

ELECTRONS PHOTONS AND WAVES

REVISION

UNIT G482

speed of light $c = 3 \times 10^8 \text{ms}^{-1}$

Plancks constant $h = 6.63 \times 10^{-34} \text{Js}$

mass of electron $= 9.11 \times 10^{-31} \text{Kg}$

Electrons Photons and Waves revision

What is electric current?

Electric current is the flow of charged particles. In metals it is the flow of electrons and in electrolytes the flow of ions

How is current defined?

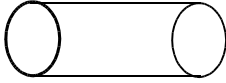
$I = Q/t$ where Q is charge in coulombs (c) and t is time (s) and I is current (A)

What is Kirchoff's first law?

sum of currents entering a junction = sum of currents leaving
this is an example of the **conservation of charge**

What is conventional current direction?

Conventional current flow is the flow of positive charge from positive to negative. Real current electron flow is from negative to positive

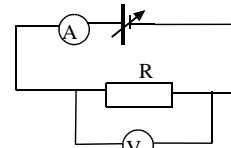


Current drift velocity $I = nAve$

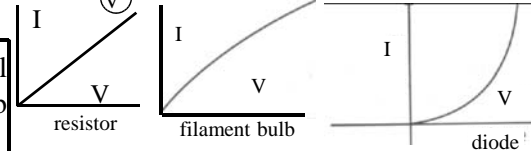
n - N^0 of charges per m^3 A - area in m^2 , v - drift velocity in m/s , e - electron charge

What is Ohm's Law?

Current is proportional to voltage at constant temperature



Current - voltage characteristics



What is potential difference? It is the electrical energy transferred to other forms per coulomb of charge. $V(V) = W/Q$.

What is E.M.F? E.m.f is the electrical energy transferred to charge per coulomb by a cell or power supply. $E(V) = W/Q$

How can the volt be defined? Two points are at a p.d. of 1V if 1J of electrical energy transferred per coulomb of charge that passes ($V=W/Q = 1/1 = 1V$)

What is the definition of resistance?

Resistance is defined as $R(\Omega) = V/I$

How is the ohm defined? The ohm is defined the resistance provided when a p.d. of 1V causes a current of 1A to flow. ($R = V/I = 1/1 = 1\Omega$)

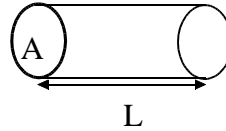
Does the resistance of a conductor depend on its dimensions?

Yes $R = \rho L/A$, A - area (m^2) L - length (m), ρ - resistivity (Ωm)

What is a thermistor? It is a resistor. The resistance of a negative temperature coefficient (NTC) thermistor drops with increasing temperature

How is resistivity defined?

$$\rho = AR/L$$



What is power? Power is the rate of energy (W) transfer. $P = W/t$. The unit of power is the watt (w)

How is energy transfer calculated? from $P = W/t$, $W = Pt$

W - energy transferred (J)
 P - power (w)
 t - time (s)

What is a kilowatt hour?

A bigger unit of energy than the joule

$$W = Pt$$

$$W(kwh) = P(kw) \times t(h)$$

Define the kwh

1kwh is transferred by a 1kw device used for 1 hour
 $W = Pt = 1 \times 1 = 1kwh$

How many joules is a kwh?

$$W = pt = 1000 \times 60 \times 60 = 3600000J$$

What are the three equations for electrical power?

$$P = IV = I^2R = V^2/R$$

What are the three equations for electrical energy transfer?

From $W = pt$

$$W = IVt = I^2Rt = (V^2/R)t$$

Fuses: fuses are made from thin wire. If there is a fault and there is too much current, they quickly melt and cut off the current preventing fire. $P = IV$ can be used to calculate current I and decide the best fuse

Resistors in Series

$$R_{total} = R_1 + R_2$$

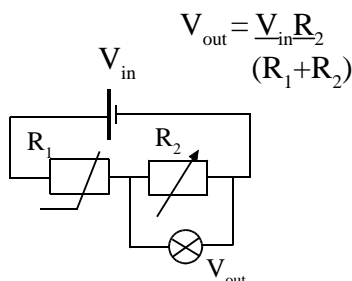
Resistors in parallel

$$1/R_{total} = 1/R_1 + 1/R_2$$

Resistance networks

To find the total resistance work out the resistance of the parallel resistors then add the series resistance

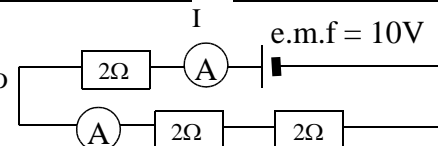
The Potential Divider



What is Kirchoff's second law?

In any closed loop the sum of the p.d's is equal to the e.m.f of the source. This law is a consequence of the **conservation of energy**

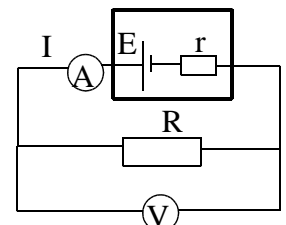
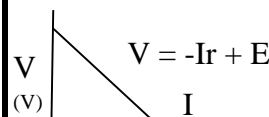
Use the second law to calculate I



$$10 = I \times 2 + I \times 2 + I \times 2 = 6I \quad \text{- from } V = IR$$

$$\text{so } I = 10/6 = 1.67A$$

Internal resistance (r) of a battery



The voltmeter reads the voltage, V across the load resistance and is called the **terminal p.d.** It is less than the e.m.f. of the source because there is a potential difference across the internal resistance of the source.

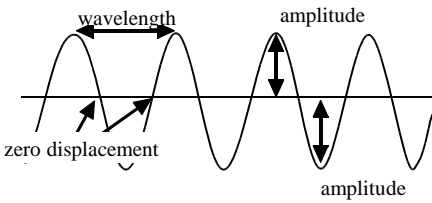
From Kirchoff's second law $E = IR + Ir$

$$E = V + Ir$$

If this is rearranged so $V = -Ir + E$

a graph of V against I would give a straight line with a gradient equal to the internal resistance and the y intercept equal to the E.M.F

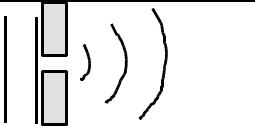
Describing Waves



Wave Speed
 speed(m/s) = frequency (Hz) x wavelength (m)
 or velocity $V = f \times \lambda$

What is wave frequency?
 Wave frequency is defined as the number of waves per second and the unit is Hertz (Hz)

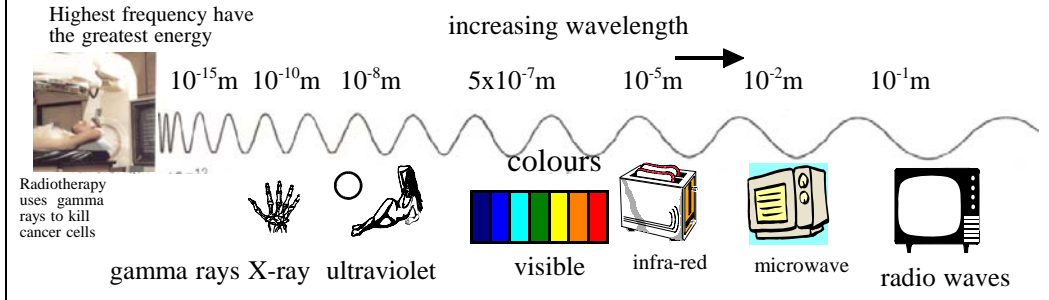
Diffraction Diffraction is the spreading out of waves when they pass through a gap or pass an object. Diffraction is greatest when the gap width is equal to wavelength



What is the intensity of a wave? The intensity of a wave is the power per metre². Its units are Wm^{-2} . As an equation Intensity $I = P/area$

How is intensity of a wave related to its amplitude? The intensity of a wave is proportional to amplitude², $I \propto A^2$. If the amplitude of a wave doubles its intensity x4. If the amplitude of a wave halves its intensity reduces by 1/4
 If a wave has amplitude A_1 and intensity I_1 and its amplitude is changed to A_2 then we can write $I_1/I_2 = A_1^2/A_2^2$

The Electromagnetic Spectrum



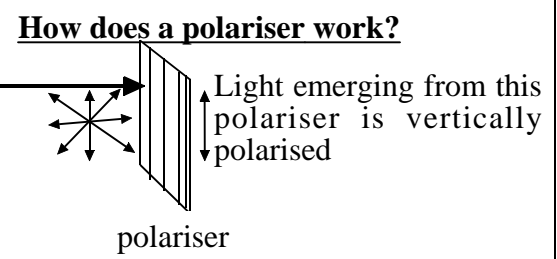
Electromagnetic waves with the largest frequency have the most energy. Ultra-violet frequencies and above can ionise atoms to make ions. This changes their chemistry and may lead to cancers. Infra-red, microwave and radio wave have a heating effect on objects. Microwaves of the right frequency can cause water molecules to resonate causing rapid heating.

What is the period of a wave?
 The period, T of a wave is the time for one complete wave or cycle and $T(s) = 1/f$

Ultraviolet UV part of the spectrum is split into UV-A, UV-B, UV-C, UV-A causes skin to wrinkle, UV-B causes cancer UV-C is mostly absorbed by ozone in the atmosphere

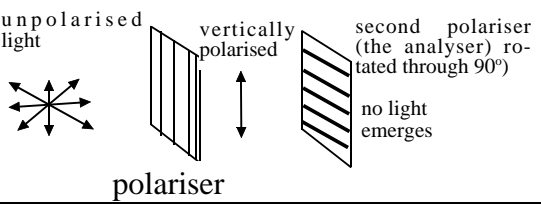
What is visible light?
 Light is a transverse wave of different wavelengths. In unpolarised light vibrations are in all planes

What is polarised light?
 Polarised light is light where vibrations are in a single plain (typically vertical or horizontal). Light can be polarised using a polariser.



How do polaroid glasses work?
 When light reflects from a surface it is partially polarised. Sunglasses contain a polariser which eliminates this polarised light.

What is Malus. Law?
 This describes the relationship between the intensity of transmitted polarised radiation and the angle through which an analyser is rotated



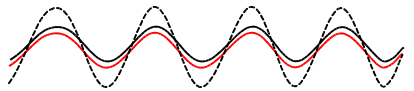
For rotations of the analyser between 0 and 90° the transmitted intensity $I = I_0 \cos^2 \theta$ where I_0 is the incident intensity and θ is the angle between the axis of the polariser and the plane of polarisation of the incident light

Interference

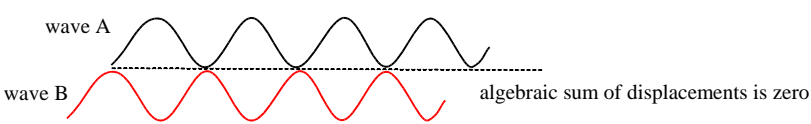
What is phase difference?
 A measure of how out of step waves are in λ or degrees

The Principal of Superposition If two waves interfere the resulting displacement is the algebraic sum of the individual displacements

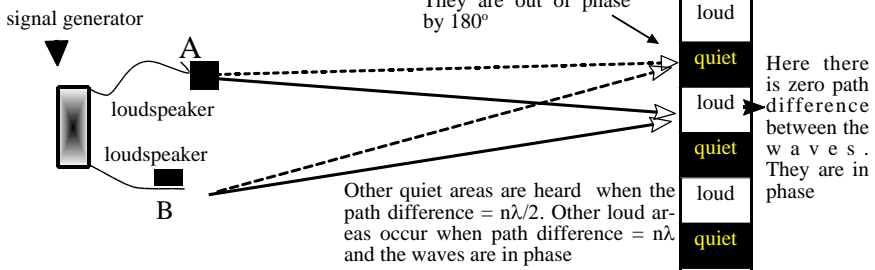
Constructive interference
 Occurs when two or more waves in phase combine



Destructive Interference
 Occurs when waves combine 180° out of phase



Interference of Sound waves



Conditions for observable interference

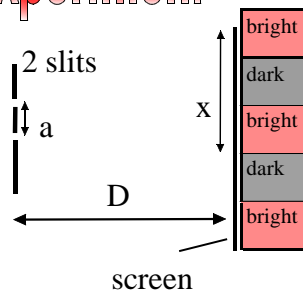
The wave sources must be **coherent**
 This means they are in phase or have a constant phase difference when emitted from the source

Youngs slit experiment

laser



Laser light - monochromatic and coherent source

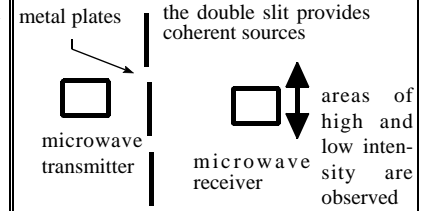


Light from the two slits have travelled different distances. When the path difference is exactly λ constructive interference occurs and a bright fringe is observed. A path difference of $n\lambda/2$ will cause destructive interference and a dark fringe is observed

$$\lambda = ax/D$$

a - slit separation, D - screen to slit separation
 x - fringe separation

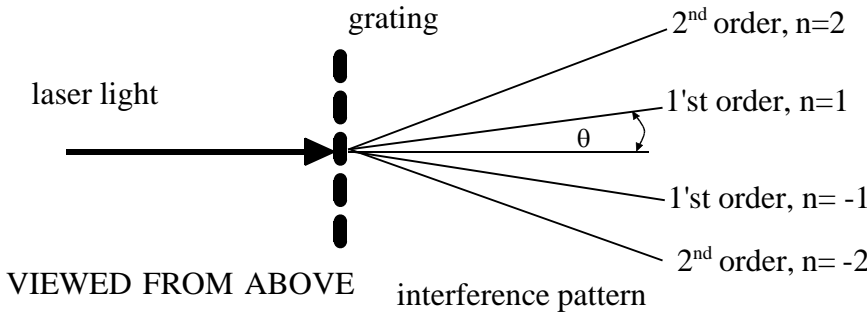
Interference of microwaves



Youngs' slit equation can be applied as for $\lambda = ax/D$ light

Using a diffraction Grating to determine wavelength of light

A diffraction grating is a material with many slits. At each slit diffraction occurs. Diffracted waves then interfere to produce an interference pattern



$$d \sin \theta = n \lambda$$

d = slit separation (m)

n - order of diffraction

θ - angle between normal to grating and the order of diffraction

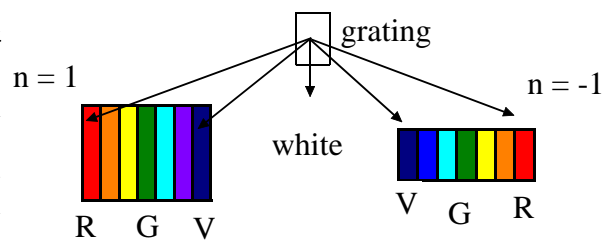
λ - wavelength (m) of light

What are the advantages of using a diffraction grating compared to Youngs' slit method?

(i) The maxima are very sharp and bright. (ii) The maxima are widely separated and the angle can be measured very accurately. (iii) In youngs slit experiment the separation of two slits needs to be measured - a big % inaccuracy. In a grating there are many slits and their separation d can be worked out accurately

What happens to white light when shone through a diffraction grating?

White light is made of all the different colours, red having the longest wavelength. For $n = 1$ light will be split into all the different colours because the amount of diffraction will be different for each wavelength. For $n = 1$ $\sin \theta = \lambda/d$ for red light this will work out a bigger angle than for violet



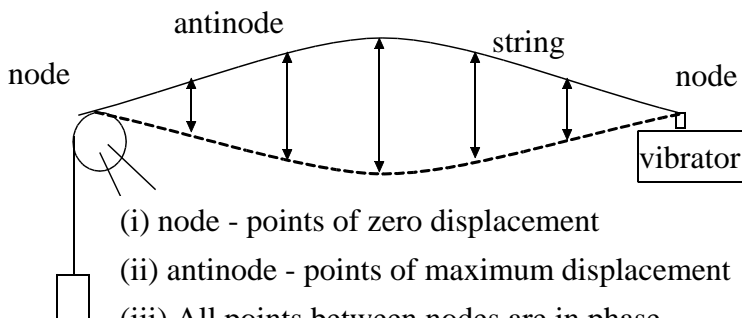
Stationary waves

How are stationary waves different from progressive waves?

(1) No energy is transferred

How is a standing wave produced? A reflected wave interferes with the incident wave, when each are in phase constructive interference occurs.

Stationary waves in a string



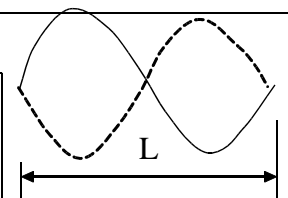
- (i) node - points of zero displacement
- (ii) antinode - points of maximum displacement
- (iii) All points between nodes are in phase
- (iv) Distance between nodes, $L = \lambda/2$

What is the fundamental? This is the lowest frequency or longest wavelength to produce an observable stationary wave

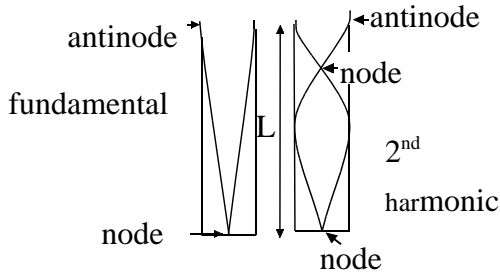
What is the second harmonic? As frequency is increased a second stationary wave is observed where the waves are in phase

$$L = \lambda$$

Other harmonics? As the frequency is increased still furthermore stationary waves are observed, when L is equal to a whole number of half wavelengths, $L = n\lambda/2$

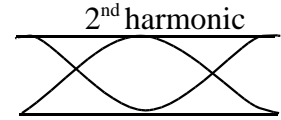
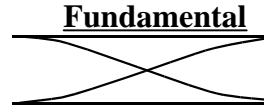


Stationary waves in closed pipes



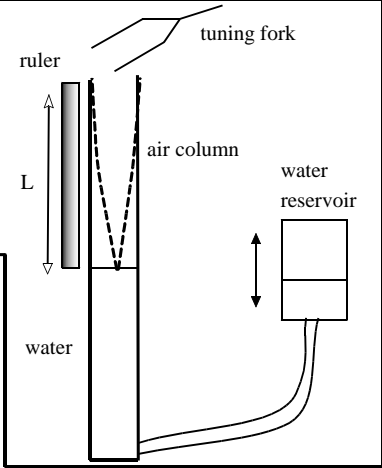
If the frequency of a sound source above a closed pipe is increased an increase in amplitude is heard which must correspond to the fundamental. The end is fixed and air cannot move, this must be a node. At the open end there is an antinode so $L = \lambda/4$. As frequency is increased a 2nd harmonic is observed and $L = 3\lambda/4$

Stationary waves in open pipes



The Speed of sound Using stationary waves

- Tuning fork of known frequency, f is sounded above the open end of a tube
- The length of the tube is increased by lowering the water level
- A loud point is heard at a length corresponding to the fundamental $L = \lambda/4$, so $\lambda = 4L$, the speed $V = f\lambda$



Light-wave or particle?

The answer is both!

Wave evidence - (i) interference, (ii) diffraction

Particle evidence - (i) Discrete packets of energy (**photons**) detected by geiger muller tube

Energy of a photon

$E = hf$ where f - frequency (Hz) h - plancks' constant = 6.63×10^{-34} Js
or $E = hc/\lambda$ since $c = f\lambda$

The Electron Volt (eV)

This is a very small unit of energy $1\text{eV} \equiv 1.6 \times 10^{-19}\text{J}$
E.g. What is $2 \times 10^{-17}\text{J}$ in eV? ans: $\frac{2 \times 10^{-17}}{1.6 \times 10^{-19}} = 1.25 \times 10^2$

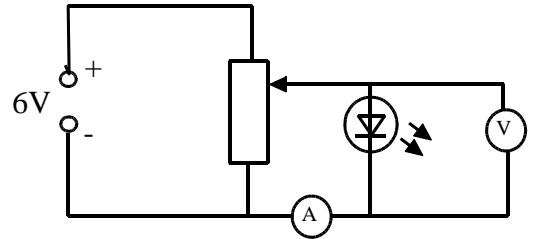
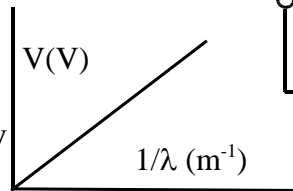
An experiment to Calculate Plancks' constant

The voltage is increased until a current just starts to flow. At this threshold voltage, V

energy lost by electron = energy of emitted photon
so $eV = hf = hc/\lambda$ so $V = \frac{hc}{e\lambda}$

If different diodes are used of known wavelength a graph of V against $1/\lambda$ will give a straight line with a gradient = hc/e .

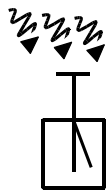
Plancks constant $h = \frac{\text{gradient} \times e}{c}$



The photoelectric effect

Solar cells, digital cameras work using the photoelectric effect

Observing it



A negatively charged electroscope discharges when light of higher enough frequency is used. Increasing the intensity above this threshold frequency f_0 increases the rate of discharge. Below f_0 no discharge occurs no matter how intense the light

Einsteins Photoelectric Equation

$hf = \phi + 0.5mv^2$ or $hc/\lambda = \phi + 0.5mv^2$
 ϕ - work function (J)
 $0.5mv^2$ - max KE of ejected electron

Important deductions (i) For an electron to be removed energy must be input.

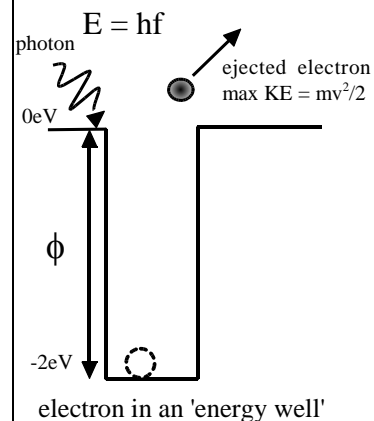
(ii) A wave model of light suggests that the greater the intensity the greater the energy, below the threshold frequency increasing intensity had **no** effect

(iii) The particle model suggests that the higher the frequency the greater the energy of the photon - this is supported by our observations i.e. discharge occurs at a threshold frequency

(iv) One photon ejects one electron

What is the work function ϕ ?

This is the minimum photon energy to just eject an electron. This occurs when the photon has a frequency called the threshold frequency, f_0 . The ejected electron has no kinetic energy and
 $hf_0 = \phi$



The De Broglie equation

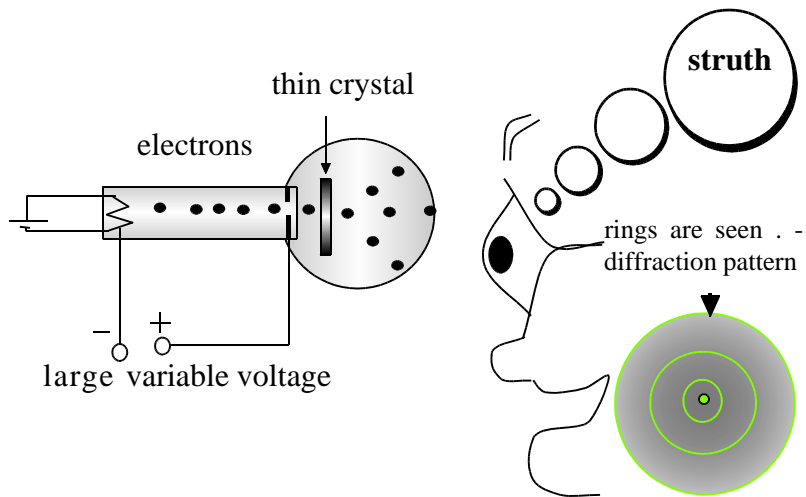
Can particles behave as waves? - Yes and the evidence is that electrons diffract when passed through thin crystals - a diffraction pattern can only be described by wave characteristics

The De Broglie equation

De Broglie linked the wave like nature of a particle to its particle properties in this equation

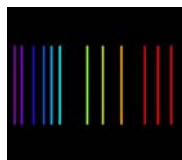
$$\lambda = \frac{h}{mv}$$

m - mass (kg), v - velocity (ms⁻¹)
h - plancks' constant



As the voltage is increased electrons are accelerated more and reach higher velocities. By the De Broglie equation wavelength reduces and when the wavelength becomes similar to the atomic spacing diffraction is observed

Spectra



What is an emission line spectrum? - A spectrum of only certain wavelengths and is caused by excited electrons returning to lower energy levels within an atom. Chemists use colour flame tests to identify elements and a line spectrum can be used to do the same

What is an absorption spectrum?

Dark lines or 'missing' wavelengths can be sometimes seen within a continuous spectrum.

This happens because of light absorption in gas between the source and the observer. The absorption wavelengths are like a finger print for the gas element.



What happens in an atom when light is absorbed?

When a photon is absorbed an electron is promoted to a higher energy level in the atom.. The difference between the energy levels is equal to the energy of the absorbed photon

Photon emission from an atom

When an electron falls back to a lower level it emits a photon. The photon energy is equal to the difference in energy levels within the atom

$$E_2 - E_1 = hf$$

(J)

Example

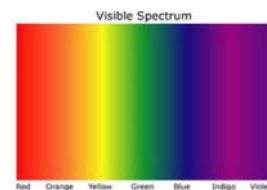
An electron is promoted by a photon from the ground state to n=2 within an atom. What is the frequency of the absorbed photon?

$$E_2 - E_1 = hf, \quad f = \frac{E_2 - E_1}{h} = \frac{-22 \times 1.6 \times 10^{-19} - (-47 \times 1.6 \times 10^{-19})}{6.63 \times 10^{-34}}$$

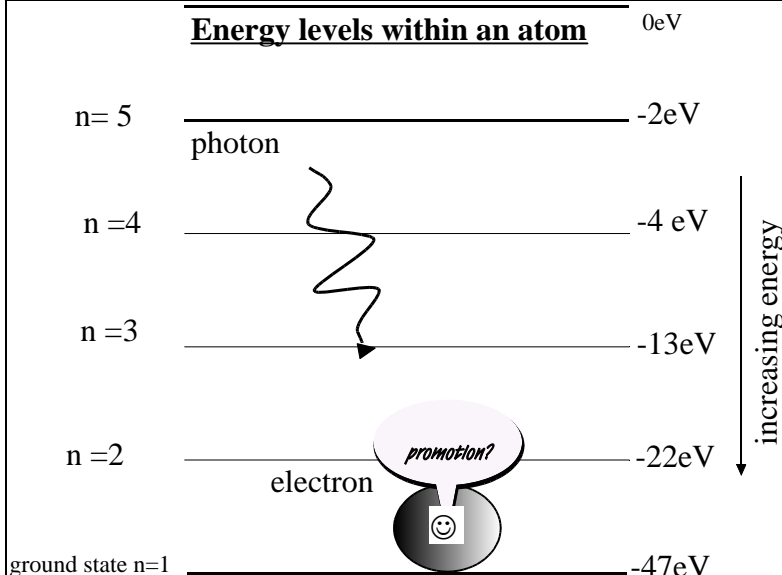
$$= 10^{15} \text{ Hz}$$

What is a continuous spectrum?

This contains electromagnetic waves of all wavelengths



Energy levels within an atom



This diagram represents energy levels within the atom. An electron can occupy these levels and nothing in between so photons only of certain frequencies can be absorbed or emitted

In an excited atom an electron falls from n=4 to the ground state. What is the wavelength of the ejected photon?

$$E_2 - E_1 = hf = hc/\lambda, \text{ so } \lambda = hc/(E_2 - E_1)$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{-47 \times 1.6 \times 10^{-19} - (-4 \times 1.6 \times 10^{-19})}$$

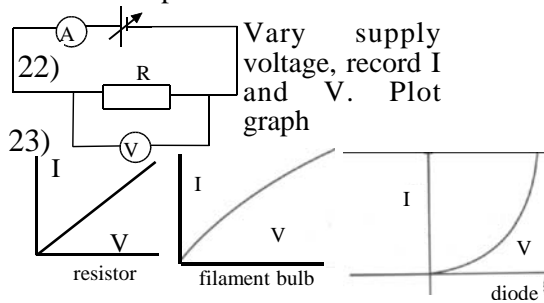
$$= 2.9 \times 10^{-8} \text{ m}$$

ELECTRONS PHOTONS AND WAVES

FOLD

- 1) Electric current is the flow of _____ particles. In metals it is the flow of _____ and in electrolytes the flow of _____
- 2) Conventional current flow is from _____ to _____. Real electron flow is from _____ to _____
- 3) The charge that passes a point in a circuit in time t can be defined as charge = _____ x _____ or $Q = It$ or in general $\Delta Q =$ _____
- 4) Charge can be _____ or _____. The unit of charge is the _____
- 5) The coulomb is defined as the charge that passes a point in a circuit if a current of _____ A flows for _____ second ($Q = It, I = 1 \times 1$)
- 6) If 20C of charge passes a point in a circuit in 2s what is the current?
- 7) Current is measured using an _____ and is always placed in _____
- 8) the charge of an electron has the symbol _____ and is equal to _____ C.
- 9) Kirchoff's first law states and is a consequence of the conservation of _____
- 10) Current flowing through a conductor can be linked to the drift velocity of charge carriers by the equation $I =$ _____,
- 11) Explain the meaning and give the units for all quantities in the equation $I = nAve$
- 12) Potential difference is the electrical _____ transferred to other forms per _____ of charge. $V = W/Q$.
- 13) The units of p.d. are the _____. The volt is defined as 1J of electrical energy transferred per _____ coulomb of charge ($V=W/Q = 1/1 = 1V$)
- 14) P.d. is measured using a _____ and placed in _____
- 15) E.m.f is the electrical _____ transferred to charge per _____ by a cell or power supply. $E = ?/?$
- 16) The difference between e.m.f and p.d. is
- 17) Resistance is defined as $R =$ _____
- 18) If the p.d across a component is 10V and its resistance is 2Ω what is the current?
- 19) The ohm is defined the resistance provided when a p.d. of _____ V causes a current of _____ A to flow. ($R = V/I = 1/1 = 1\Omega$)
- 21) Ohms law states that
- 22) Describe an experiment (circuit diagram included to obtain the I-V characteristic of a circuit component such as a filament lamp)
- 23) Draw I-V graphs for, an ohmic resistor, filament lamp, light emitting diode.
- 24) LED'S are very efficient. They waste little _____
- 25) The resistance of a material can be linked to its dimensions by the equation $R =$ _____. Where A is the _____ in _____, L is the _____ in _____ and ρ is the _____ in _____.
- 26) Resistivity can be defined as $\rho =$ _____
- 27) The resistance of a pure metal _____ with increasing temperature. The resistance of a negative temperature coefficient (NTC) thermistor _____ with increasing temperature
- 28) Power is the rate of _____ transfer. $P = W/t$. The unit of power is the _____
- 29) Electrical power $P =$ _____ or $P =$ _____ or $P =$ _____
- 30) A fuse is made from a thin piece of _____ which _____ when too higher _____ flows
- 31) A device has a power of 2000W when connected to a 250V supply. What current does it use and what would be a suitable fuse?
- 32) From $P = W/t$ energy transferred $W =$ _____ = _____ (clue $P=IV$)
- 32b) How much energy is transferred by a 20W bulb in 6s?
- 33) If an electrical heater uses 10A of current fro a 250V supply how much electrical energy is transferred to heat in 20s?
- 34) The kilowatt hour is defined as
- 35) What is 1 kwh in joules?
- 36) How much energy in kwh is used by a 4kwh in 3 hours?
- 36b) How much will this cost if 1kwh is 10p?

- 1) charged free electrons ions
- 2) positive negative negative positive
- 3) current x time $Q = It, \Delta Q = I\Delta t$
- 4) positive negative coulomb
- 5) one one
- 6) $I = Q/t = 20/2 = 10A$
- 7) ammeter series
- 8) e $1.6 \times 10^{-19} C$
- 9) sum of currents entering a junction = sum of currents leaving
- 10) $I = nAve$
- 11) n - N^o of charges per m³ A- area in m², v- drift velocity in m/s, e - electron charge
- 12) energy coulomb
- 13) volt one
- 14) voltmeter parallel
- 15) energy coulomb $E = W/Q$
- 16) e.m.f - energy transferred to charge
p.d - energy released by charge
- 17) $R = V/I$
- 18) $I = V/R = 10/2 = 5\Omega$
- 19) one one
- 21) Current is proportional to voltage at constant temperature

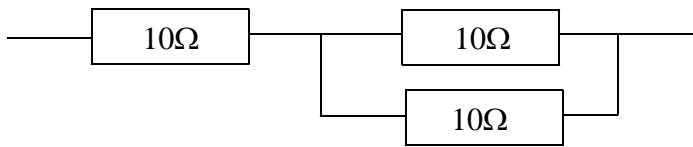


- 24) energy
- 25) $R = \rho L/A$, area m² length m, resistivity Ωm
- 26) $\rho = AR/L$
- 27) rises drops
- 28) energy watt
- 29) $P = IV = I^2R = V^2/R$
- 30) wire melts current
- 31) $I = P/V = 2000/250 = 8A$ 10A fuse
- 32) $W = Pt = IVt$
- 32b) $W = Pt = 20 \times 6 = 120W$
- 33) $W = Pt = IVt = 10 \times 250 \times 20 = 50000J$
- 34) The energy a 1kw device uses in 1 hour
- 35) $W = Pt = 1000 \times 60 \times 60 = 3600000J$
- 36) $E = Pt = 4 \times 3 = 12kwh$
- 36b) $12 \times 10 = 120p$

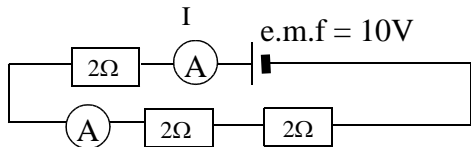
37) Kirchoff's second law states that in any closed loop the _____ of the _____ is equal to the e.m.f of the source. This law is a consequence of the conservation of _____

38) For resistors in series $R_t = \dots\dots\dots$ In parallel $1/R_t = \dots\dots\dots$

39) What is the resistance of this network



40) Use kirchoff's second law to calculate the current I in the circuit below



41) In a circuit with more than one cell e.m.f's are _____

42) In practise all sources of e.m.f have an _____ resistance

43) The voltmeter reads the voltage, V across the load resistance and is called the _____ p.d. It is less than the e.m.f. of the source because there is a potential difference across the _____ of the source.

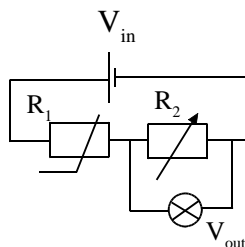
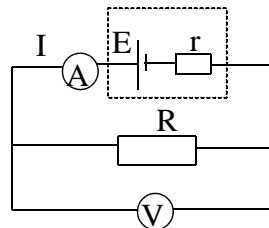
From Kirchoff's second law $E = IR + \dots$
 $E = V + Ir$

If this is rearranged so $V = -Ir + E$

a graph of _____ against _____ would give a _____ line with a gradient equal to the _____ and the y intercept equal to the _____

44) This is a _____ circuit containing a _____ and a _____ resistor.

$V_{out} = \dots\dots\dots$. If the temperature increases the thermistor resistance _____ and the p.d.across R_1 will drop and the V_{out} will increase making the lamp _____



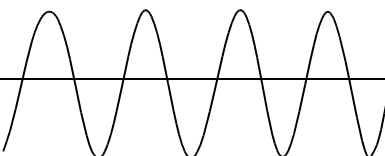
45) In the potential divider circuit what is V_{out} if $V_{in} = 20V$, $R_1 = 500\Omega$ and $R_2 = 25\Omega$?

46) What will happen to the lamp if R_2 is increased and why?

47) Wave frequency is defined as the number of waves per _____.

48) Two wave are in phase if they are in _____ with each other. Phase difference is a measure of how out of _____ two waves could be. It can be described as a fraction of a _____ eg $\lambda/2$ or as an angle 180° for example.

49) On this wave indicate the amplitude, wavelength and two points with zero displacement



50) The period, T of a wave is the time for one _____ and $T = \dots\dots\dots$

51) The speed of a wave $v = \dots\dots\dots$

52) Refraction of a wave occurs because of a change in _____ when it enters a different medium. Diffraction is the _____ out of waves through a _____. Diffraction is greatest when the gap width is equal to _____

37) sum p.d.'s energy

38) $R_1 + R_2$ $1/R_1 + 1/R_2$

39) For parallel components

$1/R = 1/10 + 1/10$

$1/R = 2/10$ so $R = 5\Omega$

total resistance = $10 + 5 = 15\Omega$

40) $10 = I \times 2 + I \times 2 + I \times 2 = 6I$

so $I = 10/6 = 1.67A$

41) Combined

42) Internal

43) terminal internal resistance

Ir

V I straight internal resistance e.m.f

44) potential divider

thermistor variable resistor

$V_{out} = \frac{V_{in} R_2}{(R_1 + R_2)}$ drops brighter

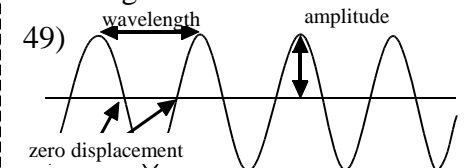
45) $V_{out} = \frac{V_{in} R_2}{(R_1 + R_2)} = \frac{20 \times 25}{(500 + 25)} = 0.95V$

46) Gets brighter because V_{out} increases

47) second

48) step step

wavelength



50) cycle or wave, $T = 1/f$

51) $v = f\lambda$ λ - wavelength

52) speed

spreading gap wavelength

53) Two properties that all electromagnetic waves share is that they all travel at the speed of _____ and they are all _____

54) The order of the electromagnetic spectrum in increasing wavelength is gamma (10^{-15} m).....

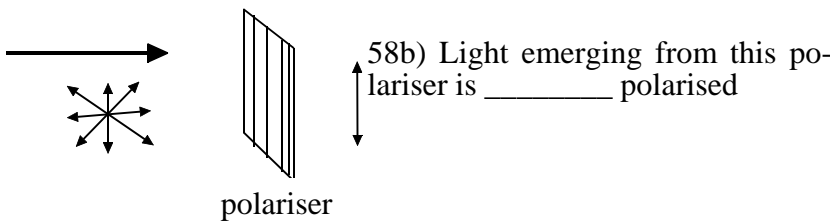
55) What is the frequency of gamma radiation with a wavelength of 10^{-15} m? $c = 3 \times 10^8 \text{ms}^{-1}$

56) Electromagnetic waves with the largest _____ have the most energy. Ultra-violet frequencies and above can _____ atoms to make ions. This changes their chemistry and may lead to _____. Infra-red, microwave and _____ have a _____ effect on objects. Microwaves of the right frequency can cause water molecules to resonate causing rapid heating.

57) UV part of the spectrum is split into UV-A, UV-B, UV-C, UV-A causes skin to _____, UV-B causes _____ UV-C is mostly absorbed by _____ in the atmosphere

58) Light is a _____ wave of different _____. In unpolarised light vibrations are in _____ planes

Polarised light is light where vibrations are in a single _____ (typically vertical or _____). Light can be polarised using a _____.



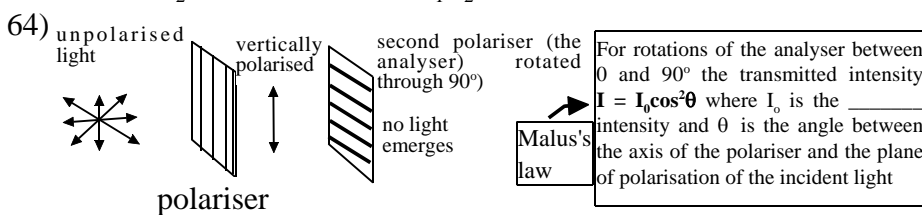
59) When light reflects from a surface it is _____ polarised. Sun-glasses contain a polariser which eliminates this polarised light.

60) The intensity of a wave is the power per _____ metre. Its units are _____. As an equation Intensity $I =$ _____

61) The intensity of a wave is proportional to _____², $I \propto A^2$

62) If the amplitude of a wave doubles its intensity _____. If the amplitude of a wave halves its intensity reduces by _____

63) If a wave has amplitude A_1 and intensity I_1 and its amplitude is changed to A_2 then we can write $I_1/I_2 =$ _____



64) unpolarised light vertically polarised second polariser (the analyser) through 90° no light emerges

65) The principle of superposition states that when two or more waves meet.....

66) These waves are in _____. If combined there would be _____ interference

67) These waves are _____ of phase by _____. If combined there would be _____ interference

68) For observable interference wave sources must be _____

69) Coherent waves are waves with the same _____

70) The path difference between two waves is the difference in _____ the two waves have travelled.

71) If the path difference between coherent waves is equal to a whole number of _____ ($n\lambda$) constructive _____ occurs

72) If the path difference between two coherent waves is equal to $n\lambda/2$ _____ interference occurs

53) light transverse

54) x ray (10^{-10} m), uv (10^{-8} m), visible (5×10^{-7} m) infrared (10^{-5} m), microwave (10^{-2} m), radio (10^{-1+} m)

55) $f = c/\lambda = 3 \times 10^8 / 10^{-15} = 3 \times 10^{23}$ Hz

56) frequency ionise cancers heating

57) wrinkle, cancer, ozone

58) transverse frequencies all plane horizontal polariser

58b) vertically

59) partially

60) square Wm^{-2} , $I = P/A$

61) amplitude

62) quadruples a quarter

63) $I_1/I_2 = A_1^2/A_2^2$

64) incident

65) the resulting displacement is the algebraic sum of the individual displacements

66) phase constructive

67) out 180° destructive

68) coherent

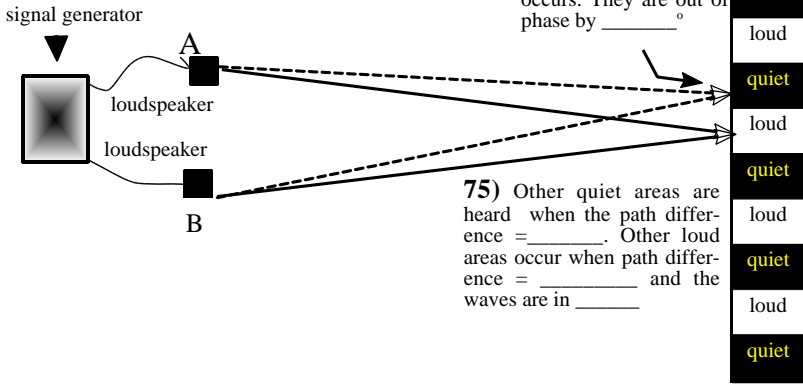
69) wavelength

70) distance

71) wavelengths interference

72) destructive

Interference



73) Here the path difference between the two waves is _____ and _____ interference occurs. They are out of phase by _____°

75) Other quiet areas are heard when the path difference = _____. Other loud areas occur when path difference = _____ and the waves are in _____

74) Here there is _____ path difference between the waves. They are in _____

73) $\lambda/2$ destructive 180

74) zero phase

75) $n\lambda/2$ $n\lambda$ phase

76) To observe interference of microwaves the same setup is used except a microwave _____ emits the signal. A barrier with two slits creates two _____ waves. These interfere and the interference pattern detected with a _____ detector.

77) In young's slit experiment a laser strikes a black slide with two parallel slits. This creates two _____ waves which interfere. The young's slit equation is $\lambda = \frac{ax}{D}$, where a is _____, x is _____ and D is _____

78) In young's slit experiment if slit separation decreases fringe separation _____. If the slit screen distance increases the fringe separation _____

79) Young's slit experiment is confirmation of the wave like nature of light because it is explained by the principle of _____ of waves.

80) A diffraction grating is a material with many slits. At each slit _____ occurs. Diffracted waves then interfere to produce an interference pattern

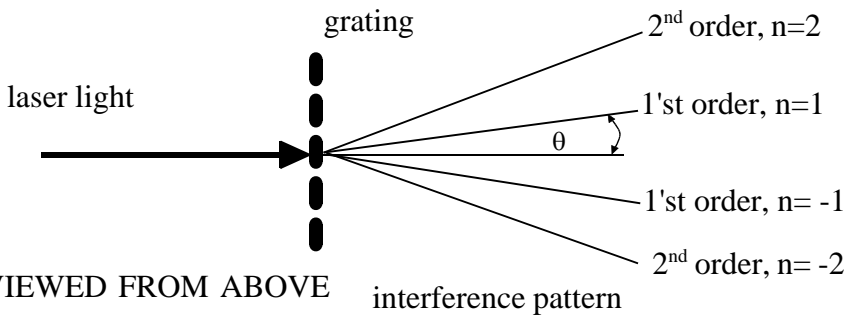
76) transmitter coherent microwave

77) coherent $\lambda = ax/D$
slit separation, fringe separation
slit to screen distance

78) increases, increases

79) superposition

80) diffraction



81) The diffraction equation is $d \sin \theta = n\lambda$. Where d isin metres, n is, and θ is the angle between the zeroth order (straight through) and the order number

82) If a diffraction grating has 3000 lines per cm the separation of each line = _____ cm = _____ m. If the first order maximum is detected at an angle of 10° as shown on the diagram what is the wavelength of the light?

83) Using a diffraction grating to measure the wavelength of light is better than young's slit experiment because maxima are very _____ and _____. The maxima are widely separated and the angle can be measured very _____. In young's slit experiment the separation of two slits needs to be measured - a big % inaccuracy. In a grating there are many slits and their separation d can be worked out accurately

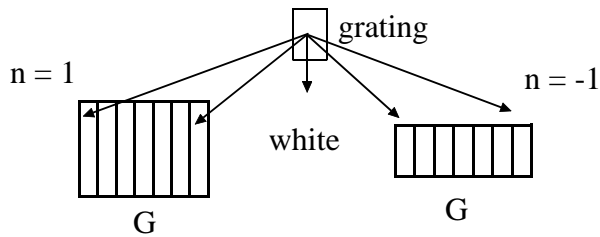
81) $n\lambda$
slit separation, the order number

82) $1/3000 = 3.33 \times 10^{-4} \text{cm} = 3.33 \times 10^{-6} \text{m}$
 $\lambda = d \sin \theta / n = \frac{3.36 \times 10^{-6} \times \sin 10}{1}$
 $= 5.8 \times 10^{-7} \text{m}$

83) bright sharp accurately

84) White light shone through a diffraction grating will produce maxima of all the colours of the _____

This happens because different colours have different _____ and from $d\sin\theta = n\lambda$ if the wavelength is bigger i.e. red light, the angle for maxima will be bigger



85) White light is shone into this grating and an interference pattern observed. The zeroth order remains _____.

86) Label the position of red R for the first order

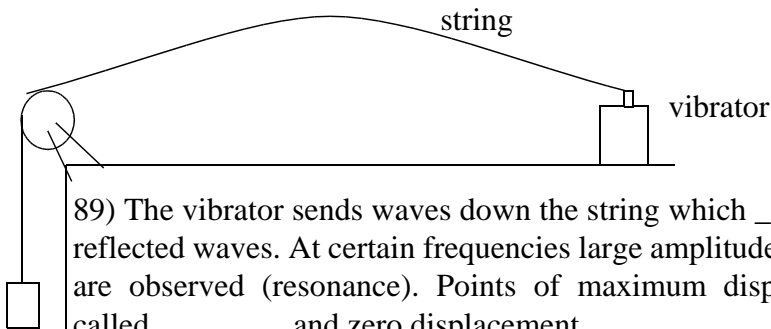
87) Transverse and longitudinal are classed as _____ waves. They transfer _____ and seem to move

Only _____ can be polarised. Sound cannot be polarised because it is a _____ wave.

88) Two properties of stationary waves are

(a) _____

(b) _____



89) The vibrator sends waves down the string which _____ with reflected waves. At certain frequencies large amplitudes of vibration are observed (resonance). Points of maximum displacement are called _____ and zero displacement _____.

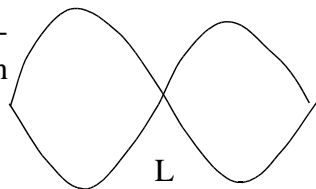
The lowest frequency resonance occurs is called the _____.

The next frequency for resonance is call the _____ harmonic

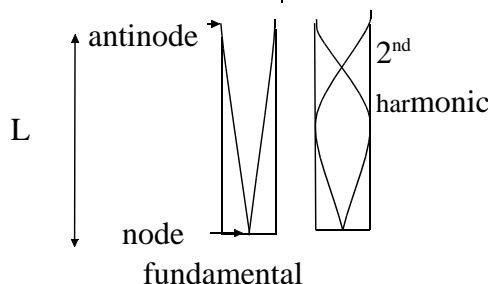
90) The distance between successive nodes is =.....

91) The distance between successive anti-nodes is =.....

92) In a vibrating string this frequency is the _____ harmonic. In terms of wavelength $L =$

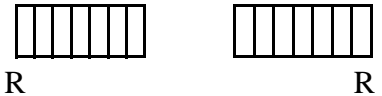


93) In an open ended pipe the closed end is fixed and air cannot vibrate this is a _____. If frequency is gradually increased a resonance occurs, (the fundamental). In terms of wavelength $L =$ _____. Increasing the frequency produces the second harmonic and $L =$ _____



84) rainbow wavelengths

85) white



87) progressive energy
transverse longitudinal

88) no energy is transferred
they do not progress

89) interfere
anti-nodes nodes

fundamental
second

90) $\lambda/2$

91) $\lambda/2$

92) second
 $L = \lambda$

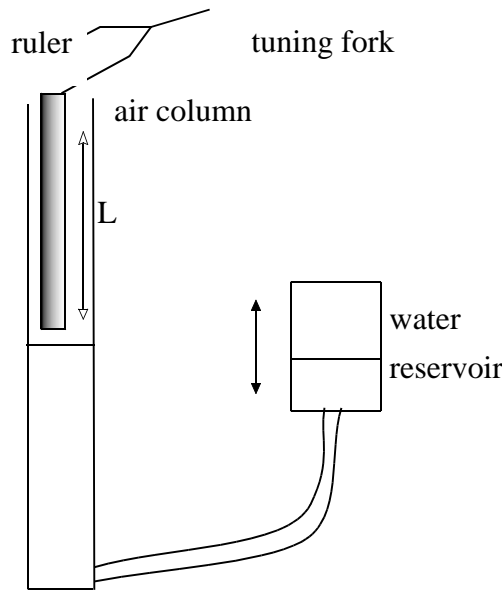
93) node

$L = \lambda/4$

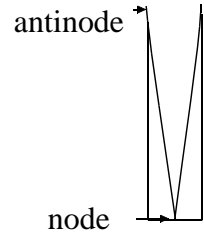
$L = 3\lambda/4$

94a) To measure the speed of sound an experimenter changed the length of an air column by dropping or raising a water reservoir. The experimenter started with the air column very short then gradually increased it until maximum volume was heard

(a) sketch the stationary water wave obtained label the node and anti-node)



94)(a)



(b) use these results to work out the speed of sound

frequency $f = 512\text{Hz}$	Length $L = 0.16\text{m}$
------------------------------	---------------------------

95) Electromagnetic radiation has a wave nature and a _____ nature.

96) Electromagnetic radiation travels as packets of energy called _____. Each photon has an energy $E = \text{_____}$ or $E = \text{_____}$

97) What is the energy of a gamma ray photon with wavelength 10^{-15}m ?

98) The electron volt is a much smaller unit of _____ than the joule

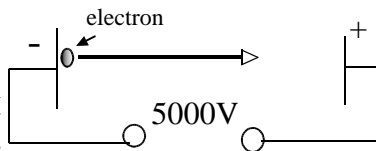
99) The electron volt is defined as the energy gained by an _____ when accelerated through a p.d. of 1 volt

from $W = QV$, $W = eV$, $= 1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}\text{J}$

100) How many joules is 10eV ?

101) How many eV's is $2 \times 10^{-18}\text{J}$?

102) Near the negative plate the electron has an electric potential energy, W . $W = QV = eV$. This electric potential energy is converted to _____ energy as it accelerates towards the positive plate. So $eV = \frac{mv^2}{2}$



94b) $v = f\lambda$. From results at the fundamental $L = \lambda/4$

so $\lambda = 4L = 4 \times 0.16 = 0.64\text{m}$

so $v = f\lambda = 512 \times 0.64 = 328\text{ms}^{-1}$

95) particle

96) photons hf hc/λ

97) $E = hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^8) / 10^{-15} = 1.99 \times 10^{-11}\text{J}$

98) energy

99) electron

100) $10 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-18}\text{J}$

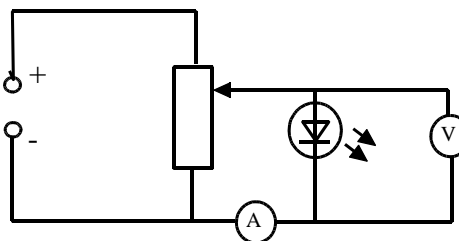
101) $2 \times 10^{-18} / 1.6 \times 10^{-19} = 12.5\text{eV}$

102) kinetic

102b) $v = \sqrt{(2eV/m)}$
 $= \sqrt{(2 \times 1.6 \times 10^{-19} \times 5000 / 9.1 \times 10^{-31})}$
 $= 4.2 \times 10^7\text{ms}^{-1}$

103) This apparatus can be used to calculate Planck's constant, h .

The voltage is increased until a 6V _____ just starts to flow. At this threshold voltage



energy lost by electron = energy of emitted _____

so $eV = hf = hc/\lambda$

so $V = \frac{hc}{e\lambda}$

e

If different diodes are used of known wavelength a graph of V against $1/\lambda$ will give a _____ line with a gradient = _____. Planck's constant $h = \text{_____}$

103) current

photon

straight hc/e

$h = (\text{gradient} \times e)/c$

104) In the **photoelectric effect** electrons are emitted from a metal surface using electromagnetic waves above a _____ frequency. Below this frequency no electrons are emitted no matter how intense.

A wave model of electromagnetic waves cannot explain this because more intensity with a wave model implies more energy.

If the intensity of electromagnetic waves above the threshold frequency is increased _____ electrons are emitted but the maximum kinetic energy of the ejected electrons remains _____. *This is evidence of the particle nature of electromagnetic waves which we call _____ with energy = _____*

105) The Einstein photo-electric equation is _____

where hf is the _____, ϕ is _____ and $1/2mv^2$ is the maximum _____ of an ejected electron

106) At the threshold frequency $hf_0 = ______$

107) The work function is defined as.....

108) (a) What are the energy of a photons in an electromagnetic wave with wavelength $2.4 \times 10^{-7}m$?

(b) If these electromagnetic waves are incident on the surface of a metal whose work function is $2.8 \times 10^{-19}J$ calculate the maximum kinetic energy of electrons emitted.

(c) Determine the maximum speed of the emitted photons ($m_e = 9.11 \times 10^{-31}Kg$)

109) **De Broglie** suggested if electromagnetic waves could behave like particles could particles behave as _____?

110) Evidence that particles can behave like waves is the _____ of electrons through a thin layer of graphite.

111) The De Broglie equation is _____

112) λ is a wave property, mass is a _____ property (the product mv is momentum also a particle property)

113) Calculate the de Broglie wavelength of an electron travelling at 10^7ms^{-1} . ($m_e = 9.11 \times 10^{-31}kg$)

114) Will the electrons in the previous question be diffracted by solid materials (inter atomic spacing in solid materials is approx $10^{-10}m$)

Emmision Spectra

115) White light has a _____ spectrum (all visible wavelengths are present). A hot gas like neon or sodium will produce a _____ spectrum where only certain wavelengths are emitted.

Absorption Spectra

116) If white light shines through a gaseous element certain frequencies are absorbed and appear as _____ lines against the continuous spectrum of the white light.

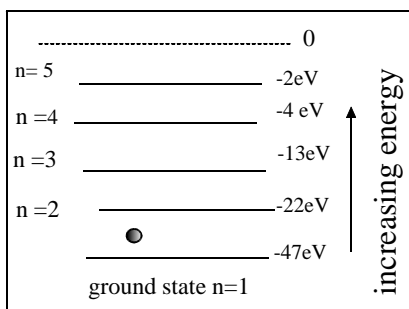
117) When a photon is absorbed an electron is promoted to a higher _____ level in the atom. When an electron falls back to a lower level it emits a _____

118) The energy of the emitted photon is equal to the difference in _____ level i.e. $hf = E_2 - E_1$

119) If the electron at $n=1$, the ground state, absorbed a photon of energy $47ev$ it would be

120) What would the energy of an emitted photon if it fell from $n = 3$ to $n = 2$?

121) What would the frequency be of the emitted photon?



104) threshold

more the same

photons hf

105) $hf = \phi + 0.5mv^2$

photon energy work function

kinetic energy

106) ϕ

107) The minimum photon energy to just eject an electron

108) $E = hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^8) / 2.4 \times 10^{-7} = 8.3 \times 10^{-19}J$

(b) $0.5mv^2 = hf - \phi = 8.3 \times 10^{-19} - 2.8 \times 10^{-19} = 5.5 \times 10^{-19}J$

(c) $v = \sqrt{(2KE/m)} = \sqrt{(2 \times 5.5 \times 10^{-19} / 9.1 \times 10^{-31})} = 1.1 \times 10^6 ms^{-1}$

109) waves

110) diffraction

111) $\lambda = h/mv$

112) particle

113) $\lambda = h/mv = 6.63 \times 10^{-34} / (9.1 \times 10^{-31} \times 10^7) = 7.3 \times 10^{-11}m$

114) yes - wavelength and gaps similar

115) continuous line

116) dark

117) energy photon

118) energy

119) just removed from the atom

120) $hf = E_2 - E_1 = -13 - (-22) = 9eV$

121) $E=hf, f = E/h = 9 \times 1.6 \times 10^{-19} / 6.63 \times 10^{-34} = 2.2 \times 10^{15}Hz$