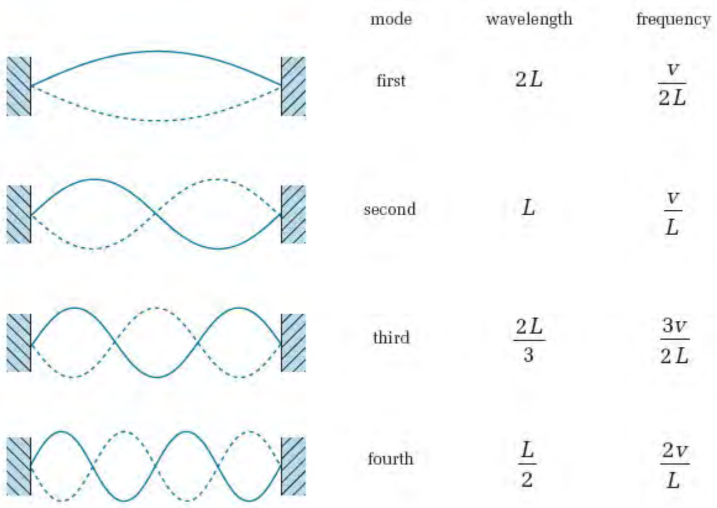
Define	
define the *coulomb*	The SI unit of electrical charge. One Coulomb is defined as the amount of charge that passes in 1 second when the current is 1 ampere.
define *potential difference* (p.d.);	Energy transfer per unit charge from electrical to other forms.
define the *volt*	1 Volt is equal to 1 Joule per Coulomb (JC^{-1}) The potential difference across a component is 1 volt when you convert 1 joule of energy moving 1 coulomb of charge through the component.
define *electromotive force* (e.m.f.) of a source such as a cell or a power supply	Energy transfer per unit charge from chemical/other to electrical form. Measured in V or JC^{-1}
define *resistance*	Resistance = Potential difference/current . Accept voltage instead of p.d.; ratio of voltage to current; voltage per (unit) current (VA^{-1}) resistance = p.d./current
define the *ohm*	A component has a resistance of 1 ohm if a potential difference of 1 volt makes a current of 1 amp flow through it.
define *resistivity* of a material	Resistivity is equal to the product of the resistance and cross sectional area divided by the length. P=RA/l
define the kilowatt-hour (kW h) as a unit of energy	A unit of energy equal to 36 MJ or 1kW for 1h (a unit of) energy equal to 3.6 MJ or 1 kW for 1 h/AW
define and use the terms *displacement*, *amplitude*, *wavelength*, *period*, *phase difference*, *frequency* and *speed of a wave*	Displacement-how far a point on the wave has moved from its undisturbed position. Displacement-Distance from the mean position expressed as a vector Amplitude- Maximum displacement Wavelength-Distance between neighbouring identical points Period-Time taking for one complete oscillation of a particle Phase Difference- The fraction of a cycle between the oscillations of two particles Frequency-Number of waves passing a point per unit time Speed-Distance travelled by the wave per unit time
define the terms *nodes* and *antinodes*	Node-When the amplitude is always zero Antinode-When the amplitude is always at its maximum possible value
define and use the terms *fundamental mode of vibration* and *harmonics*	Simplest pattern of movement and has the lowest possible frequency band and the longest wavelength Harmonics are different modes of vibration of a wave with increasing frequency and decreasing wavelength

	
define and use the electronvolt (eV) as a unit of energy	Electronvolt is defined as the kinetic energy gained by an electron when it is accelerated through a potential difference of 1 volt. 1 eV is gained or lost when an electron moves through a potential difference of 1V Energy acquired by an electron accelerated through a p.d of 1V. $1eV = 1.6 \times 10^{-19}$ an eV is the energy to accelerate/move an electron through a p.d. of 1 1 eV = 1.6×10^{-19} J – NOT a definition
define and use the terms *work function* and *threshold frequency*	Work function- the minimum energy required to release an electron from the surface of a material Threshold frequency- the lowest possible frequency of a photon that will cause and electron to be emitted from the material.
Define the term intensity	intensity is the (incident) energy per unit area per second Intensity is the rate of flow of energy per unit area at right angles to the direction of travel of the wave. It is measured in Wm-2. -number of photoelectrons emitted per second is proportional to the intensity of the radiation.

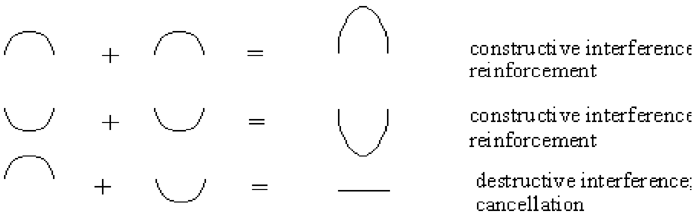
State	
state what is meant by the term *mean drift velocity* of charge carriers	The average distance travelled by the charge carriers along the wire per second
state and use Ohm's law	Provided the temperature is constant, the current through an ohmic conductor is directly proportional to the potential difference across it. R=V/I -This means the resistance is constant.
state Kirchhoff's second law and appreciate that this is a consequence of conservation of energy	Energy is conserved (sum) of e.m.f's = sum/total of voltages/p.d.s in/around a (closed) loop (in a circuit)
state typical values for the wavelengths of the different regions of the electromagnetic spectrum from radio waves to γ-rays	Visible 600-400nm (5 x 10^{-7}) UV-A 400-315nm UV-B 315-260nm UV-C 260-100nm Radio Waves (10^{-1} to 10^{6}) Micro waves (10^{-3} to 10^{-1}) Infrared (7x10^{-7} to 10^{-3}) x-rays (10^{-13} to 10^$^{-8}$) Gamma rays (10^$^{-16}$ to 10^{-10})
state that all electromagnetic waves travel at the same speed in a vacuum (this is one property of electromagnetic waves not shared by other waves)	
state that light is partially polarised on reflection If you direct a beam of unpolarised light at a reflective surface then view the reflected ray through a polarising filter, the intensity of the light leaving the filter changes with the orientation of the filter. Intensity changes because light is partially polarised when it is reflected.	
state and use the principle of superposition of waves	When two or more waves meet (at a point and interfere), The (resultant) displacement equals the (vector) sum of the displacements of each wave.
state what is meant by constructive interference and destructive interference	Interference is when (two) waves meet/combine/interact/superpose (at a point) and there is a change in overall intensity/displacement. A crest plus a crest makes an even bigger crest, this is the same with two troughs, these two are both constructive interference. However when a crest hits a trough of equal size it gives nothing, this is destructive interference.
state that a photon is a quantum of energy of electromagnetic radiation. Einstein suggested that photons are wave packets of electromagnetic radiation that carried the energy. He said that photons act as particles can either transfer all or none of its energy when colliding with another particle. Max Planck said that EM waves can only be released in packets called quanta. So a photon is a single quantum of EM radiation.	
state that energy is conserved when a photon interacts with an electron. Photons either	

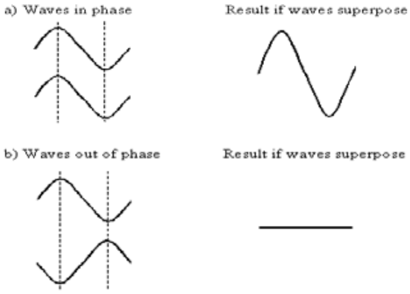
transfer all or none of their energy when the interact with another particle.
state that the charge carriers in an electrolyte are ions. Once molten the liquid conducts, the positive and negative ions are the charged carriers. Same thing in ionic solution.
state that the charge carriers moving through wires are electrons. Wires are made of metal, and in metal the charged carries are free electrons-they're the ones in the outer shell of each atom.

Select and use (Refer to the Formula sheet)	
select and use the equation	$\Delta Q = I\Delta t$
select and use the equation	$I = Anev$
select and use the equation	$W = VQ$
select and use the equation for resistance	$R = V/I$
select and use the equation	$R = \rho L/A$
select and use power equations	$P = VI$ $P = I^2R$ and $P = V^2/R$
select and use the equation	$W = IVt$
select and use the equation for the total resistance of two or more resistors in series	
select and use the equation for the total resistance of two or more resistors in parallel	
select and use the equations and	e.m.f. = $I(R + r)$, e.m.f. = $V + Ir$
select and use the potential divider equation:	$V_{out} = \frac{R_2 \times V_{in}}{R_1 + R_2}$
select and use the wave equation	$v = f\lambda$
select and use the equation for electromagnetic waves	$\lambda = ax/D$
select and use the equation	$d\sin\theta = n\lambda$
select and use the equations for the energy of a photon:	$E = hf$ and $E = hc/\Lambda$
select, explain and use Einstein's photoelectric equation	$hf = \varphi$ + KEmax
select and apply the de Broglie equation	$\lambda = h/mv$

Recall and use	
recall and use the elementary charge $e = 1.6 \times 10^{-19}$C	
recall and use appropriate circuit symbols as set out in SI Units, Signs, Symbols and Abbreviations (ASE, 1981) and Signs, Symbols and Systematics (ASE, 1995) interpret and draw circuit diagrams using these symbols	
recall and apply Malus's law for transmitted intensity of light from a polarising filter.	The intensity of light transmitted through a polarising filter is equal to $I_0 \cos^2\theta$

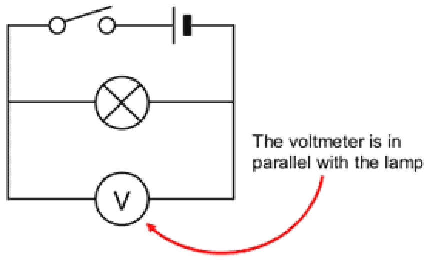
Use and apply	
use the relationships: intensity = power/cross-sectional area and intensity ∝ amplitude^2	
use the equation: separation between adjacent nodes (or antinodes) = $\lambda/2$	
use the transfer equation: $eV = 1/2mv^2$ for electrons and other charged particles	
use the relationships	$hf = E1 - E2$ and $hc = E_1 - E_2/\lambda$
apply Kirchhoff's first and second laws to circuits	

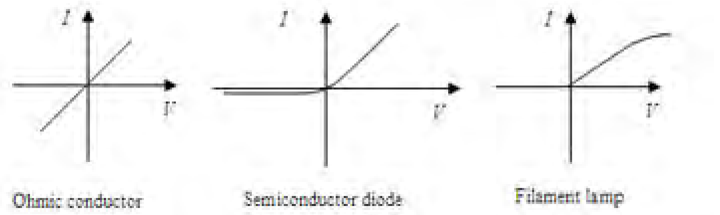




apply graphical methods to illustrate the principle of superposition

Describe

describe how an ammeter may be used to measure the current in a circuit	Must be put in series to measure the current. You can measure the current in a circuit using an ammeter which must be attached in series so that the current running through the component is the same going through the ammeter.
describe Kirchhoff's first law and appreciate that this is a consequence of conservation of charge	sum of/total current into a junction equals the sum of/total current out conservation of charge
describe the difference between conductors, semiconductors and insulators in terms of the number density *n*	-In conductors, such as metal, the charge carriers are free electrons. So there are loads of charge carries making n big. Therefore the drift velocity can be small for a high current. -In semiconductors there are fewer charge carries so n is smaller. This means that the drift velocity has to be higher to get the same current as conductors. -A perfect insulator wouldn't have any charge carries so n would be 0. Real insulators have very small numbers of charged carried so very small n figures.
describe how a voltmeter may be used to determine the p.d. across a component	 The voltmeter must be put in parallel
describe the difference between e.m.f. and p.d. in terms of energy transfer	Potential difference is transferring electrical energy into other forms (heat, light, sound). EMF is transferring other forms of energy into electrical (chemical energy stored in a battery) EMF is the amount of electrical energy the battery produces for each coulomb of charge. Measured in volts. -Whereas the p.d. is the energy transferred when one coulomb of charge flows through a load resistance.
describe the *I*–*V* characteristics of a resistor at constant temperature, filament lamp and light-emitting diode (LED)	Resistor follows ohms law so straight line through origin. Filament Lamp is non-ohmic as its temperature varies so the line should go up and then curve so the gradient= 0. LED is non-ohmic as well, so no current should flow until a certain threshold voltage, so flat line to indicate no current, then a upwards line to show current is now flowing.

	
describe an experiment to obtain the *I–V* characteristics of a resistor at constant temperature, filament lamp and light-emitting diode (LED)	Ammeter, Resistor/Filament Lamp/LED and Potentiometer in series. Place voltmeter in parallel with the component being tested. Limit the current flowing by varying the potentiometer accordingly, taking current and potential difference readings respectively
describe the uses and benefits of using light emitting diodes (LEDs).	Advantages or LED over a filament lamp in a torch-Draws lower current, light lasts longer, LEDs more efficient at converting electrical energy into light, more robust and a longer working life.
describe how the resistivities of metals and semiconductors are affected by temperature	Near room temperature, the resistivity of metals typically increases as temperature is increased, while the resistivity of semiconductors typically decreases as temperature is increased.
describe how the resistance of a pure metal wire and of a negative temperature coefficient (NTC) thermistor is affected by temperature	Thermistors are temperature sensitive resistors. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. In a pure metal a greater resistance slows the flow of electrons so a smaller current flows as temperature increases.
describe power as the rate of energy transfer	power is the rate at which energy is transferred, used, or transformed $J\ s^{-1}$
describe how the resistance of a light dependent resistor (LDR) depends on the intensity of light	Resistance decreases with increase in light intensity LDR must be shielded or be at some distance from the lamp when it switches on as the light shining will cause it to switch the illumination off causing an on/off oscillation
describe and explain the use of thermistors and light-dependent resistors in potential divider circuits	Thermistor/LDR can be used to provide an output voltage, which depends on temperature/light intensity.
describe the advantages of using dataloggers to monitor physical changes	Continuous record for a very long time scale of observations Can record very short timescale signals (at intervals) Automatic recording/remote sensing Data can be fed directly to a computer (for analysis)
describe and distinguish between progressive longitudinal and transverse waves	Longitudinal = oscillations/vibration of particles/medium in direction of travel of the wave e.g. sound Transverse = oscillations/vibration of particles/medium (in the plane) at right angles to the direction of travel of the wave e.g. surface water, string, electromagnetic

<table>
<tr>
<td>describe differences and similarities between different regions of the electromagnetic spectrum</td>
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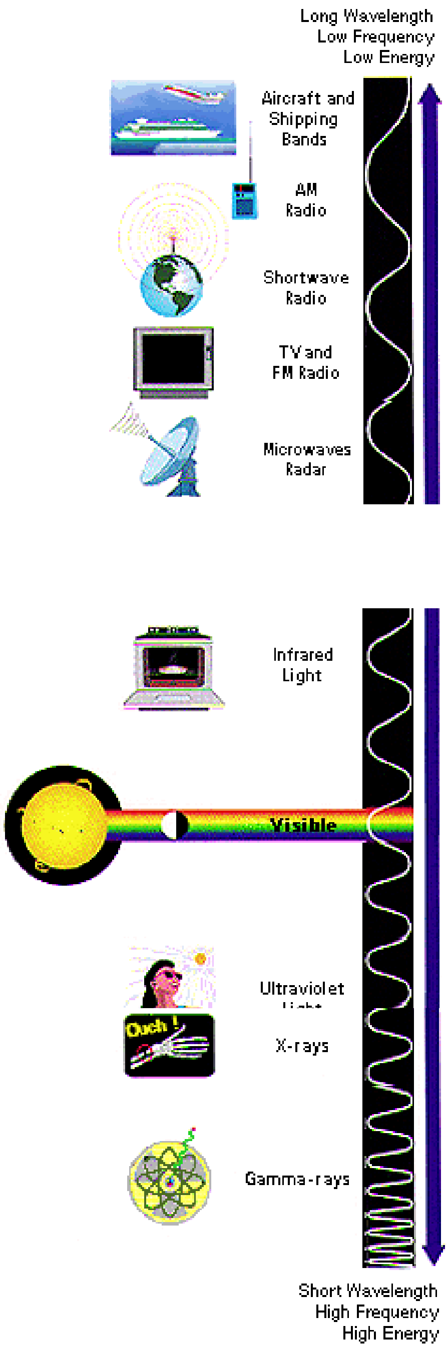

Electromagnetic radiation can be described in terms of a stream of photons, which are massless particles each travelling in a wave-like pattern and moving at the speed of light. Each photon contains a certain amount (or bundle) of energy, and all electromagnetic radiation consists of these photons. The only difference between the various types of electromagnetic radiation is the amount of energy found in the photons. Radio waves have photons with low energies, and gamma-rays have photons with the greatest energies.
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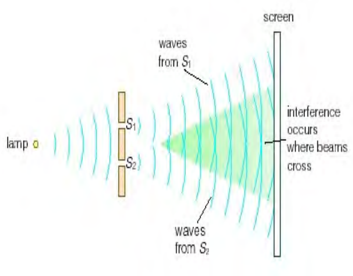
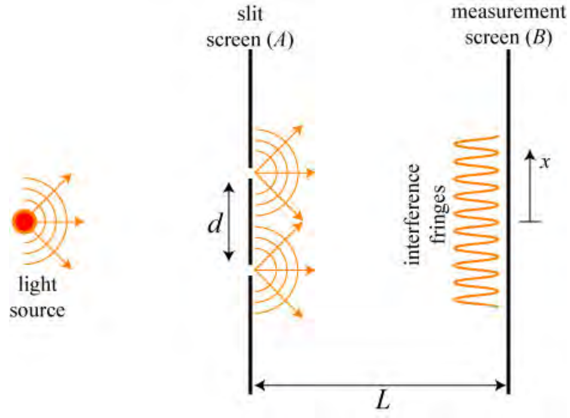
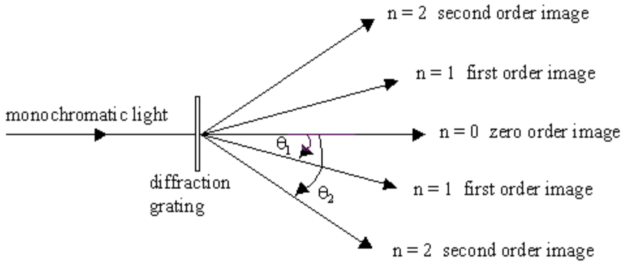
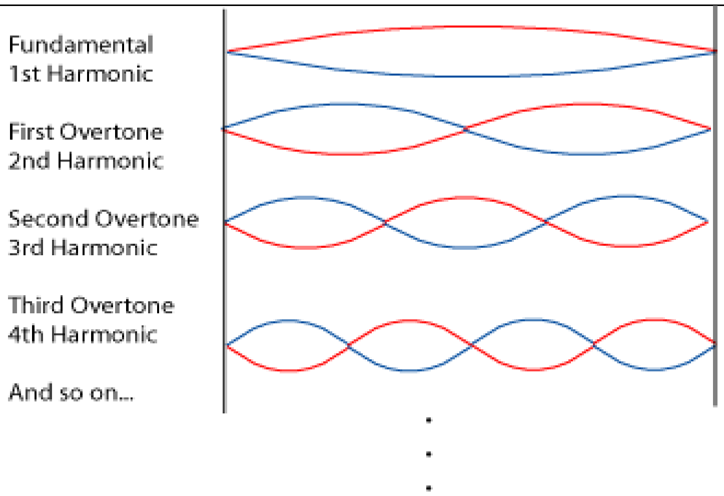
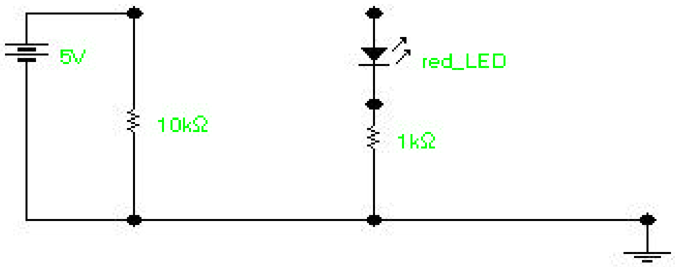
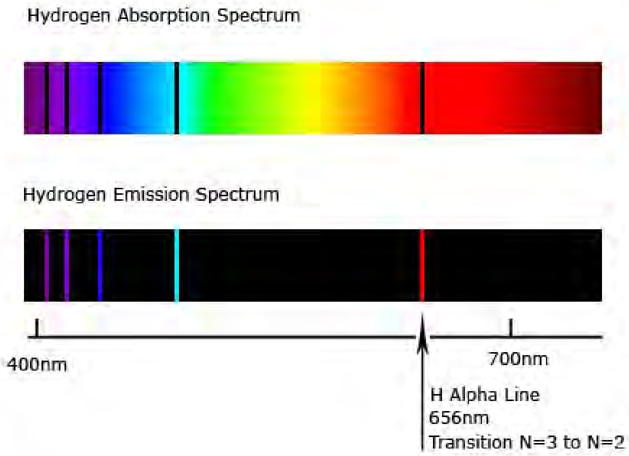
describe some of the practical uses of electromagnetic waves	Radio stations. Radio waves are emitted by stars and gases in space. Microwaves in space are used by astronomers to learn about the structure of nearby galaxies. Our skin emits infrared light and In space, IR light maps the dust between stars. Visible radiation is emitted by everything from fireflies to light bulbs to stars ... also by fast-moving particles hitting other particles. It's the light the human eye can see. The Sun, Stars and other "hot" objects in space emit UV radiation. Hot gases in the Universe also emit X-rays. They are used in scanning the bones in the body. Radioactive materials (some natural and others made by man in things like nuclear power plants) can emit gamma-rays. The biggest gamma-ray generator of all is the Universe! It makes gamma radiation in all kinds of+\ASA ways.
describe the characteristics and dangers of UV-A, UV-B and UV-C radiations and explain the role of sunscreen	filters out/blocks/reflects/absorbs UV(-B) UV-A causes tanning or skin ageing ; most of (99%) uv light; 400-315 nm UV-B causes damage or sunburn or skin cancer; 315-260 nm UV-C is filtered out by atmosphere/ozone layer; 260-100 nm
describe experiments that demonstrate two source interference using sound, light and microwaves	Two speakers playing the same note, hear constructive (loud) and destructive (quiet) interference. Light or microwaves pointed towards two slits constructive and destructive interference can be observed.
describe constructive interference and destructive interference in terms of path difference and phase difference	If the path difference between two light waves is **(m+1/2)l**, then the interference between them will be destructive. For constructive interference, path difference between two waves is **ml**
describe the Young double-slit experiment and explain how it is a classical confirmation of the wave-nature of light	 Monochromatic source sent through 2 slits which diffracts the source, since they diffract it shows wave nature.

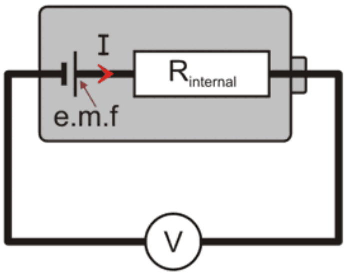
describe an experiment to determine the wavelength of monochromatic light using a laser and a double slit	$\lambda = \frac{ax}{D}$ a=d=slit separation x=fringe separation D=L=distance between slit and screen 
describe the use of a diffraction grating to determine the wavelength of light (the structure and use of a spectrometer are not required	 $d \sin\theta = n\lambda$ n=order of diffraction
describe the similarities and differences between progressive and stationary waves	Progressive-A wave which transfers energy as a result of oscillations(of the source/medium/particles through which the energy is travelling) A progressive wave transfers shape/information from one place to another. Every point on a progressive wave has the same amplitude. Every point on a progressive wave oscillates. All points on a progressive wave (in 1 wavelength) have different phase Stationary-A wave which stores energy (traps energy in pockets) The shape does not move along – does not transfer shape/information Stationary wave has nodes and antinodes. Stationary wave = the incident wave is reflected at the end of the pipe. Reflected wave interferes/superposes with the incident wave to produce (a resultant wave with) nodes and/or antinodes

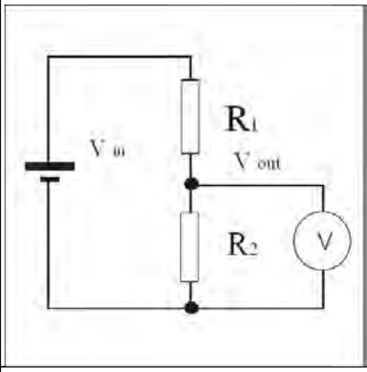
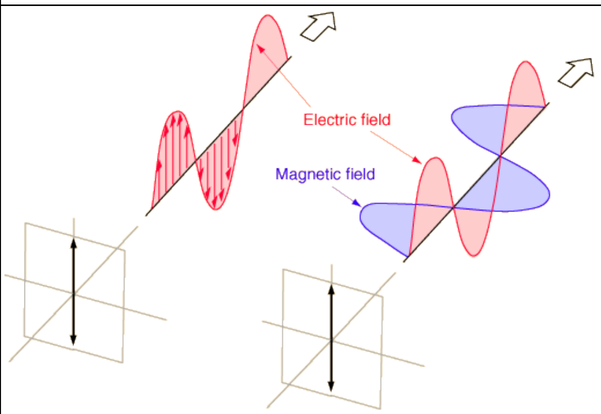
describe experiments to demonstrate stationary waves using microwaves, stretched strings and air columns	 Open/closed end air column or string vibrated with a fixed point
describe the particulate nature (photon model) of electromagnetic radiation	A photon is a quantum/lump/unit/packet/particle of (e-m) energy/light
describe an experiment using LEDs to estimate the Planck constant *h* using the equation	
describe and explain the phenomenon of the photoelectric effect	A photon is absorbed by an electron in a metal surface causing an electron to be emitted. Energy is conserved. Only photons with energy above the work function energy will be emitted. Energy=work function + Max KE of electron. The work function is the minimum energy required to release an electron from the surface. A clean zinc plate is mounted on the cap of a gold leaf electroscope where the plate is initially charged negatively Shine a UV light on the plate and watch the gold leaf collapse as charge leaves the place, indicating the emission of electrons Work function energy is the minimum energy to release an electron from the surface Number of electrons emitted also depends on light intensity Emission is instantaneous energy of the infra-red photon is less than the work function of the metal surface State: emission of electron(s) from a metal (surface) when photon(s)/light/uv/em radiation are inciden (on surface)
describe the origin of emission and absorption line spectra	(Emission) Line spectrum = light emitted from (excited isolated) atoms produces a line spectrum a series of

	(sharp/bright/coloured) lines against a dark background. Absorption spectrum is a series of <u>dark</u> lines (appears against a bright background/within a continuous spectrum) 
The difference between the directions of conventional current and electron flow	current moves from + to – (of battery in circuit) and electrons move from – to +

Determine	
determine the correct fuse for an electrical device	The next number of amps above the current of the circuit. (smallest value above possible) You can usually only get fuses with ratings of 3amps, 5amps or 13amps.
determine the standing wave patterns for stretched string and air columns in closed and open pipes	
determine the speed of sound in air from measurements on stationary waves in a pipe closed at one end	Sound waves in the tube are in the form of <u>standing waves</u>, and the <u>amplitude</u> of vibrations of air is zero at equally spaced intervals along the tube.. The powder is caught up in the moving air and settles in little piles at these nodes. The distance between the piles is one half <u>wavelength</u> *λ/2* of the sound. By measuring the distance between the piles, the wavelength *λ* of the sound in air can be found. If the frequency *f* of the sound is known, multiplying it by the wavelength gives the speed of sound *c* in air:

Explain	
explain that electric current is a net flow of charged particles	There is a current when charged particles flow past a point in a circuit. Current is the rate of flow of charge. Current in a wire is like water flowing in a pipe. The amount of water that flows depends on the flow rate and the time. Current is the rate of flow of charge.
explain that electric current in a metal is due	Wires are made from metal. The metal

to the movement of electrons, whereas in an electrolyte the current is due to the movement of ions	contains a sea of delocalised electrons which move in random directions. When a cell is connected to the wire and electrical force is applied to the electrons making them 'drift'. They still move in random directions however they have an overall velocity or movement, creating a current. This can happen with ions in an electrolyte too.
explain what is meant by conventional current and electron flow	The direction of the current is from the positive terminal to the negative. However electrons are what flow in metals and are negatively charged and therefore flow from negative to positive
explain how a fuse works as a safety device	The fuse needs to have a current rating big enough to cover the initial current in the circuit. If the current gets too big, it melts the wire which breaks the circuit.
explain that all sources of e.m.f. have an internal resistance	All sources of emf have what is known as INTERNAL RESISTANCE (r) to the flow of electric current. The internal resistance of a fresh battery is usually small but increases with use. Thus the voltage across the terminals of a battery is less than the emf of the battery. $E = I(R + r)$ 

explain how a potential divider circuit can be used to produce a variable p.d	If you use two fixed resistors in series and connect the ends to a voltage supply then the voltage between both ends and the mid point where they connect will be in proportion their resistor value. It is possible to vary the midpoint voltage by changing one of the resistors. This can be done readily with a variable resistor which than then be altered to get any value between 0-MaxV By adjusting the value of R1, the potential dropped 
explain what is meant by reflection, refraction and diffraction of waves such as sound and light	Reflection-Bouncing back of wave from a surface Refraction-Change in direction of a wave as it crosses and interface between two materials where its speed changes Diffraction-Spreading of a wave when it passes through a gap or past the edge of an object
explain the meaning of the term *terminal p.d.*;	The terminal p.d. of a source is the potential difference across its terminals
explain what is meant by plane polarised waves and understand the polarisation of electromagnetic waves	 Transverse waves/vibrations in plane are normal to the direction of energy propagation. Oscillations are in one direction only
explain that polarisation is a phenomenon associated with transverse waves only	Electromagnetic waves are transverse waves so can be polarised whereas sound waves cannot since they are not transverse.
explain the terms *interference*, *coherence*, *path difference* and *phase difference*	Interference-When two waves meet at a point Coherence-Constant phase difference between the two waves **Path difference**-of any point in an

	interference pattern of waves is the difference between the distance travelled by each wave from their source to that point **Phase difference-** difference in velocity of similar points in two waves expressed as an angle Coherence = constant phase relationship or are continuous and have the same f/period/ λ
explain the advantages of using multiple slits in an experiment to find the wavelength of light.	
explain that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature	There is a threshold frequency which suggests particle nature, as the wave theory states that photoelectric emission should happen as long as the light is bright enough. However this is not the case. Diffraction and interference are wave properties, suggesting that electromagnetic radiation has wave nature.
explain the formation of stationary (standing) waves using graphical methods	(open end tube and speaker) Using a tube with one end closed and a loud speaker, the incident wave is reflected at the end of the pipe and it interferes with the incident wave to produce a resultant wave (string and oscillator) The incident wave is reflected at the fixed end of the wire, the reflected wave interferes with the incident wave to produce a resultant wave with nodes and antinodes
explain and use Einstein's photoelectric equation *hf* = φ + KEmax	Individual photons are absorbed by individual electrons in the metal's surface. These electrons must absorb sufficient energy to overcome the work function energy of the metal. The number of electrons emitted depends on light intensity as emission is instantaneous. Infra-red foes not have enough energy to cause photoelectric emission it is less than the work function
explain why the maximum kinetic energy of the electrons is independent of intensity and why the photoelectric current in a photocell circuit is proportional to intensity of the incident radiation	$hf = \emptyset + KE_{MAX}$ Therefore independent of intensity. The larger the intensity, the greater the number of photons emitted, therefore releasing more electrons generating a larger current.
explain electron diffraction as evidence for the wave nature of particles like electrons	Electron diffraction refers to the wave nature of electrons by firing electrons at a sample and observing the resulting interference pattern. This phenomenon is commonly known as the wave-particle duality, which states that the behaviour of a particle of

	matter (in this case the incident electron) can be described by a wave. Diffraction is a property unique to waves. If electrons can be diffracted then they are behaving as waves
explain that electrons travelling through polycrystalline graphite will be diffracted by the atoms and the spacing between the atoms	Graphite, because of its layered structure, can act as a diffraction grating with very small slit diameter.
explain that the diffraction of electrons by matter can be used to determine the arrangement of atoms and the size of nuclei.	Slow moving electrons, electrons with wavelengths (E=hf) of the order of magnitude of the structure (or nuclei) can be used to probe the properties of atomic structures.
explain how spectral lines are evidence for the existence of discrete energy levels in isolated atoms, ie in a gas discharge lamp	Photon produced by electron moving between levels Photon energy equal to energy difference between levels
Explain how sunscreen protects the human skin	Filters out/blocks/reflects/absorbs UV (-B)
Explain why electrons can be emitted from a clean metal surface illuminated with bright UV light but never when IR is used, however intense	Energy of the infra-red photon is less than the work function of the metal surface
Explain what is meant by the de Broglie wavelength of an electron	Electrons are observed to behave as waves/show wavelike properties where the electron wavelength depends on its speed/momentum
Explain what is meant by a continuous spectrum	All wavelengths/frequencies are present (in the radiation)

Maths	
calculate energy in kW h and the cost of this energy when solving problems	
solve circuit problems involving series and parallel circuits with one or more sources of e.m.f	
derive from the definitions of speed, frequency and wavelength, the wave equation *v* = *f*λ	$v = \frac{x}{t}$ and $f = \frac{1}{t}$ then $v = \frac{x}{\frac{1}{f}}$ Wavelength λ is the displacement x between subsequent wave peaks therefore $v = f\lambda$
draw a simple potential divider circuit	