# Equations & quantities reference

### Given equations (Papers 1 & 2)

Note that the guides and units are not given.

s = (u+v)t \* 0.5 [-a]

v = u + at [-s]

s = ut + 1/2at² [-v]

v² = u² + 2as [-t]

F = ma

W = mg

p = mv [p: momentum]

v = s / t [@ a = 0]

ΔW = F \* Δs [Work done J]

KE = 1/2mv² [J]

GPE = mgΔh [Gravitational potential J]

P = E / t = W / t [W]

Efficiency = Useful out / Total in

ρ = m / V [ρ: density]

F = 6(pi)ηrv [η: viscosity] [stroke's law] [v: terminal velocity]

ΔF = k Δx [Δx: extension][k: stiffness constant][hooke's law]

ΔEelastic = 1/2 FΔx

E = σ / ε [Young modulus]

σ = F / A [Stress]

ε = Δx / x [Strain]

v = fλ [Transverse wave speed]

v = sqrt(T/μ) [Wave speed on string] [T: Tension] [μ: kg m²]

I = P / A [Intensity of radiation] [A: Area m²]

nsinθ = nsinθ [Snell's law]

n = c / v

sinC = n⁻¹ [Critical angle]

nλ = dsinθ [d: slit width] [n: index of fringe] [θ: angle to fringe] [d = 1 / num of gratings]

V = W / Q = E / Q [Potential difference] [Q: charge]

V = IR

P = VI = I²R = V² / R

W = VIt [Work done J]

R = ρl / A [ρ: Resistivity] [l: length]

I = ΔQ / Δt [Q: charge]

I = nAve [A: Area m2] [n: density of electron]

E = hf

hf = Φ + 1/2mv² [Φ: work function] [v: maximum velocity]

λ = h / p [λ: de broglie wavelength]

### Given equations (Papers 4 & 5)

dP = F \* dT [dP: impulse Ns]

w = dθ / dV [w: angular velocity rad s-1]

v = rw [v: instantaneous velocity of rotating object]

a = rw² v²/r [a: centripetal acceleration]

F = mrw² mv²/r [F: centripetal force]

KE = VQ

E = F / Q [E: electric field strength]

E = V / d [d: distance between parallel plates]

E = Q / 4(pi)(perm0)r² [perm0: 8.85e-12 Fm-1] [r: distance from charge]

V = Q / 4(pi)(perm0)r

F = Q₁Q₂ / 4(pi)(perm0)r² [r: distance between charges]

C = Q / V [C: capacitance F]

E = .5QV [E: energy stored in capacitor]

tc = RC [tc: time constant]

x = x₀e^(-t/RC) [x: Q | V | I]

Φ = BsinθA [Φ: magnetic flux] [B: magnetic flux density T]

ΦN = BAN [ΦN: magnetic flux linkage]

emf = -ΔBAN / Δt [emf: induced emf]

### Given quantities

g = 9.81 ms-2

e = -1.6e-19 C

mass of e = 9.11e-31 kg

eV = 1.6e-19 J

h = 6.63e-34 Js

c = 3e8 ms-1

### Not given equations

Equations not given in the exam

I = fQ [f: frequency]

### Conversions

1 kWh = 3.6e6 J

1 km/h = 3.6 m/s

### SI Base units

|  |  |  |  |
| --- | --- | --- | --- |
| Unit | Name | Quantity | Symbol |
| s | seconds | time | t |
| m | meter | length | l,x,d |
| kg | kilogram | mass | m |
| A | ampere | electric current | I |
| K | kelvin | temperature | T |
| mol | mole | amount of substance | n |
| cd | candela | luminous intensity | Iv |

# Topic 5 – Further mechanics

## Further momentum

Elastic collision: KE conserved

Inelastic collision: KE not conserved

Impulse is the change in momentum:

## Circular motion

Angular velocity: Instantaneous velocity:

C. acceleration:

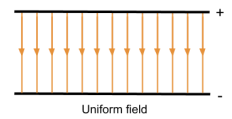
C. force:

Centripetal force acts 90 degrees to the direction of motion

# Topic 6 - Electric and magnetic fields

## Electric fields

Electric field - force field in which charged particles experience a force



To draw field lines:

1. Current +ve → -ve terminal

2. Straight parallel lines

3. Evenly spaced lines

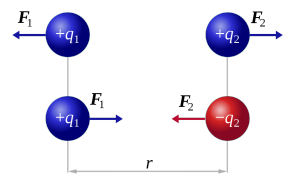
### Uniform fields

### Radial fields

To explain the direction of the electric field at a point:

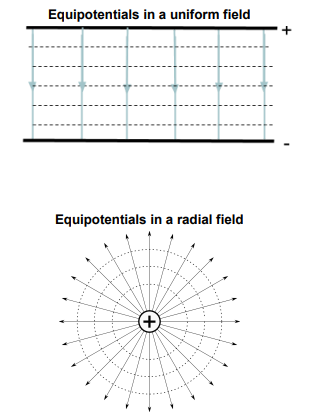
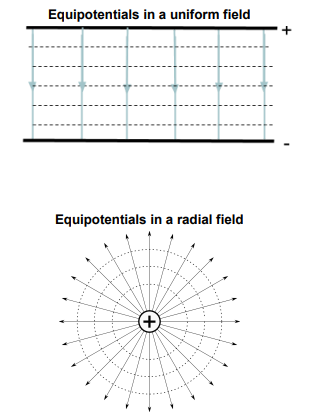
1. Due to A being +ve, e-field is exerted away from A:
2. Due to B being -ve, e-field is exerted towards B:
3. (as vertical component cancelled out)

### Coulomb’s law

If charges have the same sign, F ≥ 0 and hence the force will be repulsive, else it will be attractive

### Equipotentials

Join points with equal potential in an electric field together to create surfaces of equipotentials



### Electron guns

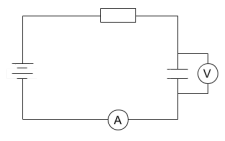
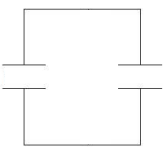
1. hot metal surface → thermionic emission → release e-

2. Anode +ve charge accelerates e-

### Earth’s magnetic field

Distance from poles ↓ Magnetic field strength ↑

## Capacitors

Stores charge, has no resistance

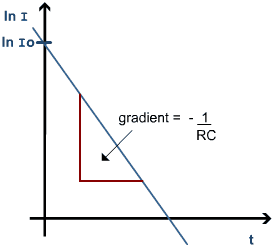
To explain charging capacitor with e- flow

* e- move from one plate to another through external circuit
* As capacitors charge, rate of flow of e- ↓
* When fully charged, equal amounts of e- stored on each plate

### Charging and discharging properties

|  |  |
| --- | --- |
| Charging | Discharging |
|  |  |

To find the time constant with \*-t graph:

1. Locate the initial value for Q | V | I
2. Calculate value at 37% if charging, 63% if discharging
3. Use the graph to find corresponding time

To find time constant with straight-line graph

1. Natural log both sides →
2. Re-arrange variables to make

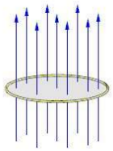
## How Magnets WorkMagnetic fields

Magnetic poles always exist with both North and South poles, N → S, S → N if at the center

### Magnetic flux

Uniform magnetic fields - constant magnetic flux density

Magnetic flux density (B, Unit Testa (T)) is a measure of the strength of the field

Magnetic flux (, Unit Weber (Wb)) describes magnetic field lines cutting through a given area:

When , there are no field lines cutting through A

Magnetic flux linkage:

### Directions of vectors

⨀: Out of paper F: Magnetic force

⊗︀: Into paper iL: Induced current

To explain directions of vectors:

* State “Using LHR”, or state

|  |  |  |
| --- | --- | --- |
| Force direction: LHR | Induced current direction: RHR | Magnetic field direction: Grip rule |
|  | Electromagnetism Resource | Right-hand rule - Wikipedia |

To think of questions with magnet on a weigh:

* Note that the reason for the increasing reading is due to the reaction force experienced by magnet when it exerts an **upward** force onto the conducting material, which by 3rd law, it exerts a **downwards reaction** force onto the magnet
* Directions of forces should reference LHR

### Charged particles in magnetic fields

A force acts on charged particles moving in a magnetic field

­Magnetic Force on wires:

Magnetic Force on particles:

As force acts to motion of charged particles (LHR), particle motion is circular:

Radius of circular path of particles:

For a negative charge, the current will be flowing in the opposite direction relative to its movement

### Electromagnetic induction

Lines of magnetic field cut through coil → emf is induced.

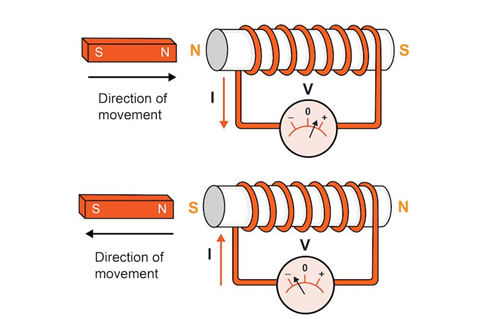
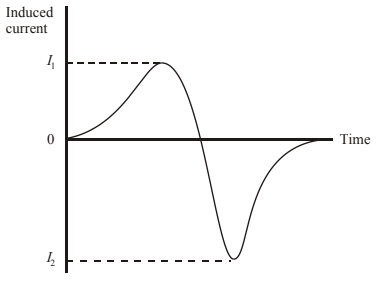
Coil forms a complete circuit → Current is induced.

Lenz’s law: Direction of induced current is such as to oppose the motion causing it

Faraday’s law: definition

To demonstrate Lenz’s law:

1. Due to Lenz’s law, **direction of induced is such as to oppose the motion** of the magnet  
   **Same pole** is induced to the pole of the magnet **approaching** coil, causing magnet to slow down due to **repulsion** force
2. Due to Lenz’s law, **direction of induced is such as to oppose the motion** of the magnet  
   **Opposite pole** is induced to the pole of the magnet **leaving** coil, causing magnet to slow down due to **attraction** force

“Induced current flows in a direction such that it opposes the change which produces it”

Note that the magnitude of the second peak is greater ∵magnet at higher velocity ∴rate of change of flux greater

Work done due to Lenz’s law:

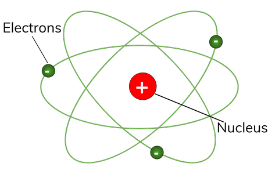
* , therefore the movement caused by Lenz’s law does work

|  |  |
| --- | --- |
| AC Generator | DC Motor |
| * The coil is rotated mechanically * F and B 🡪 induces emf & current onto coil (RHR) * Current alternates (AC) as coil cuts max and no field lines when rotating, inducing max and 0 emf | Draw a labelled diagram of an electric motor. Explain its principle and  working. What is the function of a split ring in an electric motor?   * Current is supplied to the system * I and B 🡪 exerts magnetic force onto coil (LHR) * Coil rotates by resultant force |
| Animation: [Click me](https://www.youtube.com/watch?v=gOB4OmwK7yc) | Animation: [Click me](https://www.youtube.com/watch?v=0q5bARctt7M) |

# Topic 7 – Particle physics

## Alpha Particle Scattering and Rutherford's Nuclear Model of Atom: ModelsAtomic model

### Nuclear model of an atom

Evidenced by α-scattering

1. Most α no deflection 🡪 Atom is mostly empty
2. Small amounts α deflected 🡪 Center is +ve charged
3. Very small amounts α deflected > 90° 🡪 Center is very dense

## Particle accelerators

|  |  |
| --- | --- |
| **Linear accelerators**: Alternating electric fields  Approaching pole will be same pole 🡪 Attraction  Leaving pole will be opposite pole 🡪 Repulsion  Linear particle accelerator - Wikipedia | **Cyclotron**: Electric + Magnetic fields  Cyclotron | Definition, Examples, Diagrams |

## Particle detection: Bubble chambers

### Mechanism

1. Superheated liquid in chamber
2. **Charged** particles vaporizes the liquid, creating visible tracks
3. Magnetic field into page causes charged particles to travel in a curved path

### Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| e- 🡪  e+ 🡪 |  |  | |
| Pair of lines produced from nowhere:  photon (0) undergoes pair production  e+ (1) can only be produced from pair production | Curve from another track:  Induced particle interacts / collides with a particle in liquid | Curve ↑ +ve  Curve ↓ -ve  For a negative charge, the current will be flowing in the opposite direction relative to its movement | r of curvature ↑ momentum ↑ |

## Mass and energy

### Generation and destruction of mass

* E, Q & p are all conserved
* Pair production can only occur near a nucleus as the nucleus can allow conservation of energy by receiving recoil

|  |  |
| --- | --- |
| Pair production | Pair annihilation |

### Time dilation & relativistic increase in velocity

Time dilation - Time travels slower for faster moving objects.

If particle moving at speeds approaching c, lifetime observed stationarily > predicted lifetime. This is due to the relativistic increase of velocity of the particle.

## Standard model of elementary particles

Hadrons - Formed of quarks

Leptons - Fundemental particles

Quarks - Makes up leptons. Fundemental particles

Fundemental - Cannot be broken down further

### Quarks & leptons

You’ll need to memorize particle charges for exams:

All quarks have an antiquark with same mass but **opposite charge**

|  |  |  |  |
| --- | --- | --- | --- |
| Quark | | | Charge |
| u | c | t |  |
| d | s | b |  |
| Leptons | | |  |
|  |  |  | -1 |
|  |  |  | 0 |

### Hadron particles – Baryons

Formed by 3 quarks, with sum of charge being integer

### Hadron particles – Mesons

Formed by quark & antiquark, with sum of charge being integer

### Electromagnetic force

Particles pass photons back and forth between each other

### Particle interactions

Interaction can only occur if all properties below are conserved

1. E, Q & p
2. Baryon number (is: 1, anti: -1, not: 0)
3. Lepton number (is: 1, anti: -1, not: 0)
4. Strangeness (is: -1, anti: 1, not: 0)