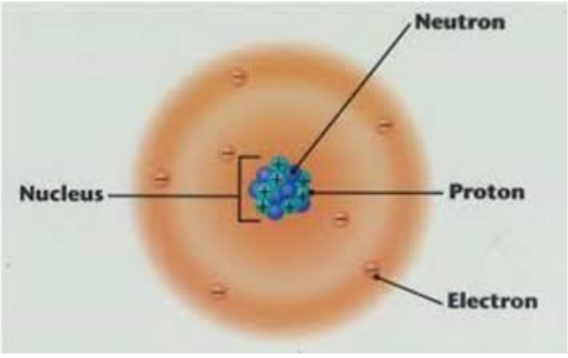
DO PHYSICS ONLINE

MOTORS AND GENERATORS

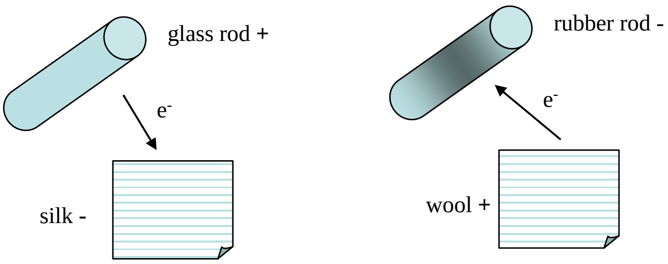
1 Charge q Q [coulomb C]

ATOM



Positive nucleus surrounded by a negative electron cloud
Diameter atom ~ 10^{-10} m
Diameter nucleus ~ 10^{-15} m

- Two types of charge: Positive (+) and negative (-)
- Like charges repel / opposite charges attract
- Objects become charged via the **transfer of electrons** to or from the object
- Positively charged object: lost electrons
- Negatively charged object: gained electrons



- charge on an electron $q_e = -1.6\text{x}10^{-19}$ C
- charge on a proton $q_p = +1.6\text{x}10^{-19}$ C
- 1 C = $6.26\text{x}10^{18}$ electrons

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2 Current i I [ampere A]

- Rate of movement of charge
- Direction: in which positive charges would move
- DC: current in the one direction or polarity (+ / -) of voltage does not change
- AC: direction of current oscillates or polarity (+ / -) of voltage oscillates

$$I = \frac{\Delta q}{\Delta t} \qquad I = n\,q\,v\,A$$

I current [A]

ΔQ amount of charge [C] crossing a cross-section of the conductor in a time interval Δt [s]

n number of charge carriers / volume [m^{-3}]

q charge on particle [C]

v drift velocity of charged particles [$m.s^{-1}$]

A cross sectional area [m^2]

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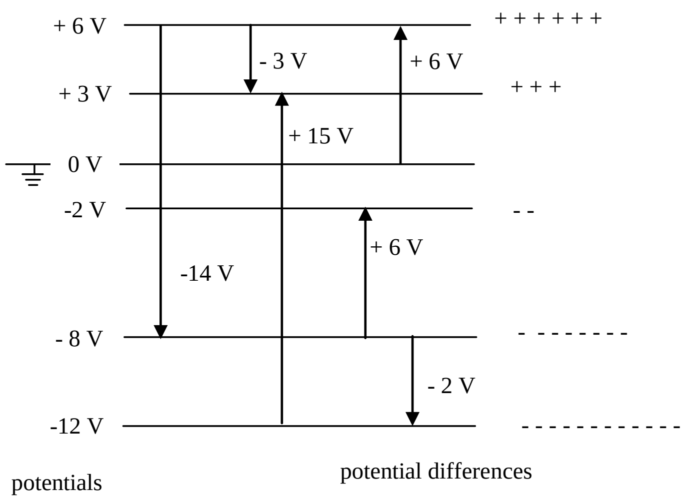
3 Potential difference V [volt V]

- Measure of the imbalance of charge: the potential difference is always measured between two points
- Created by charge separation or changing magnetic fields
- Potential difference / potential / potential drop / emf / voltage
- emf: potential difference for a source of electrical energy: positive (+) and negative (-) terminals of a battery
- Work is done when a charge moves through a potential difference (voltage)

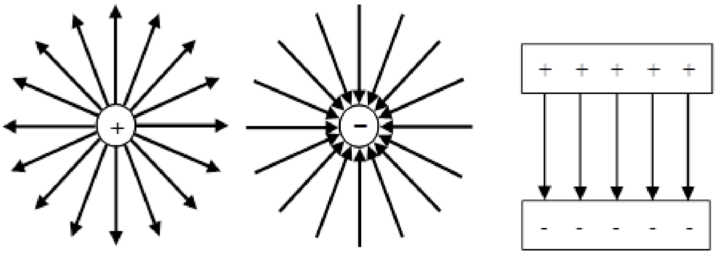
$$V = \frac{\Delta W}{\Delta q} \qquad \Delta W = V \Delta q$$

V potential difference between two points [V]
Δq amount of charge moved between two points [C]
ΔW work done on or by charge [J]



Electric Field E [V.m^{-1} N.C^{-1}]

- Region surrounding charge distribution

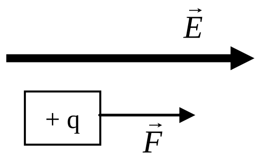


Electric field POSTIVE charge

Electric field NEGATIVE charge

Uniform electric field

- Electric charge experiences a force in an electric field

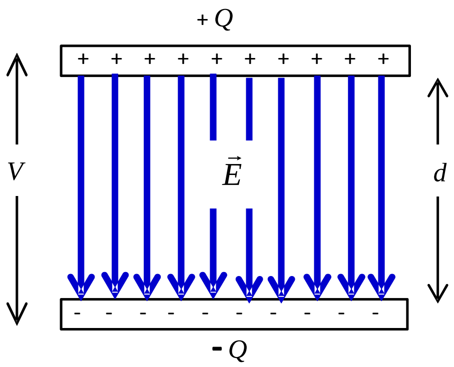


$$F = qE \qquad \vec{F} = q\vec{E}$$

- A charge q of mass m in an electric field E, accelerated by a voltage V increases its kinetic energy

$$\Delta E_K = W = qV = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mu^2$$

- Uniform electric field: region between two parallel charged plates with a small separation: $+Q$ on one plate and $-Q$ on the other plate



$E = \dfrac{V}{d}$ uniform electric field

$E_x = -\dfrac{\Delta V}{\Delta x}$ X component of electric field (electric field may not be uniform)

- Electric field is equal to the gradient of the potential

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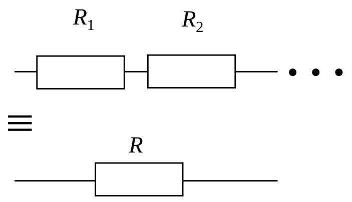
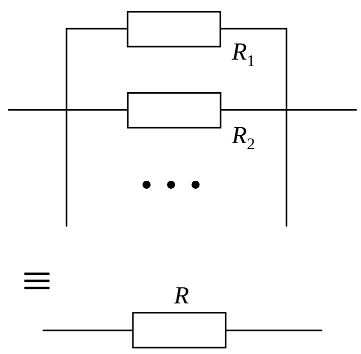
4 Resistance R [ohm Ω]

- Opposition to a flow of charge
- The opposition to the movement of charges (current) due to energy being dissipated as thermal energy is known as resistance.

$$R = \frac{V}{I} \qquad R = \rho \frac{A}{L}$$

R resistance [ohm Ω]
V potential difference across resistance [V]
I current through resistance [A]
ρ resistivity of material [Ω.m]
A cross sectional area of resistance [m^2]

Resistors in series	**Resistors in parallel**
$R = R_1 + R_2 + \ldots$	$R = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}}$
	
Adding extra resistors increases the equivalent resistance	Adding extra resistances decreases the equivalent resistance

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5 Energy *W* [joule J] Power *P* [watt W]

- **Work** is done when a force moves an object through some displacement

  $W = F_{avg}\,\Delta s \cos\theta$

- **Power**: rate of energy conversion

- Current through a resistance produces a heating effect:
-
  electrical energy $\rightarrow$ thermal energy

  $$P = \frac{\Delta W}{\Delta t} = V\,I = \frac{V^2}{R} = I^2 R$$

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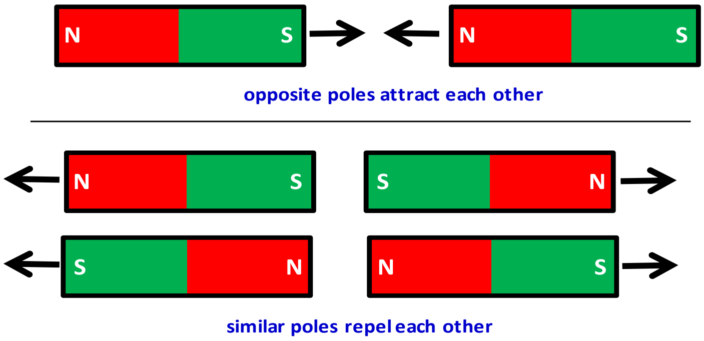
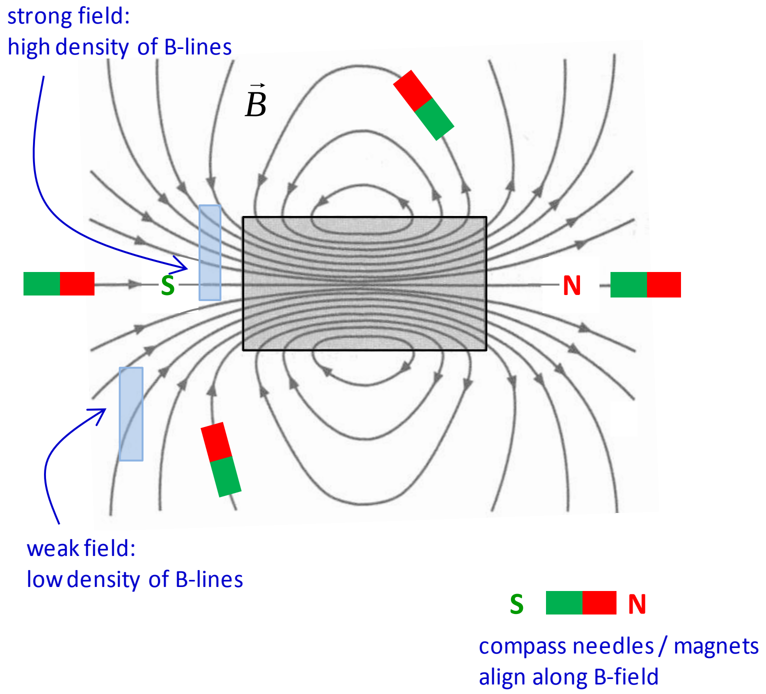
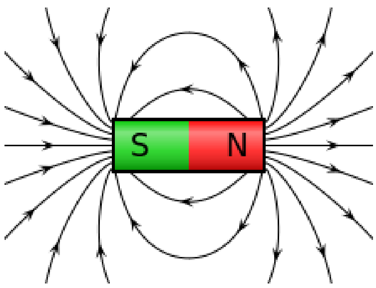
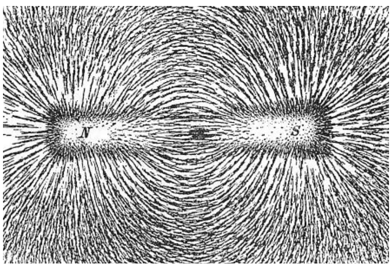
6 Magnetic field B [tesla T]

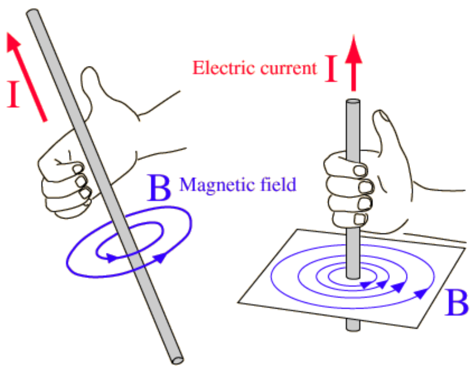
- Region in space in which a moving charges or currents experience forces











$$B = \frac{\mu_0 I}{2\pi R}$$

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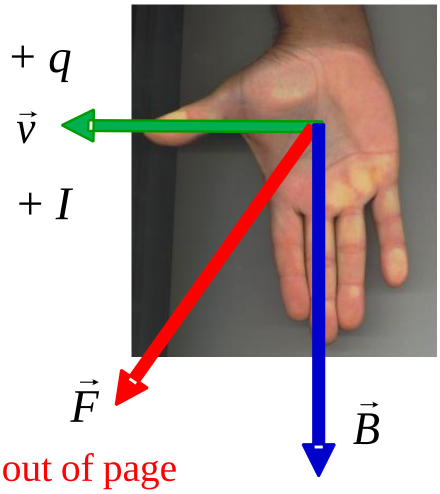
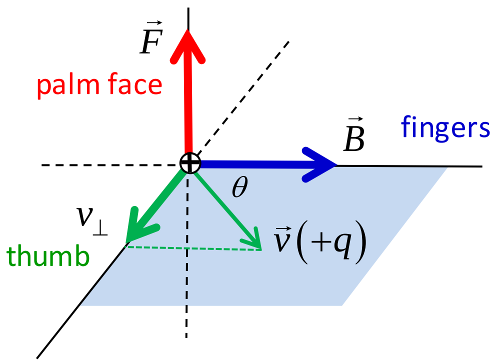
7 Magnetic force on a conductor

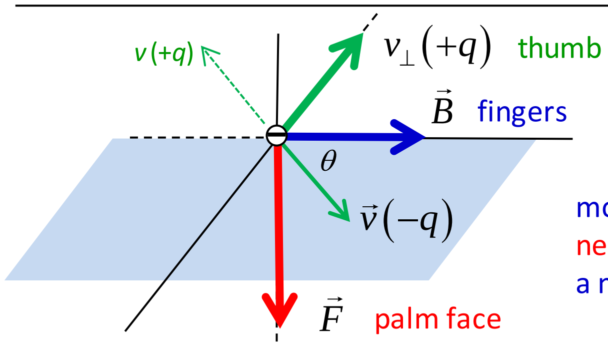
MAGNETIC FORCE F_B [N]

- A moving charge (current) in a magnetic field will experience a force.
- Direction of force given by **right hand screw rule**

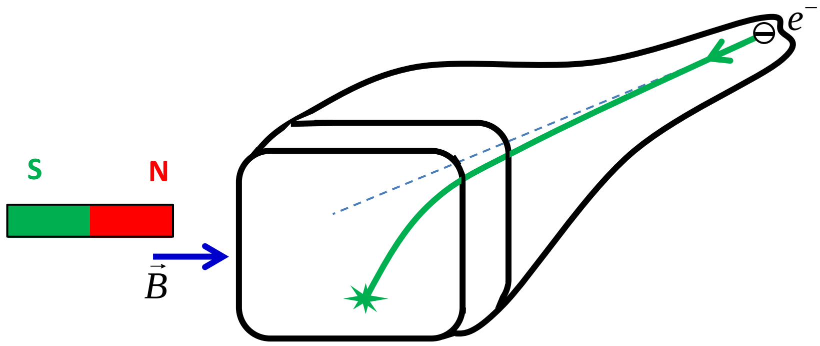


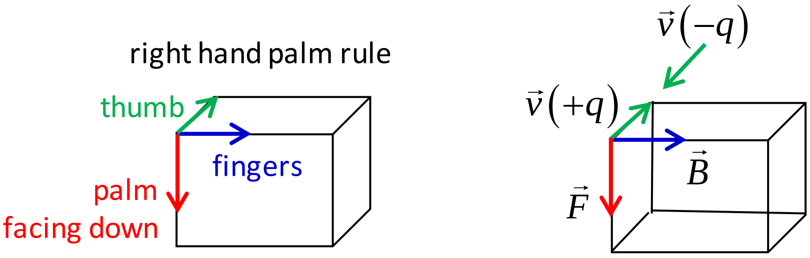


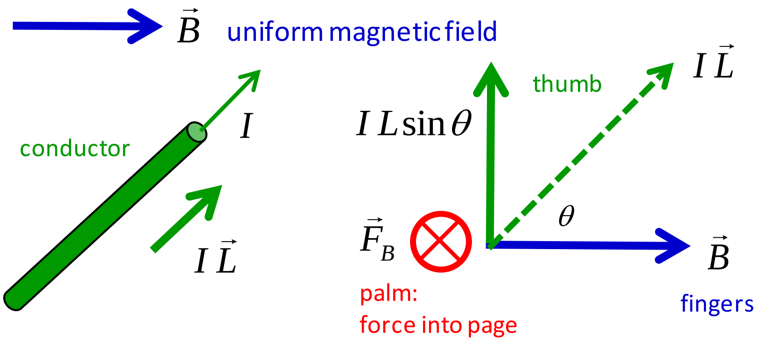
motion of a *positive* charge in a magnetic field

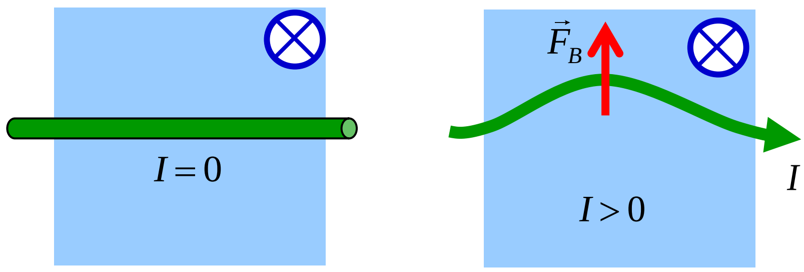


motion of a negative charge in a magnetic field









uniform magnetic field directed into page

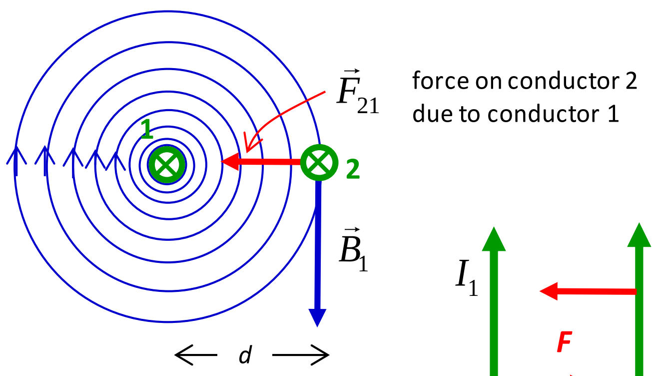
$F_B = F = B\,I\,L\sin\theta$ direction given by right hand screw rule

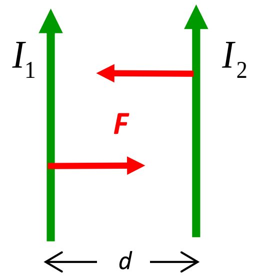
F_B	F	magnetic force acting on conductor [N]
B		magnetic field strength [T]
I		current through conductor [A]
L		length of conductor in B field [m]
q		angle between B field and conductor

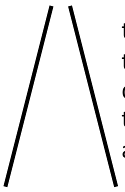
top more more

8 Magnetic force between parallel conductors

currents I_1 and I_2 are into page

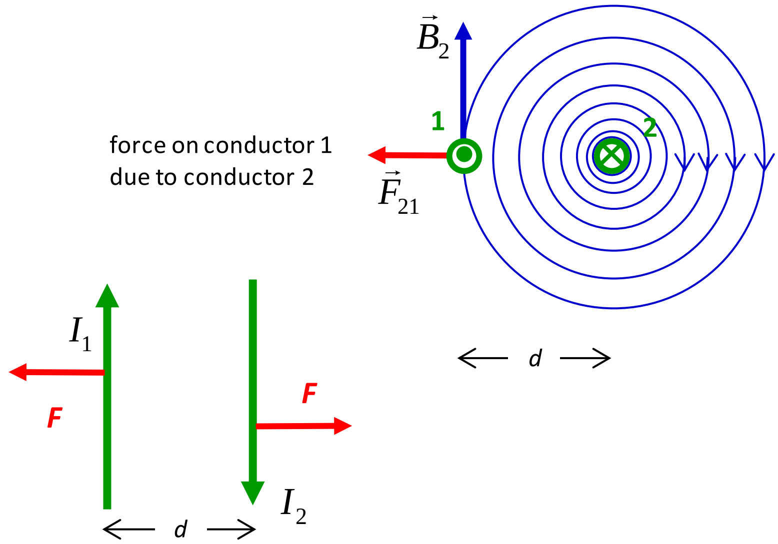






think of two railway tracks merging in the distance – currents in the same direction attract

current I_1 out of page and I_2 are into page



$$\frac{F_B}{L} = \frac{\mu_o}{2\pi}\frac{I_1 I_2}{d} = k\frac{I_1 I_2}{d} \qquad k = \frac{\mu_o}{2\pi} = 2\times 10^{-7}\ \mathrm{T.m.A^{-1}}$$

- Currents in same direction: attractive force
- Currents in opposite direction: repulsive force

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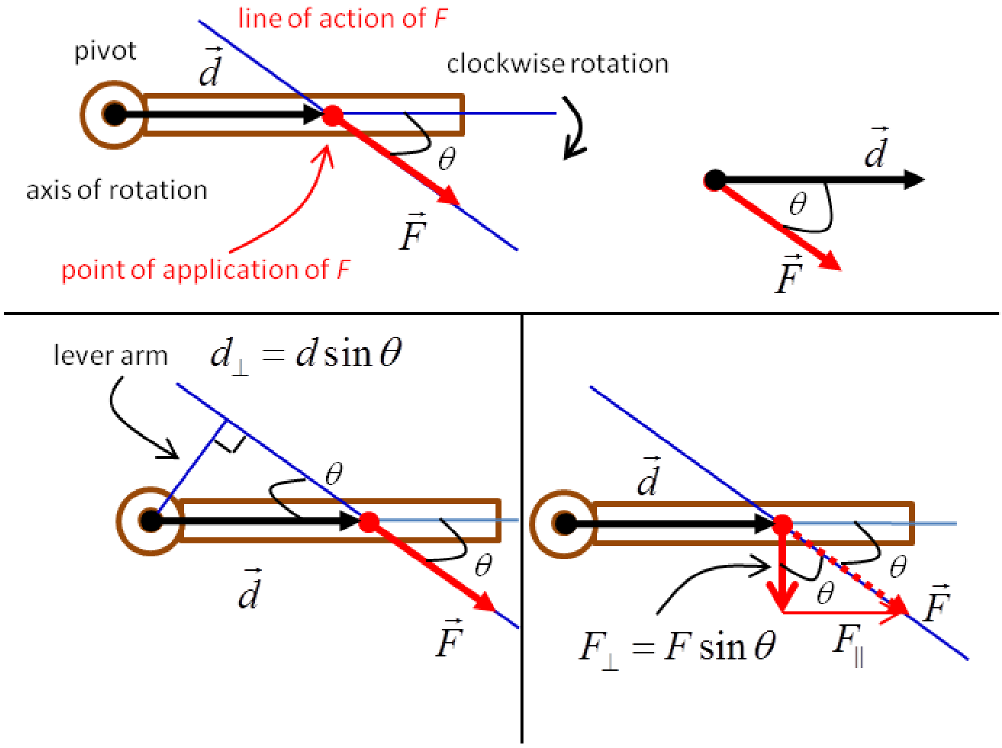
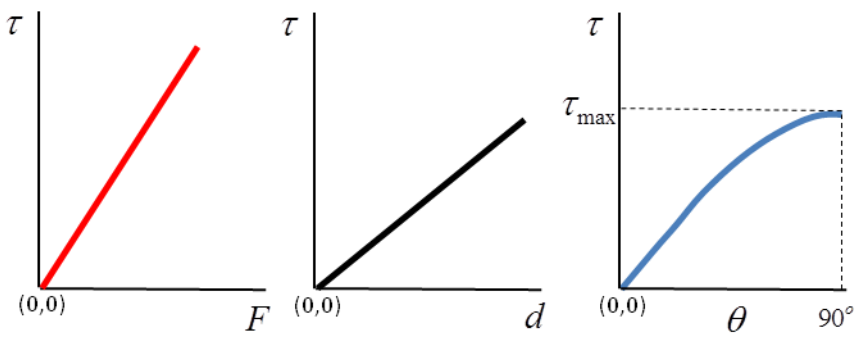
9 Torque τ [N.m]

- A torque causes the rotation of an object

$$\tau = F\,d\sin\theta = F_{\perp}\,d = F\,d_{\perp}$$



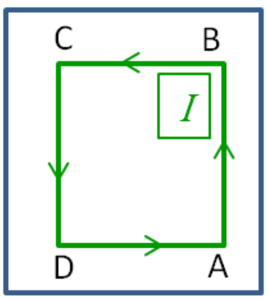


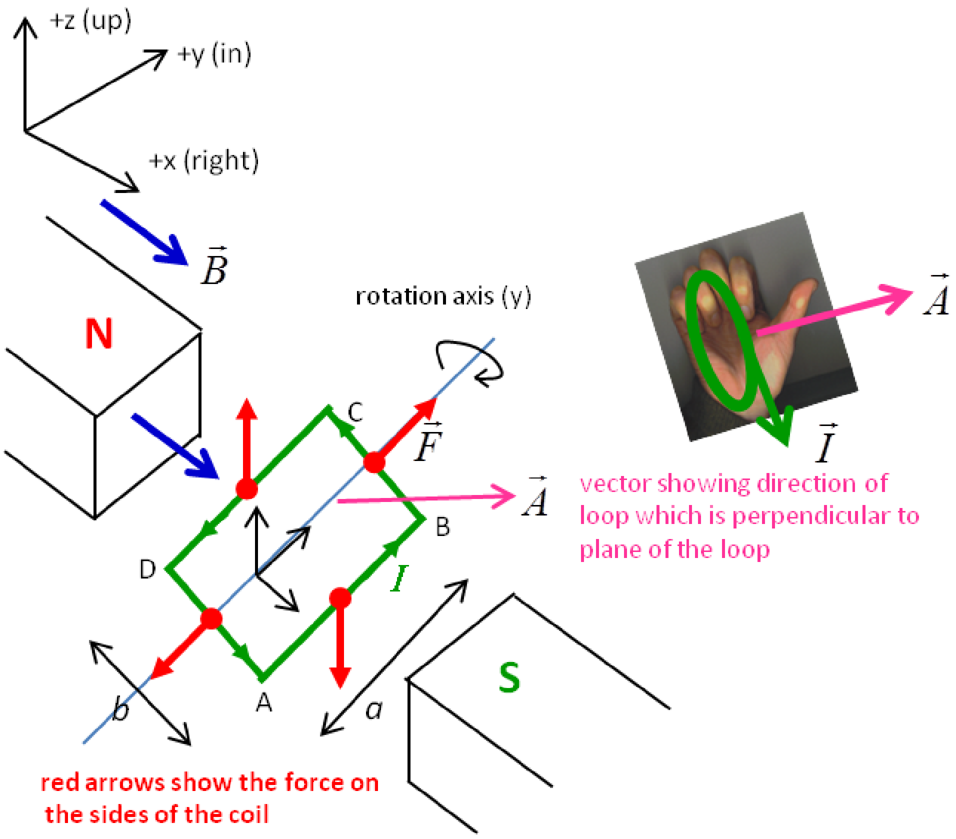
$$\theta = 0 \;\Rightarrow\; \sin\theta = 0 \;\Rightarrow\; \tau = 0$$

$$\theta = 90^o \;\Rightarrow\; \sin\theta = 1 \;\Rightarrow\; \tau = \tau_{max}$$

Learning aid

Draw and label a rectangle on a sheet of paper and use it to help identify the forces and torque acting on the current loop.





$$\tau = n\,I\,B\,A\cos\theta$$

τ	torque [N.m]
n	number of turns (coil windings)
I	coil current [A]
B	magnetic field strength [T]
A	area of coil cutting magnetic field [m^2]
θ	angle between magnetic field and plane of coil

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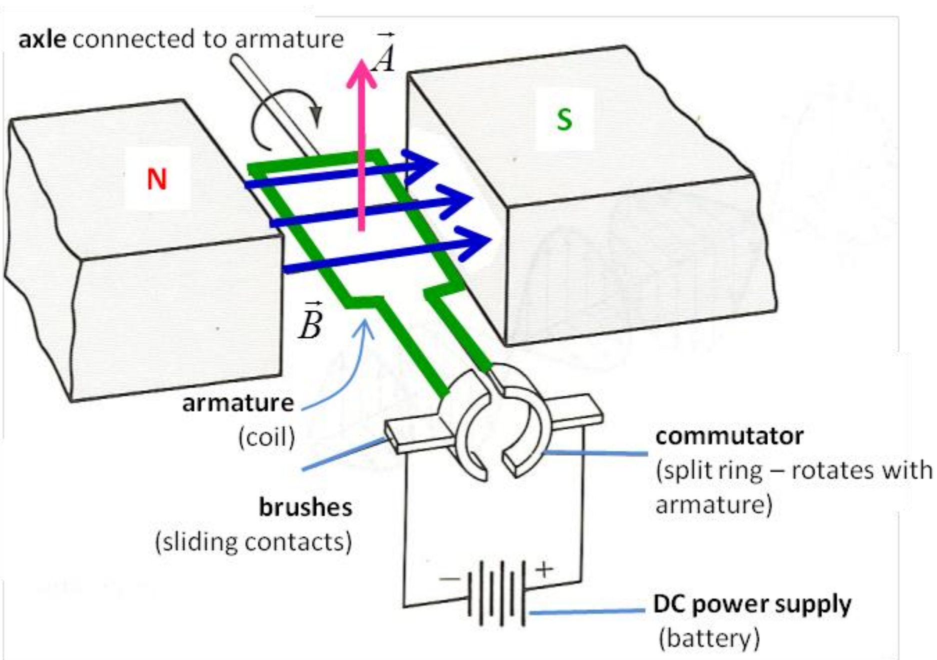
10 DC electric motor

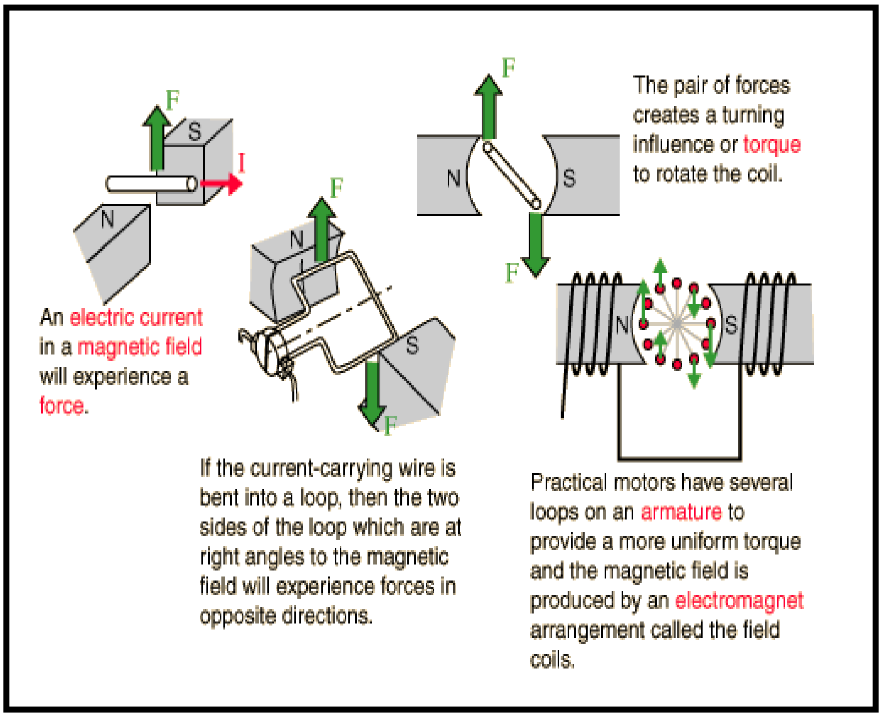
- A coil carrying a current in a magnetic field will experience a force which produces a torque that causes a rotation of the coil.

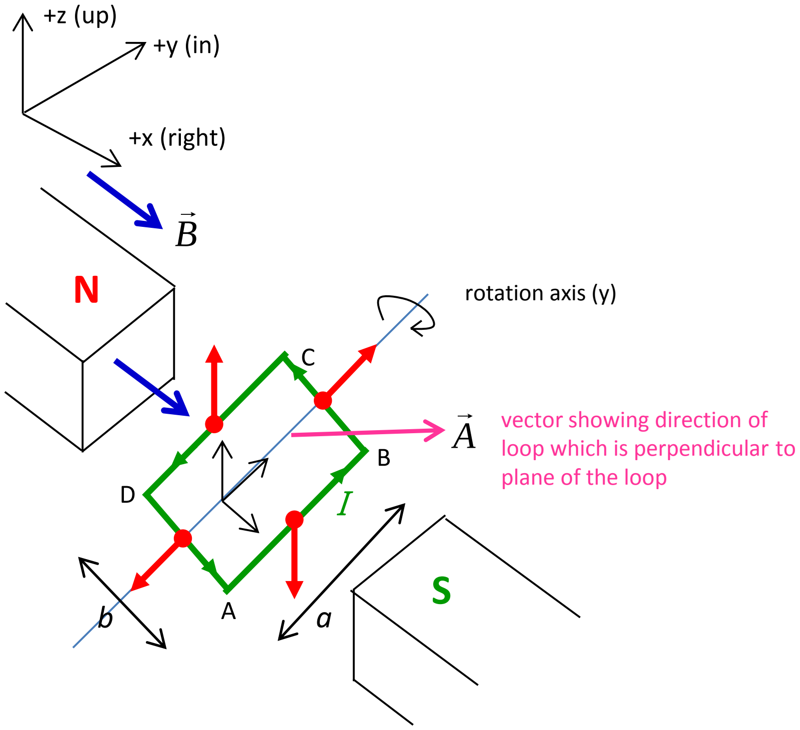
- Electrical energy $\rightarrow$ mechanical energy

- Components: coil armature (rotating assembly) commutator (split ring and brushes) magnetic field (permanent magnet or current carrying coil)

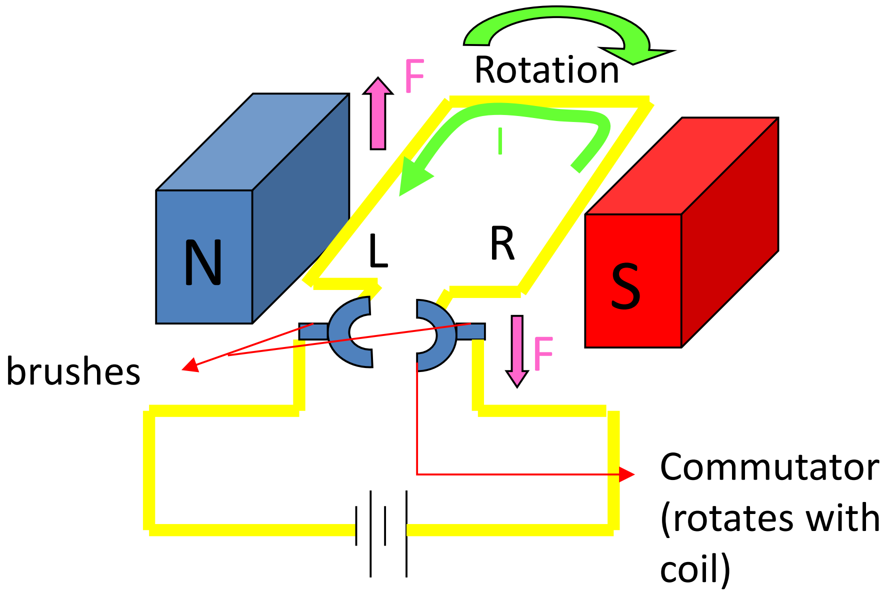
- **Motor effect**: current carrying conductor in a magnetic field will experience a force / torque







Motion of a current-carrying loop in a magnetic field



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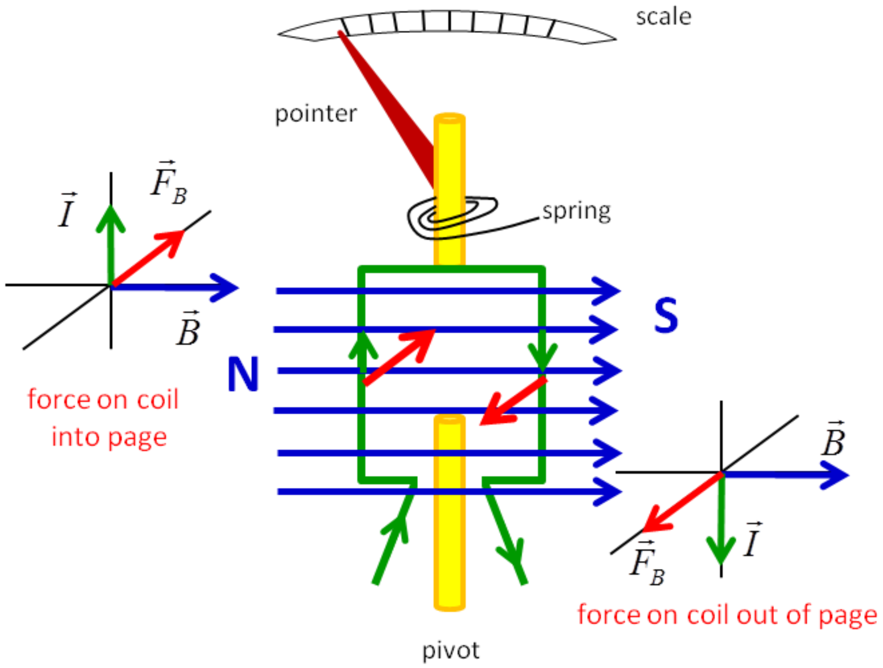
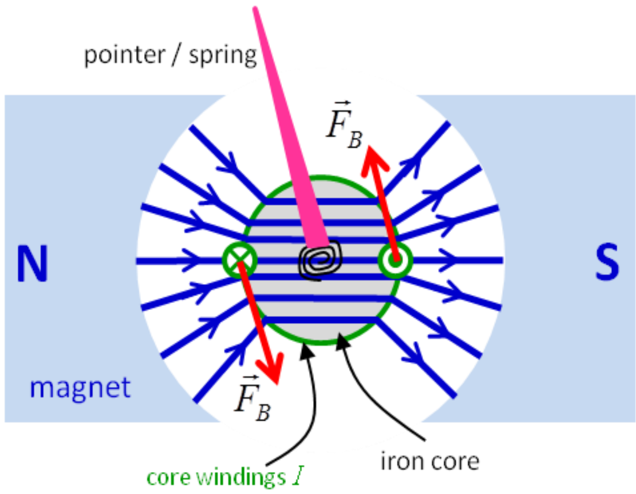
[animation](#)

11 Motor effect: galvanometer (current measuring instrument)

- Current measuring instrument.
- Current through a coil produces a rotation of a pointer which is proportional to the current.
- The larger the current through the coil then the larger the torque experienced by the coil.
- The coil and the attached pointer will rotate only to the point where the torque due to the magnetic field balances the torque exerted by the spring.





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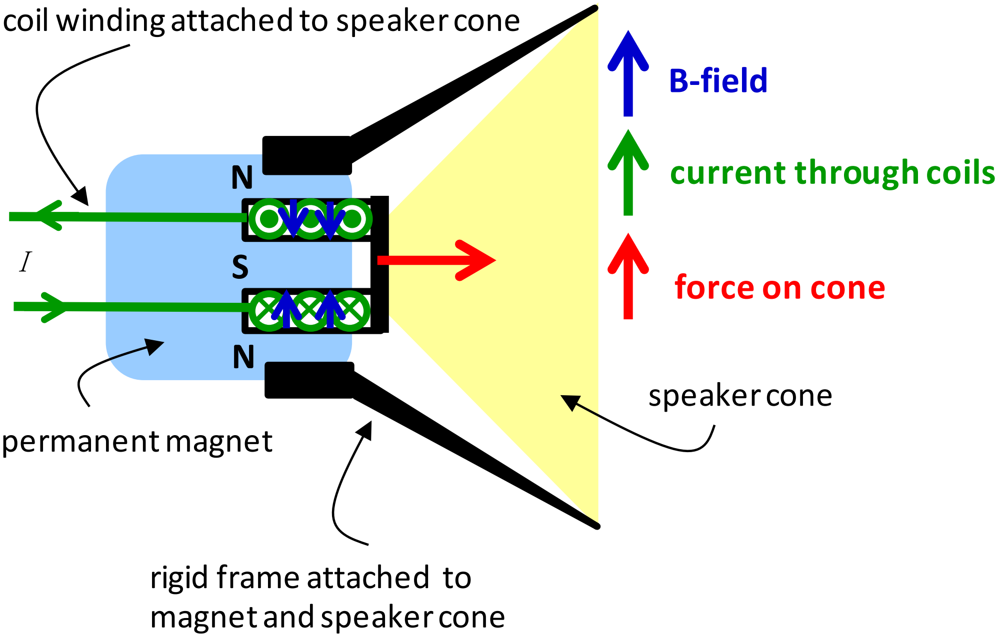
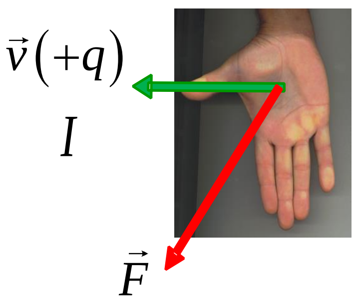
12 Motor effect: loudspeaker

- An alternating current (AC) through a coil in a magnetic field produces a fluctuating force which acts to vibrate a diaphragm.
- Electrical energy $\rightarrow$ mechanical energy $\rightarrow$ sound energy



- When a AC current passes through the coil, an alternating force moves the speaker back and forth to produce the sound wave. At any instant, the direction of the force on the speaker can be determined from the right hand palm rule.



right hand palm rule

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