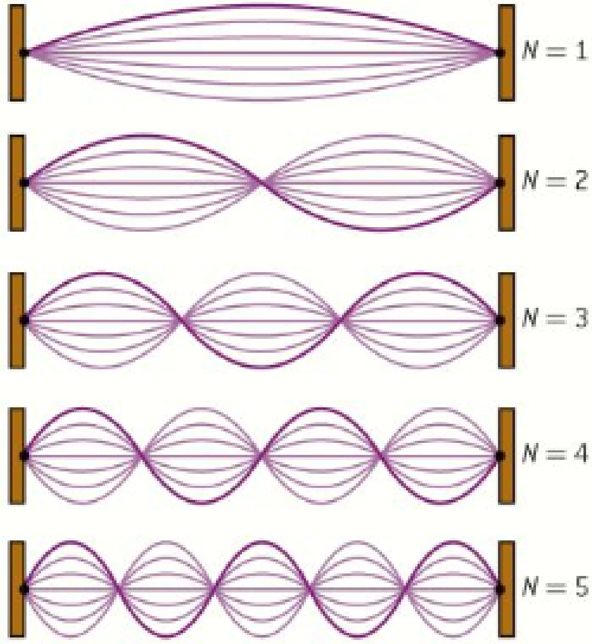
<td>
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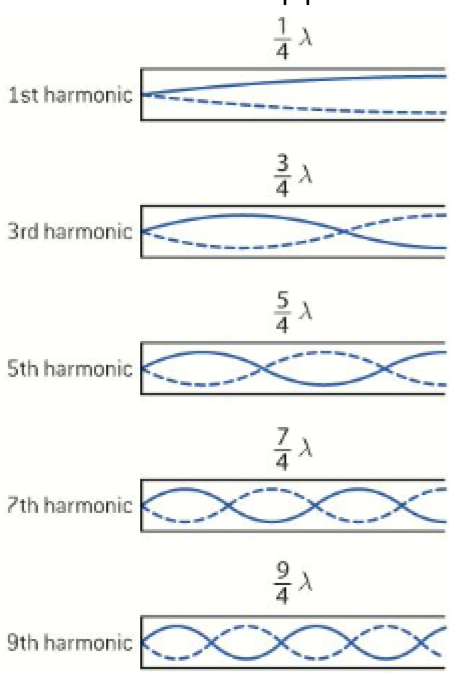
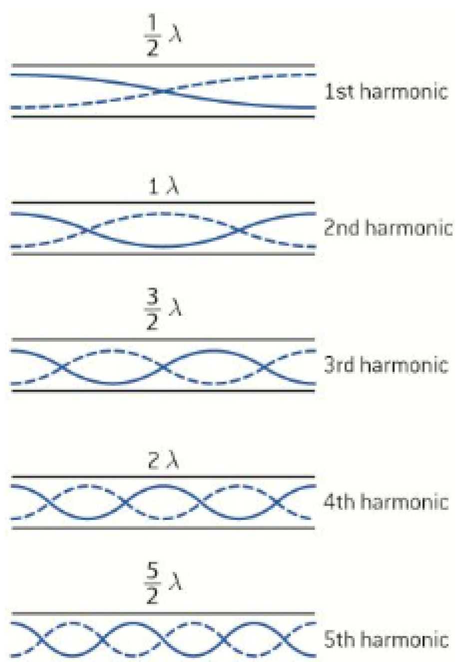
<td>Standing waves in pipes</td>
<td>“A harmonic is named by the ratio of its frequency to that of the first harmonic”
The waves are longitudinal
Harmonics for closed pipes:


Harmonics for open pipes:

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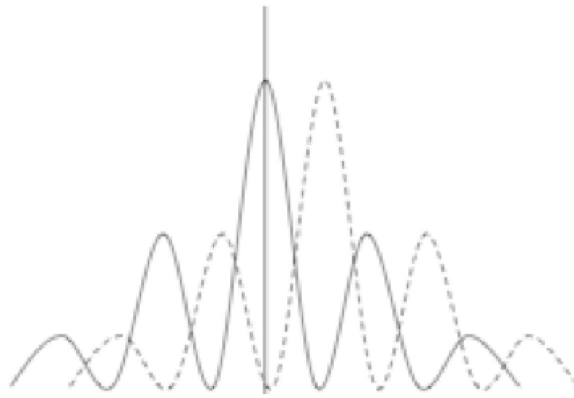
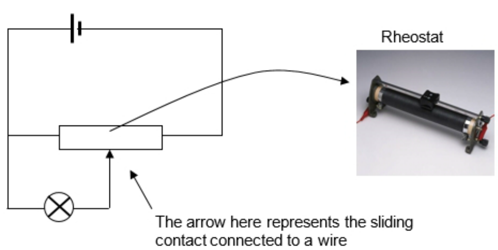
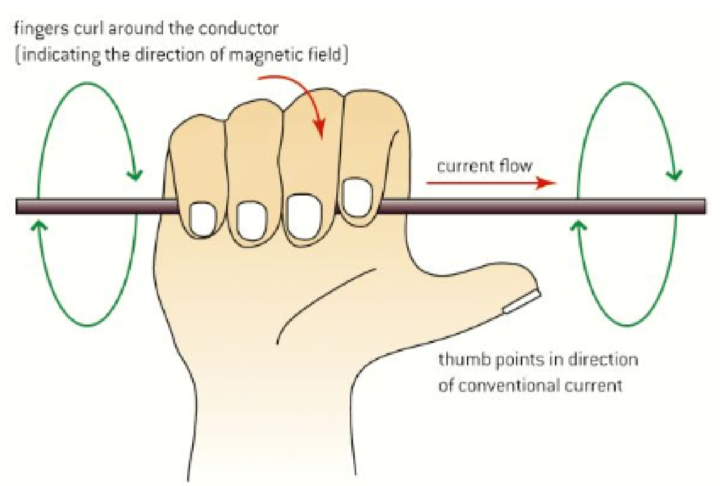
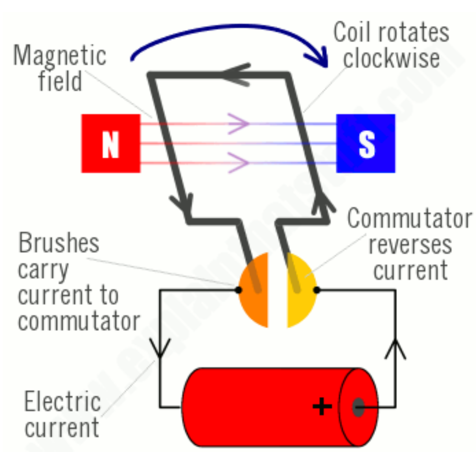
Doppler effect	The change in received frequency of sound (wave); as a result of relative motion of source and observer;
	the difference between the emitted and received frequency; when there is relative motion between the source and the receiver;
Rayleigh criterion	The maximum of one diffraction pattern is coincident with the first minimum of the other; 

Electricity, Magnetism and fields (5, 10, 11)	
Electric Circuits and cells (5.2, 5.3, 11.2, 11.3)	
Coulomb	The charge transported by a current of one ampere per second.
Coulomb's law	Force is proportional to the product of the size of the point charges q1 and q2. Also inversely proportionate to the square of the distance.
Drift speed	The slow speed at which the ions move along a conductor.
Conductor and Insulator	A conductor contains free moving electrons, an insulator does not.
Resistance	$\frac{\text{the pd across a component}}{\text{the current in the component}}$ Conducting electrons transfer kinetic energy by interacting with vibrating ions.
Electric current	The flow of charge
Potential difference	The work done when one unit of charge moves between two points.
Electromotive force	The work done per unit charge in moving charge completely around the circuit.
Emf of a cell	The terminal pd when no current is supplied.
Electronvolt (eV)	The energy gained by an e^- when it moves through a potential difference of 1V.

Ampere	The current which when flowing in two infinite parallel wires 1m apart produces a force of $2 \cdot 10^{-7} N/m$.
Ammeter	• measure current • connected in series • ideally has zero resistance
Voltmeter	• measures voltage • connected in parallel • ideally has infinite resistance
Ohm's law	The pd across a conductor is proportional to the current in the conductor unless the physical conditions of the conductor changes.
Non-ohmic filament resistance	Increases with temperature.
Semi-conductor resistance	Decreases with temperature.
Resistivity	Dependent on dimensions of conductor.
Potential Divider	A circuit that is able to vary (divide) the potential difference of the supply. A common potential divider circuit includes the rheostat. The **resistance is varied by changing the length** of the wire that passes through via the sliding terminal in the middle Rheostat (wire wound resistor) used as a potential divider 
Cells	Primary cells are non-rechargeable, while secondary cells can be recharged.
Capacity of a cell	The constant current supplied for a given discharge.
Capacitance	The ratio of the charge between the plate per volt. can only change because of a physical characteristic change. (increase A or d)
Dielectric	an electric insulator.
internal resistance of a cell	$r = \frac{\varepsilon - IR}{I}$

Magnetism (5.4, 11.1)	
Types of magnetism	Paramagnetism • The domains tend to be randomly oriented when no magnetic field, and align under a magnetic field. Ferromagnetism • The domains have the tendency to become aligned parallel to each other under the influence of a magnetic field. Unlike paramagnets the domains remain aligned. (permanent magnets)
Magnetic force	The attraction or repulsion that arises between charged particles due to their motion.
Magnetic field strength (B)	$B = \frac{F}{Il}$, unit tesla (T) **The magnetic field strength is numerically equivalent to the magnetic flux density.**
Strength of the magnetic field in a solenoid	Can be increased by: • Increasing the current • Increasing the number of turns (N) • Adding an iron core inside the solenoid.
Right hand rule	
Electromagnetic induction	The phenomenon that occurs when a movement or change in a magnetic field relative to a stationary charge gives rise to an electric current.
Magnetic Flux	product of normal component of magnetic field strength and area that it links
Magnetic flux density	The amount of flux per area. $B = \frac{\Phi}{A}$
magnetic flux linkage	product of number of turns in a coil and the flux through the coil

<table>
<tr><td>Weber (Wb)</td><td>Unit of flux defined as such: “a rate of change of flux of one 1Wb/s induces an emf of 1V across a conductor.”</td></tr>
<tr><td>Faraday’s law of electromagnetic induction</td><td>the induced emf is equal to the rate of change of the magnetic flux linkage.</td></tr>
<tr><td>Lenz’s law</td><td>The direction of the induced current is such as to oppose the change that created the current.</td></tr>
<tr><td colspan="2">Power generation and transmission</td></tr>
<tr><td>motors</td><td>


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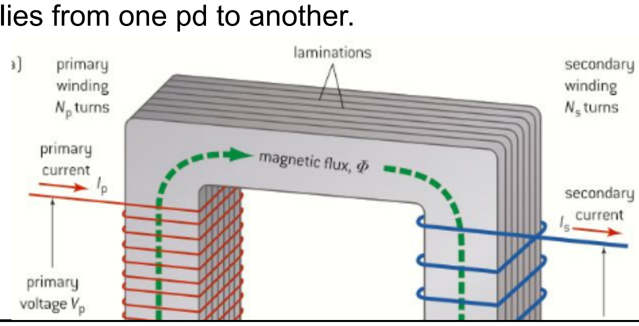
<tr><td>Root mean square</td><td>The average power/current/voltage in an ac circuit.</td></tr>
<tr><td>Transformer</td><td>Used to change alternating supplies from one pd to another.
They consist of three parts:
Primary (input) coil.
Secondary (output) coil.
Iron core on which both coils are wound.


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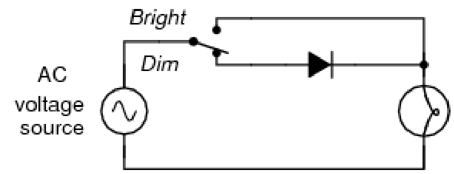
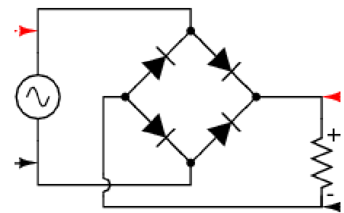
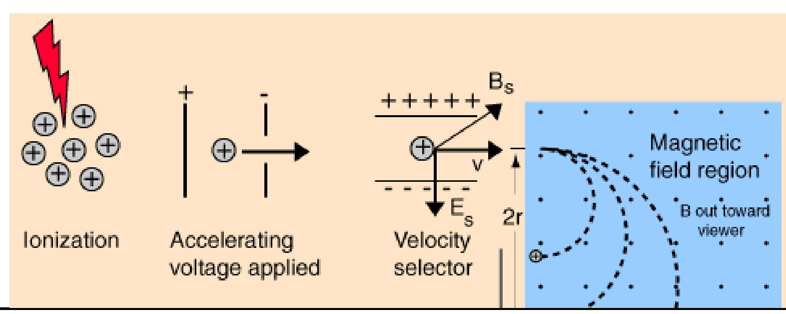
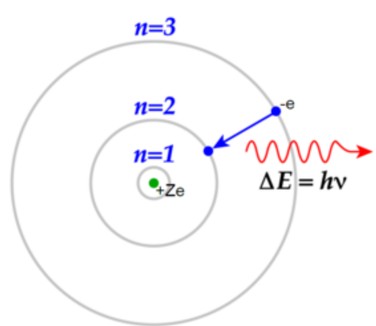
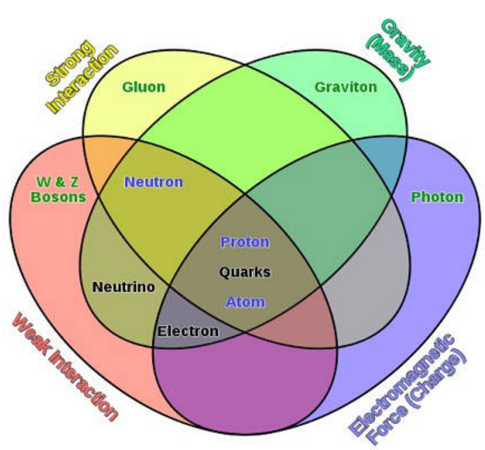
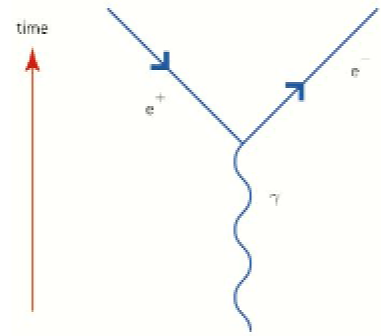
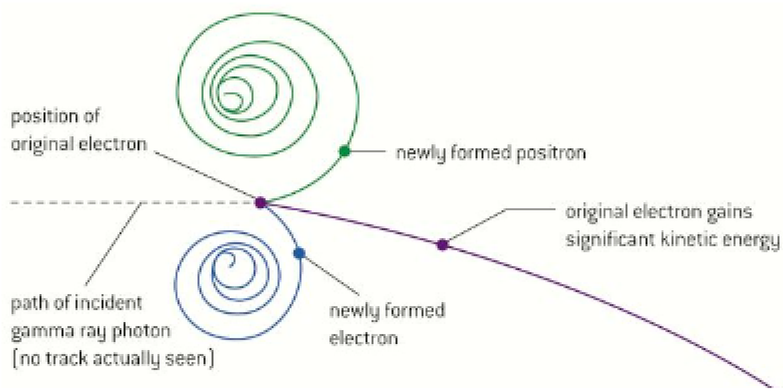
Energy loss in transformer	Eddy currents (current flowing inside the core) → prevented by laminating the core. Joule heating (high resistance coils lead to heating losses)
AC Rectification (Juan or tomas pls)	A diode conducts electric current in only one direction. <u>Half wave:</u> Allows half of an AC waveform to pass through. <u>Full wave:</u> Allows full rectification through a diode bridge.  

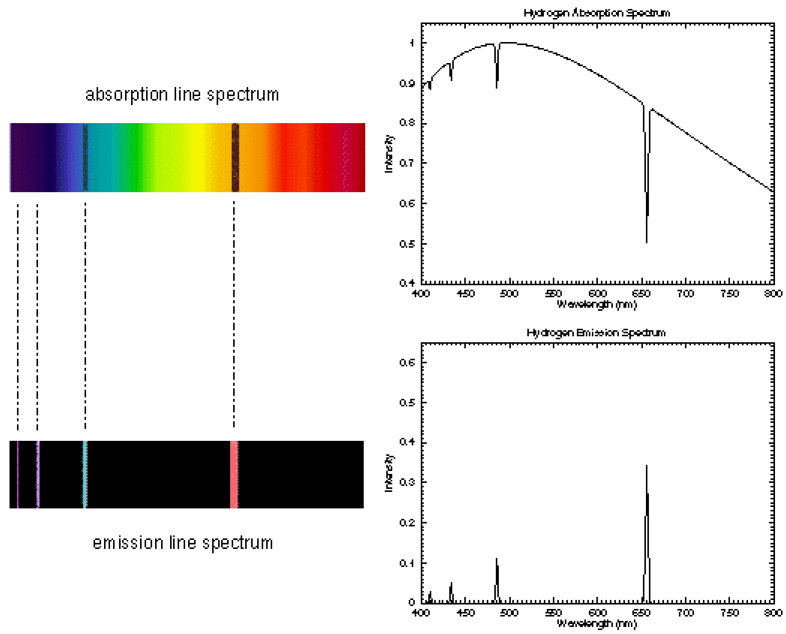
Atomic, nuclear, and particle physics (7, 12)	
Discrete energy and nuclear reactions (7.1 and 7.2)	
Nuclide	a species of atom characterized by the number of protons and neutrons in the nucleus.
Isotopes	same number of protons in the nucleus but different number of neutrons / OWTTE;
Unified Atomic Mass Unit	1/12 of the mass of a carbon-12 atom =$1.66x10^{27}kg$
Bainbridge Mass Spectrometer (determining mass of nuclei)	Sample of atoms put into its gaseous state are bombarded with electrons to leave the remaining nucleus. These are then accelerated through an electric field and deflected by a magnetic field, and then received by a detector. Mass of the nuclei can then be determined by v = E/B If a moving ion enters a constant magnetic field B, it will follow a circular path where the magnetic force provides the centripetal force. $Bqv=mv^2/r$ where r is the radius of the circle radius of circle will depend on mass of the ion, a larger mass ion will travel in a larger circle. 

Strong Nuclear Force	Force that acts between neighbouring nucleons within the nucleus with a range of 10^{-15}m or 1fm.
Weak Nuclear Force	Responsible for beta decay. The W and Z particles responsible for weak interactions are massive. It is the only mechanism by which a quark can change into another quark. It acts on a range of 10^{-18}m.
Electromagnetic Force	Can be attractive or repulsive and acts upon all charged particles. is responsible for the binding of atoms, creation of magnetic fields.
Binding energy	The work needed to overcome the strong nuclear force and deconstruct a nucleus from nucleons.
Mass defect	Difference between the mass of the nucleus and the sum of the masses of the individual nucleons.
Excited state	An atom with an electron occupying an energy level higher that the ground state.
Photon	A discrete unit or package of light energy.
Nuclear Fusion	Two light nuclei join to form a heavier nuclei (The main source of the sun's energy)
Nuclear Fission	A heavy nucleus splits into two smaller nuclei of roughly equal mass.
Transmutation	The conversion of one element to another by capture or emission of a particle.
Alpha Decay	In alpha particle decay, an unstable nuclei emits a particle of the same configuration as a helium nucleus He_2^4.
Negative Beta Decay	An unstable nuclide emits an electron accompanied by antineutrino. the antineutrino has no proton or nucleon number.
Positron Decay (positive beta)	In positron of positive beta-particle emission, an unstable nuclide emits a positron accompanied by neutrino.
Gamma Ray Emission	High energy electromagnetic radiation.
Half Life	The time it takes for radioactive activity to fall by half its original value.
Natural Radioactive Decay	The random spontaneous process where unstable radioisotopes decay releasing gamma rays, alpha particles, and beta particles exponentially decreasing over time.
Decay Constant	the probability that an individual nucleus will decay in a given time interval.
The structure of matter (7.3)	

Antiparticle	A subatomic particle with the same mass as a given particle but opposite electric or magnetic properties.
Lepton and antilepton	Fundamental particles, not affected by the strong force, such as an electron, muon, tau, or their antiparticles, neutrinos, or antineutrinos.
Muon	an unstable lepton, but with $\frac{1}{9}$ mass of a proton. Muons make up much of the cosmic radiation reaching the earth's surface.
Quark	A subatomic particle carrying a fractional electric charge, postulated as building blocks of the hadrons.
Meson	A subatomic particle composed of two quarks and transmits the strong interaction that binds nucleons together in the atomic nucleus.
Baryon	A subatomic particle composed of three quarks, (e.g. p^+)
Hadron	Particles made up of quarks and include either or, baryons and mesons.
Lepton Conservation	All leptons have lepton number of +1 and anti leptons have lepton number -1.
Strangeness	one of six flavors of quark.
Virtual particle	A particle that appears as an intermediate particle in a Feynman diagram / a particle that is not observed and may violate energy and momentum conservation at a vertex;
Neutral current	a process in which the intermediate particle is the Z^0 / a process involving Z^0 exchange;
Differences between a photon and a W boson.	rest mass is non-zero for W, zero for photon; range of photon is infinite, not for W; photon carries electromagnetic force, W weak force; photon is uncharged, W is charged;
Exchange particle.	a particle that mediates one of the fundamental forces
Higgs Boson	An elementary particle responsible for giving masses to quarks, leptons and are the exchange particles of the weak interaction.
Quantum and nuclear physics (12)	
Photoelectric effect	The observation that metals emit electrons when light shines upon them. Each photon interacts with a single electron.
Threshold frequency	The minimum photon frequency for the photoelectric effect to occur.
Work Function	Energy needed to do the work to overcome the attractive forces that act on the electron

	within the metal.
Describe the de Broglie hypothesis and the concept of matter waves.	•all moving particles have a "matter wave" associated with them. •all particles can act and travel as waves (wave-particle duality) with a wavelength of $\lambda = \frac{h}{mv}$.
Heisenberg Uncertainty Principle	It is impossible to know both the momentum and the position of a particle at the same time. $\Delta x \Delta p = \frac{h}{4\pi}$ and/or $\Delta E \Delta t = \frac{h}{4\pi}$
Quantum mechanics	The Bohr Model
Bohr Model	
Schrodinger's wave function	ψ describes the quantum state of the particles. The square of the wave function $\lvert\psi\rvert^2$ represents the probability of finding an electron distance r from the nucleus.
Copenhagen interpretation	States that a particle exists in all states at once until observed. (Nothing is real unless observed)
Fundamental forces	
Quantum tunnelling	A particle's wave function has a finite probability physical

	of being everywhere in the universe at the same time. A particle can “borrow” energy from its surroundings, pass through a barrier and pay the energy back. Quantum tunnelling is responsible for low temperature fusion in main sequence stars.
Pair production and annihilation	Under a strong electric field, the spontaneous conversion of a photon with minimum energy E=2mc^2 to a particle along with its antiparticle. The feynman diagram:  When a particle meets its antiparticle they annihilate and form two photons. 

Emission Spectra & Absorption Spectra	 Two ways of showing the same spectra: on the **left** are pictures of the dispersed light and on the **right** are plots of the intensity vs. wavelength. Notice that the pattern of spectral lines in the absorption and emission line spectra are the **same** since the gas is the same.

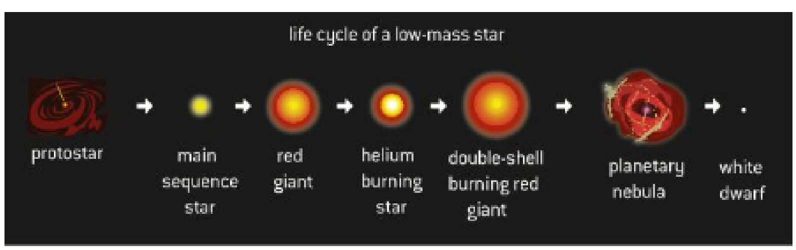
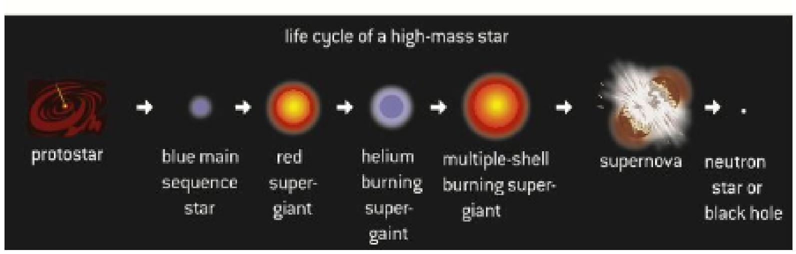
Energy Production and Transfer (8)	
A primary source of energy	One that has not been transformed or converted before use by the consumer. (e.g. fossil fuels)
A secondary source of energy	One that results from the transformation of a primary source. e.g. electrical energy is generated from the conversion of a primary source of energy.
Renewable energy source	Can be replenished in relatively short times (on the scale of a human lifetime), e.g. biomass. Or can be continually generated from the sun's energy, e.g. wind and water sources.
Non-renewable energy source	Can be replaced but only over very long geological times.
Energy degradation	Thermal energy transferred to the surroundings / energy that is converted to thermal energy; that is no longer available to produce useful work / OWTTE;
Fuel + examples	Source of energy (in a useful form) Example: peat, coal, oil, gas, etc.
Explain why fossil fuels are said to be non-renewable	Rate of production of fuel much smaller than rate of usage; so fuel will be exhausted/run out;

Primary Sources: Energy Sources			
		Source	**Energy From**
Non-renewable sources	**Nuclear fuels**	uranium-235	Nuclear
	Fossil fuels	crude oil	Chemical potential
		coal	
		natural gas	
Renewable sources		Sun	Radiant (Solar)
		Water	Kinetic
		Wind	Kinetic
		Biomass	Chemical Potential
		Geothermal	Internal

Energy Transfer (8.2)	
Thermal Equilibrium	The rate of energy absorbed is equal to the rate of energy emitted → temperature stays constant.
Blackbodies	Perfect absorbers and emitters of radiation.
Albedo	The fraction of light that is reflected by a body or surface. $a = \frac{energy\ reflected\ by\ a\ given\ surface\ at\ any\ given\ time}{total\ energy\ incident\ on\ the\ surface\ at\ the\ same\ time}$
Emissivity	The ratio of the radiation emitted by a surface to the radiation emitted by a blackbody at the same temperature. $e = \frac{power\ emitted\ by\ radiating\ object}{power\ emitted\ by\ a\ black\ body\ of\ the\ same\ dimensions\ at\ the\ same\ temperature}$
Solar Constant	Amount of solar energy that falls per second on an area of 1m² above the earth's atmosphere that is at right angles to the sun's rays
Greenhouse effect	Phenomenon in which certain gases in the earth's atmosphere absorb IR radiation and re-emit in all directions within the Earth system and produce a consequent rise in the average temperature of the Earth. (CO_2, H_2O, CH_4, N_2O)
Natural greenhouse effect vs. Enhanced	Natural: due to the naturally occurring levels of greenhouse gases Enhanced: due to an increased concentration of greenhouse gases, possibly as a result

Greenhouse effect	of human derived processes (burning fossil fuels, etc.)
Resonance	When the frequency of a photon matches the vibrational state in a greenhouse gas molecule, resonance occurs.
Conduction	The direct transfer of heat between objects that touch.
Convection	The transfer of heat as a result of rising warm gas or liquid.
Radiation	The transfer of heat through space by waves.

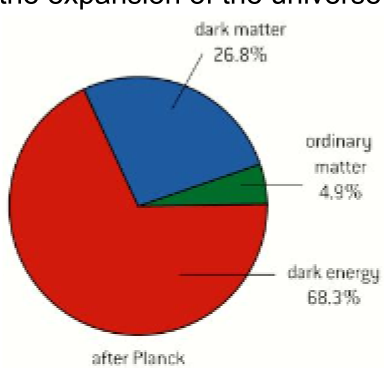
Astrophysics (Option D)	
Constellation	A group of stars distant in space that form a recognizable pattern viewed from Earth.
Stellar cluster	A group of stars (including gas and dust) held together by gravity forming a globular/open arrangement / a group of stars close to each other (in space);
Binary stars	Consist of two stars that rotate around a common centre of mass.
Luminosity of a star	The total power radiated by the star.
Apparent brightness	The power per square meter received at the surface of Earth/observer;
Black body	A perfect emitter and absorber of light
Standard candle	Star with a known luminosity
Hydrostatic equilibria	The balance between radiation pressure from fusing nuclei, and gravitational pressure.
Wien's (displacement) law	Explains why stars are different colours. Using the blackbody model, stars have a peak emission wavelength. Hot stars have a shorter peak wavelength while cooler stars have a longer one. $\lambda_{max} = \frac{2.9\times10^{-3} m\cdot K}{T}$
Astronomical distances to Stars	

Stellar Parallax (Method)	The apparent shifting of a star against a background of very distant fixed stars when viewed from two different points. ● Angular position of star measured ● relative to the background of fixed stars ● in two positions six months apart Only applicable for stars no more than a couple of parsecs away from Earth.
Cepheid variable	A star which has luminosity that varies periodically over time due to the outer layers undergoing periodic expansion and contraction causing variations in surface area and temperature. 1. Measure period of star (brightness against time) 2. look up which luminosity corresponds to that period 3. since you know L and measure b, use formula to find distance. Also known as ‘standard candles’ because they allow us to measure the distance to galaxies containing cepheid variable stars.
Hubble's Law	The recessional velocity of a galaxy is proportional to its distance away from Earth. Assumption made when calculating age of universe from hubble constant: ● Assumes that the universe has always had a constant rate of expansion.
Big bang evidence	The cosmic microwave background (CMB) is the thermal radiation left over from the time of recombination in Big Bang cosmology. Approx. 2.7K Universe is expanding because every distant galaxy is moving away from us.
Fate of Stars	
Evidence of black holes	● The X-rays emitted by matter spiralling towards the edge of a black hole and heating up has been measured by NASA telescopes. ● Unimaginably strong gravitational fields have been seen to spiral stars; a black hole has been detected in the centre of the milky way.
Life cycle of low vs high mass stars	 
Chandrasekhar Limit	The upper limit to the mass of a white dwarf, equal to 1.44 solar masses. Further

<table>
<tr><td></td><td>collapse is restricted by electron degeneracy pressure.
IB: sets upper limit on mass of white dwarf;</td></tr>
<tr><td>Oppenheimer-Volkoff Limit</td><td>The upper limit on a neutron star for which neutron degeneracy is able to resist further collapse into a black hole. $1.5<M<3$ solar masses
IB: sets upper limit on mass of neutron star;</td></tr>
<tr><td>Supernovae</td><td>They are classified as Type I or Type II in terms of their absorption spectra.
<table>
<tr><td></td><td>Type Ia</td><td>Type II</td></tr>
<tr><td>Absorption spectra</td><td>No hydrogen line
Strong silicon line</td><td>Hydrogen line</td></tr>
<tr><td>Produced by</td><td>The accretion of matter between a white dwarf and another star (binary)</td><td>Young, massive stars (8-10 solar masses)</td></tr>
<tr><td>Property</td><td>Behave as a standard candle (can determine distance from luminosity)</td><td>Collapse of star to form supernovae fuses heavier elements (>Fe)</td></tr>
</table></td></tr>
<tr><td colspan="2">Fate of the universe</td></tr>
<tr><td>Critical density</td><td>The theoretical value of the density that would create a flat universe, has been measured as 4.5 x 10^{-27} kgm^{-3} but this is not a certain value.

Density at which the universe will expand forever but the rate of expansion will approach zero.</td></tr>
<tr><td>Open universe</td><td>A universe which continues to expand and gravity slows the rate of expansion but cannot stop it.
Density of universe $<$ Critical Density</td></tr>
<tr><td>Closed universe</td><td>A universe which will eventually collapse on itself resulting in a big crunch, (the reverse of Big Bang)
Density of universe $>$ Critical Density</td></tr>
<tr><td>Flat universe</td><td>In-between an open and closed universe, gravity keeps slowing down the expansion but theoretically it takes infinite time to come to rest.
Density of universe = Critical Density</td></tr>
<tr><td>Accelerated expansion of the universe</td><td>By using Type Ia supernovae as standard candles to estimate galactic distances and measure their redshifts, evidence suggested the universe is undergoing an accelerated expansion.

The universe contains a significant amount of baryonic matter that should slow down</td></tr>
</table>

	its expansion. This acceleration should therefore require a form of invisible energy, namely, dark energy.
The Cosmological Principle	Einstein made two assumptions about the cosmos: 1. The universe is homogenous. (the same everywhere) 2. The universe is isotropic. (there is no centre)
Dark matter	Undetectable matter that emits no radiation. Evidence is found when considering the rotational curve for spiral galaxies, where theoretically $v \alpha \frac{1}{\sqrt{r}}$. Dark matter can either be: ● MACHOs (Massive compact halo objects) ○ Include black holes, neutron stars, brown dwarfs. ● WIMPs (weakly interacting massive particles) ○ Non-baryonic subatomic particles with mass (small) ○ Possibly neutrinos.
Dark energy	Undetectable energy that overcomes the gravitational pull of matter and accelerates the expansion of the universe. 
Anisotropies in the CMB	Anisotropies are minute temperature fluctuations in the essentially isotropic reading of the universe. They result from tiny random variations in density, implanted during cosmic inflation (380,000 years old). This revelation is important because the universe has structure (solar systems, galaxies, clusters, etc.) and structures only develop if there are fluctuations in density/temperature (which is what the anisotropies show).