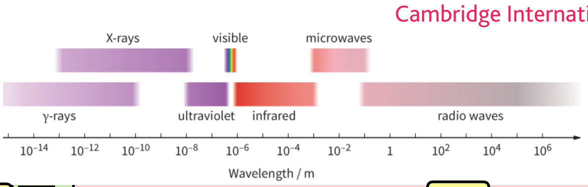
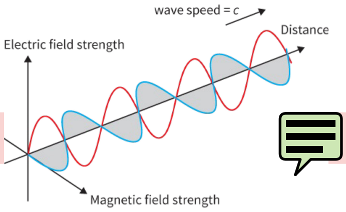




7.4 Electromagnetic spectrum

Candidates should be able to:

$$c = 299\ 792\ 458\ \text{m s}^{-1}$$

1 state that all electromagnetic waves are transverse waves that travel with the same speed *c* in free space

$$c = f\lambda$$

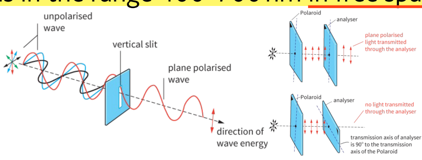
2 recall the approximate range of wavelengths in free space of the principal regions of the electromagnetic spectrum from radio waves to γ-rays

Type of electromagnetic waves	Wavelength range / m
radio waves	$>10^{6}$ to 10^{-1}
microwaves	10^{-1} to 10^{-3}
infrared	10^{-3} to 7×10^{-7}
visible	7×10^{-7} (red) to 4×10^{-7} (violet)
ultraviolet	4×10^{-7} to 10^{-8}
X-rays	10^{-8} to 10^{-13}
γ-rays	10^{-10} to 10^{-16}

Type of radiation	Approximate range of wavelength in a vacuum/m	Properties and uses
Gamma	10^{-16} to 10^{-11} #Gamma<10^-11 and X-rays>10^-11 when choosing between x or y rays	Produced by the disintegration of atomic nuclei; very penetrating, causes ionisation, affects living tissue
X-radiation	10^{-13} to 10^{-8}	Produced from rapidly decelerated electrons; properties similar to gamma-rays, the only real difference is in their method of production
Ultraviolet	10^{-8} to 4×10^{-7}	Ionising radiation, affects living tissue, stimulates the production of vitamin D in mammals
Visible light	4×10^{-7} to 7×10^{-7}	Stimulates light-sensitive cells on the retina of the human (and other animals) eye
Infrared	7×10^{-7} to 10^{-3}	Has a heating effect and is used for heating homes and cooking
Microwaves	10^{-3} to 10^{-1}	Used in microwave cooking where it causes water molecules to resonate; also used in telecommunications, including mobile telephones
Radio waves	10^{-1} to 10^{6}	Used in telecommunications

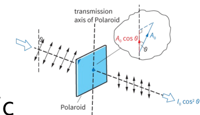
3 recall that wavelengths in the range 400–700 nm in free space are visible to the human eye

7.5 Polarisation



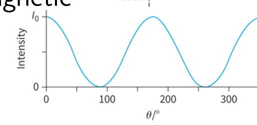
Candidates should be able to:

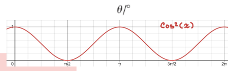
1 understand that polarisation is a phenomenon associated with transverse waves



2 recall and use Malus's law ($I = I_0 \cos^2\theta$) to calculate the intensity of a plane polarised electromagnetic wave after transmission through a polarising filter or a series of polarising filters

The half rule- when unpolarised life passes through the first polariser, half the intensity of the wave is always lost.





8 Superposition

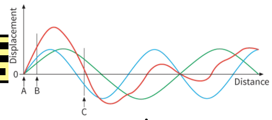
Stationary waves	Progressive waves
Energy is stored in the vibrating particles	Energy is transferred from one place to another
All the points between successive nodes are in phase	All the points over one wavelength have different phases
The amplitudes of different points vary from a maximum to zero	All the points along the wave have the same amplitude

	Progressive wave	Stationary wave
wavelength	λ	λ
frequency	f	f
speed	v	zero

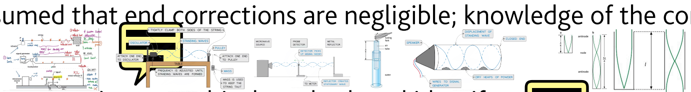
8.1 Stationary waves

Candidates should be able to:

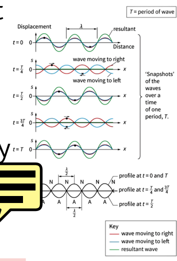
1 explain and use the principle of superposition



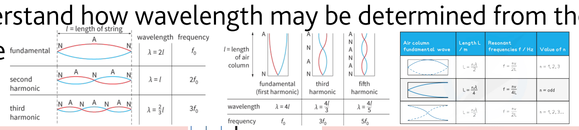
2 show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required)



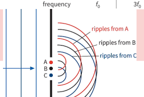
3 explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes



4 understand how wavelength may be determined from the positions of nodes or antinodes of a stationary wave

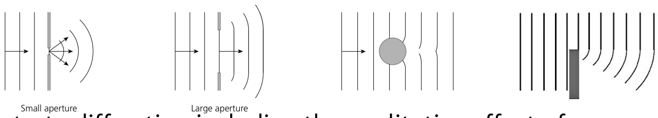


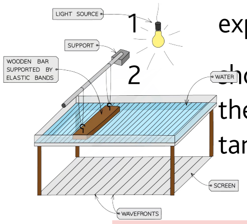
8.2 Diffraction



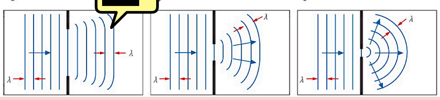
Candidates should be able to:

1 explain the meaning of the term diffraction



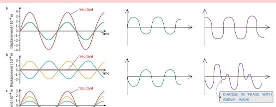


2 show an understanding of experiments that demonstrate diffraction including the qualitative effect of the gap width relative to the wavelength of the wave; for example diffraction of water waves in a ripple tank



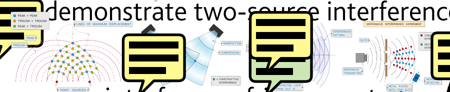
8.3 Interference

Candidates should be able to:



1 understand the terms interference and coherence

2 show an understanding of experiments that demonstrate two-source interference using water waves in a ripple tank, sound, light and microwaves



3 understand the conditions required if two-source interference fringes are to be observed

4 recall and use $\lambda = ax / D$ for double-slit interference using light

For **constructive interference** the path difference is a whole number of wavelengths:

path difference = 0, λ, 2λ, 3λ, and so on

or

path difference = nλ

For **destructive interference** the path difference is an odd number of half wavelengths:

path difference = $\frac{1}{2}\lambda, 1\frac{1}{2}\lambda, 2\frac{1}{2}\lambda$, and so on

or

path difference = $(n + \frac{1}{2})\lambda$

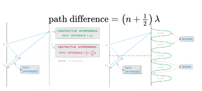
$$\lambda = \frac{ax}{D}$$

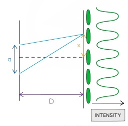
DISTANCE BETWEEN CENTRES OF THE SLIT

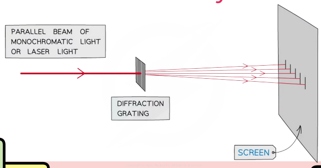
FRINGE WIDTH (DISTANCE BETWEEN SUCCESSIVE BRIGHT FRINGES) (m)

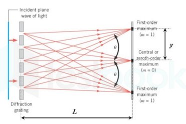
WAVELENGTH OF SOURCE (m)

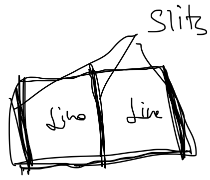
DISTANCE BETWEEN DOUBLE SLIT TO THE SCREEN (m)

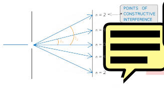






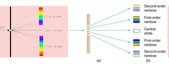






$n = \frac{d}{\lambda}$

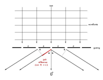
8.4 The diffraction grating



Candidates should be able to:

ANGULAR SEPARATION BETWEEN THE ORDER OF MAXIMA (DEGREES)
WAVELENGTH OF SOURCE (m)
$d \sin(\theta) = n\lambda$
SPACING BETWEEN ADJACENT SLITS (m)
ORDER OF MAXIMA $n = 0, 1, 2, 3 \ldots$

Exam questions sometime state the lines(not slits) per m (or per mm, per nm etc.) on the grating which is represented by the symbol N
d can be calculated from N using the equation: $d = \frac{1}{N}$



1 recall and use $d \sin \theta = n\lambda$

2 describe the use of a diffraction grating to determine the wavelength of light (the structure and use of the spectrometer are not included)

9 Electricity

9.1 Electric current

Candidates should be able to:

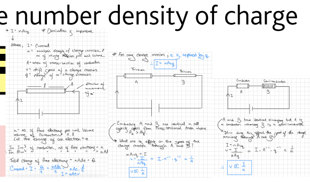
1 understand that an electric current is a flow of charge carriers

2 understand that the charge on charge carriers is quantised

3 recall and use $Q = It$

4 use, for a current-carrying conductor, the expression $I = Anvq$, where n is the number density of charge carriers

$I = Anvq$
CROSS-SECTIONAL AREA (m^2)
AVERAGE DRIFT SPEED OF CHARGE CARRIERS (ms^{-1})
CHARGE OF EACH CHARGE CARRIER (C)
CURRENT (A)
NUMBER DENSITY OF CHARGE CARRIERS (m^{-3})



9.2 Potential difference and power

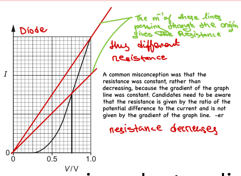
Candidates should be able to:

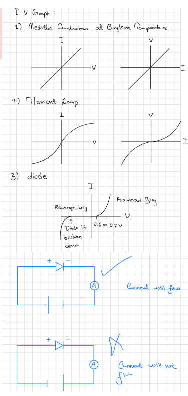
1 define the potential difference across a component as the energy transferred per unit charge

2 recall and use $V = W / Q$

3 recall and use $P = VI$, $P = I^2R$ and $P = V^2 / R$

9.3 Resistance and resistivity



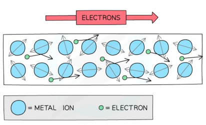


Candidates should be able to:

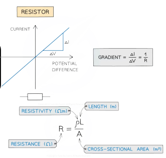
1 define resistance

2 recall and use $V = IR$

3 sketch the I–V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp

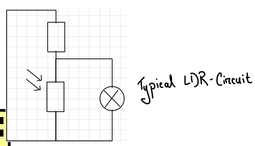


4 explain that the resistance of a filament lamp increases as current increases because its temperature increases



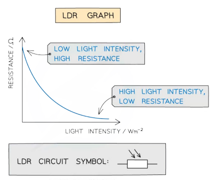
Material	Resistivity ρ (Ω-m) at 20°C	Temperature coefficient of resistivity (ppm/°C)
Copper	1.68×10^{-8}	3900
Silver	1.59×10^{-8}	3800
Gold	2.44×10^{-8}	3400
Aluminum	2.82×10^{-8}	3900
Lead	2.2×10^{-7}	3900
Tin	1.09×10^{-7}	4500
Tungsten	5.28×10^{-8}	4500
Iron	1.0×10^{-7}	5000
Resistive alloy	1.0×10^{-7}	700

Table. *Material resistivity properties.*



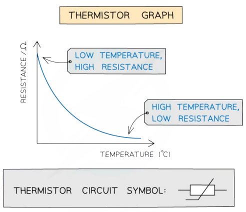
5 state Ohm's law

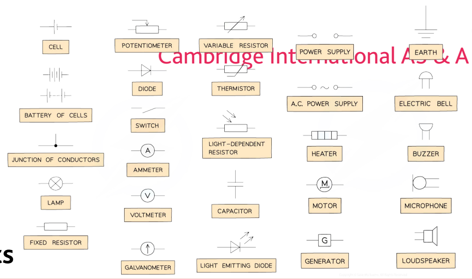
6 recall and use $R = \rho L / A$

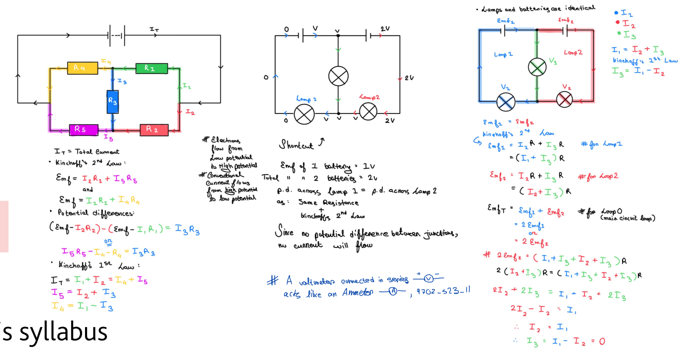


7 understand that the resistance of a light-dependent resistor (LDR) decreases as the light intensity increases

8 understand that the resistance of a thermistor decreases as the temperature increases (it will be assumed that thermistors have a negative temperature coefficient)





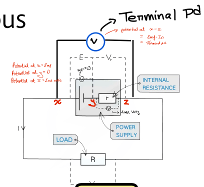


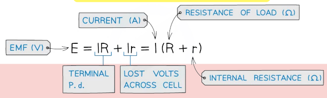
10 D.C. circuits

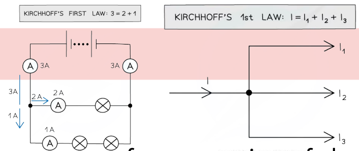
10.1 Practical circuits

Candidates should be able to:

1. recall and use the circuit symbols shown in section 6 of this syllabus
2. draw and interpret circuit diagrams containing the circuit symbols shown in section 6 of this syllabus
3. define and use the electromotive force (e.m.f.) of a source as energy transferred per unit charge in driving charge around a complete circuit
4. distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations
5. understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference



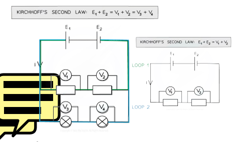


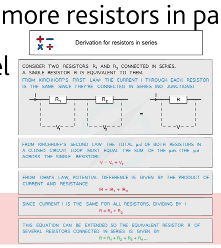


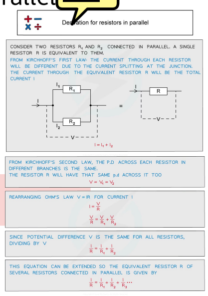
10.2 Kirchhoff's laws

Candidates should be able to:

1. recall Kirchhoff's first law and understand that it is a consequence of conservation of charge
2. recall Kirchhoff's second law and understand that it is a consequence of conservation of energy
3. derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series
4. use the formula for the combined resistance of two or more resistors in series
5. derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel
6. use the formula for the combined resistance of two or more resistors in parallel
7. use Kirchhoff's laws to solve simple circuit problems



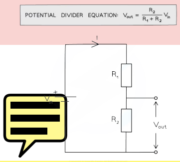


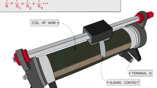


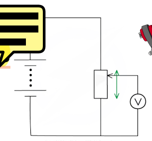
10.3 Potential dividers

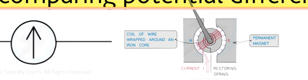
Candidates should be able to:

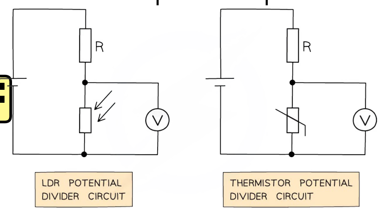
1. understand the principle of a potential divider circuit
2. recall and use the principle of the potentiometer as a means of comparing potential differences
3. understand the use of a galvanometer in null methods
4. explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and light intensity

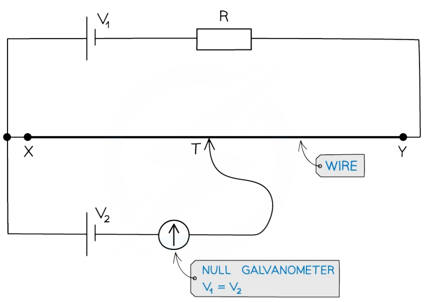


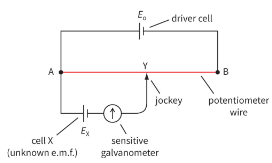








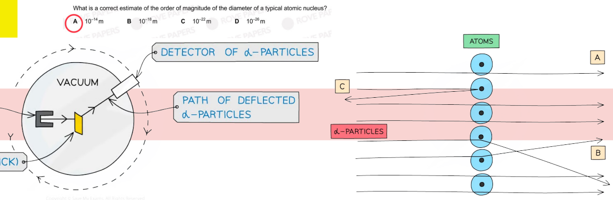


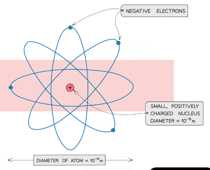


$$E_X = \frac{AY}{AB} \times E_o$$

The electron-volt is a unit of energy or work. An electron-volt (eV) is the work required to move an electron through a potential difference of one volt. E = VQ, so 1 eV = (1.6 x 10^-19 coulombs)x(1 volt) = 1.6 x 10^-19 Joules.

***Gamma-radiation is usually emitted after α or β decay, to release excess energy from the nuclei.



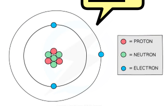


11 Particle physics

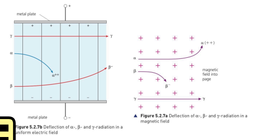
11.1 Atoms, nuclei and radiation

Candidates should be able to:

1. infer from the results of the α-particle scattering experiment the existence and small size of the nucleus
2. describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons

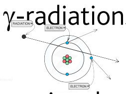


3. distinguish between nucleon number and proton number
4. understand that isotopes are forms of the same element with different numbers of neutrons in their nuclei
5. understand and use the notation ${}^{A}_{Z}X$ for the representation of nuclides

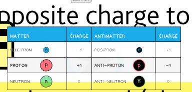


6. understand that nucleon number and charge are conserved in nuclear processes
7. describe the composition, mass and charge of α-, β- and γ-radiations (both β^- (electrons) and β^+ (positrons) are included)

${}^{4}_{2}\alpha$ OR ${}^{4}_{2}He$ ${}^{0}_{-1}\beta$ ${}^{0}_{0}\gamma$

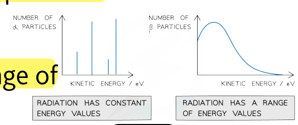


8. understand that an antiparticle has the same mass but opposite charge to the corresponding particle, and that a positron is the antiparticle of an electron



9. state that (electron) antineutrinos are produced during β^- decay and (electron) neutrinos are produced during β^+ decay

10. understand that α-particles have discrete energies but that β-particles have a continuous range of energies because (anti)neutrinos are emitted in β-decay



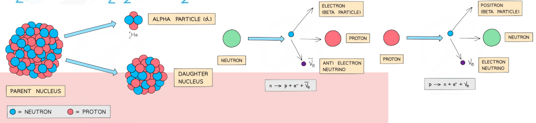
11. represent α- and β-decay by a radioactive decay equation of the form ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$
12. use the unified atomic mass unit (u) as a unit of mass

Particle	Mass / u
Proton	1
Neutron	1
Electron	0.0005
Alpha (α)	4

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}_e \qquad {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}\beta + {}^{0}_{0}\nu_e$$

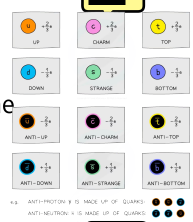
$${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}_e \qquad {}^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{+1}\beta + {}^{0}_{0}\nu_e$$



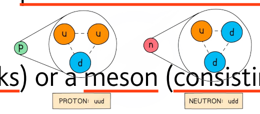
11.2 Fundamental particles

Candidates should be able to:

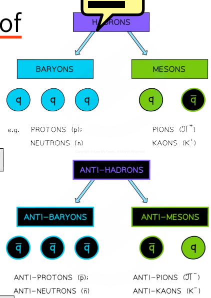
1. understand that a quark is a fundamental particle and that there are six flavours (types) of quark: up, down, strange, charm, top and bottom



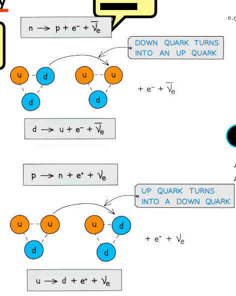
2. recall and use the charge of each flavour of quark and understand that its respective antiquark has the opposite charge (no knowledge of any other properties of quarks is required)
3. recall that protons and neutrons are not fundamental particles and describe protons and neutrons in terms of their quark composition



4. understand that a hadron may be either a baryon (consisting of three quarks) or a meson (consisting of one quark and one antiquark)



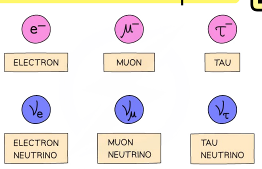
5. describe the changes to quark composition that take place during β^- and β^+ decay



6. recall that electrons and neutrinos are fundamental particles called leptons

and positrons

and anti-neutrinos



Muon and Tau not in syllabus