PHYSICS UNIT 3+4 SUMMARY MOTION IN ONE AND TWO DIMENSIONS

If const vel $d = vt$

x = position (m), t = time (s), v = velocity, a = acc'n

Δx or s = displacement (change in position) (m), $\Delta x = x_{final} - x_{initial}$

v = velocity (ms^{-1}), $v_{average} = \frac{\Delta x}{\Delta t}$ a = acceleration (ms^{-2}), $a_{average} = \frac{\Delta v}{\Delta t}$

$kmh^{-1} \div 3.6 \rightarrow ms^{-1}$

Calc MODE → DEGREES

Graphs & const acc'n eqns

$x-t$ graph: gradient = velocity **$a-t$ graph**: area = Δv

$v-t$ graph: gradient = accel'n, area = Δx av. v = area/time

$v = u + at$ $v^2 = u^2 + 2as$ $s = \left(\frac{u+v}{2}\right)t$ $s = ut + \frac{1}{2}at^2$ (*)

Catch up probs/graphs Find displ. when graphs become parallel, then find extra time = displ diff ÷ vel diff.

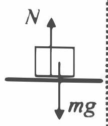
(*) or $t = \left(-u \pm \sqrt{u^2 + 2as}\right) \div a$ careful with +, – signs, or find v first, then find t. (use v^2 = …., then $v = u + at$)

When using kinematics eqns, + =initial direction.

Newton's laws: **1**. Inertia. No net force, no change in v; **2**. Net F: $\Sigma F = ma$

3. Action / Reaction forces: $F_{AB} = -F_{BA}$

N = Force of floor on mass = Force of mass on floor



$a = \frac{\Sigma F}{m}$ $\Sigma F = ma$

Gravity: g = 10 ms^{-2} or 10 Nkg^{-1}, Weight $W = mg$

Lifts, falling (up = +a): $F_{floor} - mg = ma$

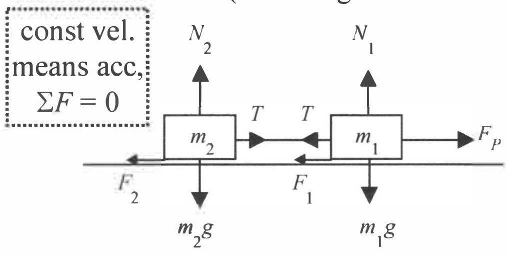
Apparent weight in Newton = F_{floor}, Apparent mass = $F_{floor} \div g$

Walking: Feet push ground backwards, ground friction pushes you forwd.

Forces and systems. Use $\Sigma F = ma$ If no friction, set $F_1, F_2 = 0$

Show ALL forces (including Normal reaction and mg) on each mass. eg:

const vel. means acc, $\Sigma F = 0$



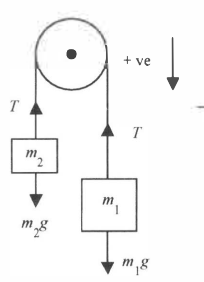
*System: $F_P - F_1 - F_2 = (m_1 + m_2)a$

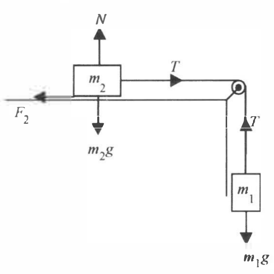
On m_1: $F_P - F_1 - T = m_1 a$

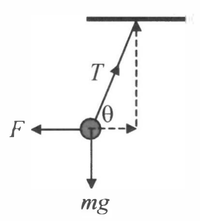
*On m_2: $T - F_2 = m_2 a$

Note: $N_1 = m_1 g$ and $N_2 = m_2 g$

Power $P = Fv$







$T\sin\theta = mg$

$T\cos\theta = F$

Apparent weight/mass in a lift

UP accn:

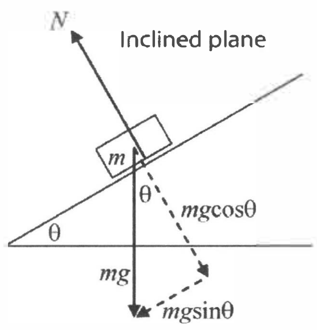
$W = m(g + a)$ Newton

mass = $m(g + a)/g$ kg

DOWN accn:

$W = m(g - a)$ Newton

mass = $m(g - a)/g$ kg

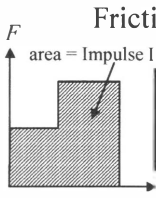


Component of gravity force down plane: $= mg\sin\theta$

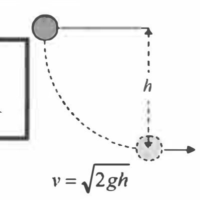
acc'n down slope: $a = g\sin\theta$ if no friction

Normal reaction = $mg\cos\theta$

Friction (if any) acts against motion.



Use powers of 10 for ans > 999 or < 0.01



Force graphs – key point is where constant velocity (and hence balanced (equal) driving and resistance forces occur.

Frames of reference / relative velocity $\rightarrow - \downarrow = \rightarrow + \uparrow$ use pythagoras

Newton's law and motion identical in frame moving at constant velocity (called a inertial frame). velocity of A relative to B: $v_{AB} = v_A - v_B$ (vector addn)

Momentum: $P = mv$ ($kgms^{-1}$), **Impulse**: $I = Ft$ (Ns) or area under $F - t$ graph.

Ext answer: When a car stops in a collision, a certain impulse ($I = Ft$) is required to stop the passenger. An air bag will increase the time t the passenger takes to come to rest. Since I is same, F must decrease, meaning less damage to passenger.

Use numerical values in $Ft = m\Delta v$ or $F = \frac{m\Delta v}{t}$ or $F = \frac{\Delta p}{t}$ to show diff. in F for two sets of values (e.g. m = 10 kg, Δv = 20 ms^{-1}, t = 1 s) & comp. when t = 0.01 s

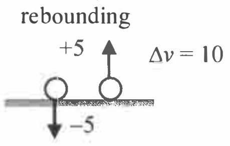
Use brackets on calculator

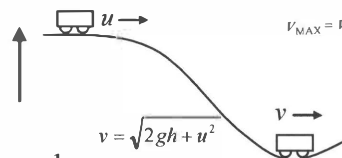
Impulse = Change in momentum $I = \Delta p$ or $Ft = m\Delta v$ or $Ft = m(v - u)$

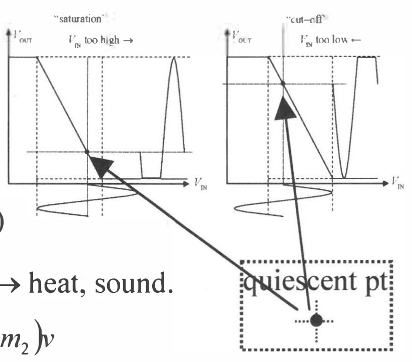
No external forces ⇒ Momentum is always conserved. i.e.:

$\Delta P = 0$, $P_{final} = P_{initial}$, mtm before = mtm after, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Momentum never lost in elastic or inelastic collisions (but may be transferred to earth).







Kinetic Energy: $KE = \frac{1}{2}mv^2$ (speed × 2, 4 × KE)

Inelastic collision: $KE_{after} < KE_{before}$ Energy lost → heat, sound.

quiescent pt

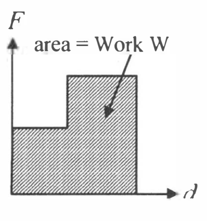
e.g. Masses sticking together: $m_1u_1 + m_2u_2 = (m_1 + m_2)v$

Elastic collision: $KE_{after} = KE_{before}$

Work $W = Fd$ (if F parallel to d) or $W = (F\cos\theta)d$

Work (Joules) = Area under Force–distance graph.

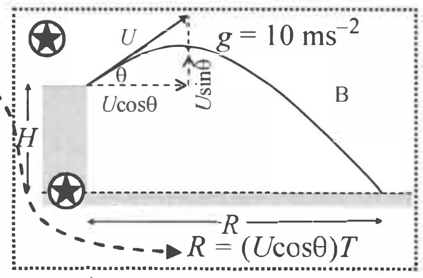
If $F \perp d$, no work is done (e.g. in circular motion)



$W = Fd = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ or $W = \Delta PE$

$T = \frac{U\sin\theta + \sqrt{(U\sin\theta)^2 + 2gH}}{g}$

speed at B: $V = \sqrt{U^2 + 2gH}$



Grav'l Pot Energy

GPE = mgh, $mgh = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Loss GPE = Gain KE, Gain GPE = Loss KE

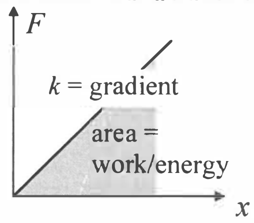
Springs: Potential Energy, Hooke's law $F = kx$

(k = stiffness), x = extension or compression only

SPE = $0.5kx^2$ or Area under F–x graph.

Springs and Hooke's law: $F = -kx$

SPE = $\frac{1}{2}kx^2$



Power $P = W/t$, $P = Fv$ $E = Pt$ Units: Watts or W (= Js^{-1})

Projectile motion Accel'n occurs only vertically. Horiz. velocity constant.

Find components of initial velocity U $d_{Horiz} = v_{Horiz} \times t$, $d_H = U\cos\theta \times t$

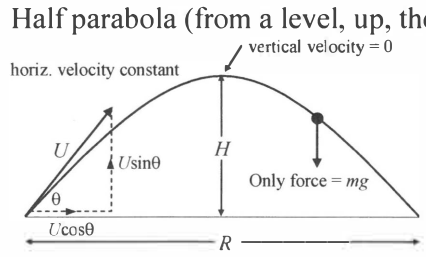
(Vertically: $u = U\sin\theta$, $a = -g = -10$, Horizontally: $u = U\cos\theta$, $a = 0$)

Use Kinematics eqns (a) Vert., and (b) Horiz.

tonne t = 1000 kg

May also use: $mgh = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

(i) Half parabola (from a level, up, then down to same level).

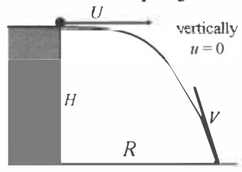


Range: $R = (U\cos\theta)T$

$R = \frac{U^2\sin(2\theta)}{g}$, $H = \frac{(U\sin\theta)^2}{(2g)}$

Time to max. height: $t = \frac{U\sin\theta}{g}$, Total time (↑ + ↓): $T = \frac{2U\sin\theta}{g}$

(ii) Horizontal projection from cliff of height h.



$R = UT$, $R = U\sqrt{\frac{2H}{g}}$, $V = \sqrt{U^2 + 2gH}$

Time of flight $T = \sqrt{\frac{2H}{g}}$, $H = \frac{T^2 g}{2}$

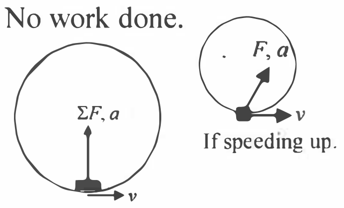
(iii) Oblique proj'n from cliff of height H. Use kin eqns, + = initial direction, or

Circular motion – uniform (constant speed) Velocity: $v = \frac{2\pi R}{T}$, $T = \sqrt{\frac{m4\pi^2 R}{F}}$

Sum of forces is towards centre. Velocity is tangential. No work done.

$F = \frac{mv^2}{R}$ $F = \frac{m4\pi^2 R}{T^2}$ $F = \frac{m2\pi v}{T}$ $F = m4\pi^2 Rf^2$

$a = \frac{v^2}{R}$ $a = \frac{4\pi^2 R}{T^2}$ $a = \frac{2\pi v}{T}$ $a = 4\pi^2 Rf^2$



Gravity and Newton's law of univ'l gravit'n (see also circ motion above)

$G = 6.67 \times 10^{-11}$, M = central body, m = orbiting obj't

$M_{earth} = 5.98 \times 10^{24}$ kg, $R_{earth} = 6.37 \times 10^6$ m, $M_{sun} = 2 \times 10^{30}$ kg

R is from centre

1 day = = 86400 s, 1 year = 3.15 × 10^7 s Weight W = Force F, field (g) = acc'n a

$v = \frac{2\pi R}{T}$ $T = \frac{2\pi R}{v}$ $R = \frac{vT}{2\pi}$

Add height above planet to radius to find orbital Radius if necessary.

$F = \frac{GMm}{R^2}$ grav. field: $g = \frac{GM}{R^2}$, $a = \frac{GM}{R^2}$, $g = \frac{v^2}{R}$, $a = \frac{v^2}{R}$

Mars 0.1074 M_E Jupiter 317.87 M_E Saturn 95.152 M_E

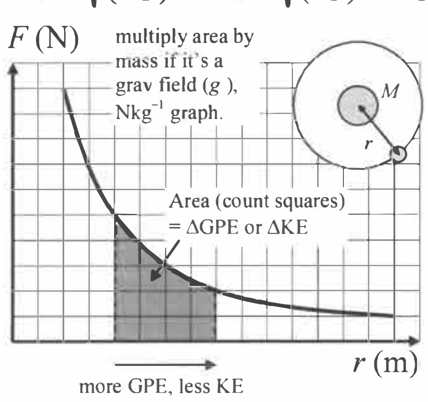
$F = \frac{mv^2}{R} = \frac{GMm}{R^2} \Rightarrow v = \sqrt{\frac{GM}{R}}$, $R = \frac{GM}{v^2}$, $M = \frac{v^2 R}{G}$, KE = $\frac{1}{2}mgR$

$F = \frac{m4\pi^2 R}{T^2} = \frac{GMm}{R^2} \Rightarrow \frac{R^3}{T^2} = \frac{GM}{4\pi^2}$ = constant for **same central body** M

$R = \sqrt[3]{\frac{GMT^2}{(4\pi^2)}}$ $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$ $T = \sqrt{\frac{4\pi^2 R}{g}}$ $M = \frac{4\pi^2 R^3}{(GT^2)}$ $v = \sqrt[3]{\frac{2\pi GM}{T}}$

Ratio questions: Two masses m_1, m_2 orbiting central body M. $T = \frac{2\pi GM}{v^3}$

$\frac{T_1}{T_2} = \sqrt{\left(\frac{R_1}{R_2}\right)^3}$, $\frac{R_1}{R_2} = \sqrt[3]{\left(\frac{T_1}{T_2}\right)^2}$, $\frac{a_1}{a_2} = \frac{g_1}{g_2} = \left(\frac{R_2}{R_1}\right)^2$, $\frac{v_1}{v_2} = \sqrt{\frac{R_2}{R_1}}$, $\frac{F_1}{F_2} = \frac{m_1}{m_2}\left(\frac{R_2}{R_1}\right)^2$



$F = \frac{GMm}{R^2}$, $v = \frac{2\pi R}{T}$

KE = $\frac{1}{2}mv^2 = \frac{1}{2}mgR$

k = 10^3
M = 10^6
G = 10^9

*If using g field graph (Nkg^{-1}), multiply by mass to get ΔPE or ΔKE or Work.

Geostationary (geosynchronous) orbit: Period T of satellite = period (length of "day" in sec) of rotation of planet. T_{earth} = 86400 s

Apparent weight = Force of Floor (F_{floor} or normal reaction N) on object.
"Weightlessness": In orbit, apparent weight = 0 since you have same acc'n as craft.
Like freefall, matching accn's ⇒ force on floor, F_{floor} = 0, so no apparent weight.

ELECTRONICS AND PHOTONICS

Voltage V or PD or EMF (Units: JC^{-1} or V), $V = \frac{W}{Q} = \frac{\text{Energy in Joules}}{\text{Change in Coulombs}}$

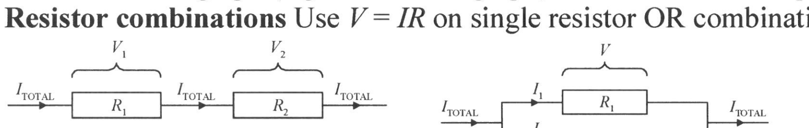
Current I (Units: Amps or Cs^{-1})   Resistance R (Units: Ohms or Ω)
1 Coulomb (1 C) of charge = 6.25×10^{18} electrons
Charge on 1 electron = 1.6×10^{-19} Coulomb
Current $I = \frac{Q}{t}$, Charge $Q = It$ measured in Coulombs (C)

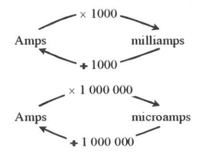
nano (n) = 10^{-9}
micro (μ) = 10^{-6}
milli (m) = 10^{-3}

Ohms law $V = IR$ and $R = \frac{V}{I}$ for any circuit or part of circuit.

If V–I graph linear, $R = \frac{V}{I}$ = constant, device is "Ohmic" (e.g. resistor)

Non–linear V–I graph (e.g. curved V–I graph) ⇒ non–Ohmic component (e.g. globe).
Resistor combinations Use $V = IR$ on single resistor OR combination

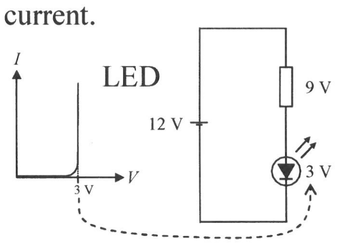




Series (in one line): $R_T = R_1 + R_2 + ...$
Voltages add to give total voltage, current same in each section.
Parallel (branches): Special case: R in parallel with R is equivalent to ½ R
Voltage same for each branch, currents add to give total current.

Two resistors only in parallel: $R_T = \frac{R_1 R_2}{R_1 + R_2}$

Any number in parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$



Power $P = IV$, $P = I^2R$, $P = \frac{V^2}{R}$, $P = \frac{E}{t}$, Units: Watts (W) If AC, use RMS values

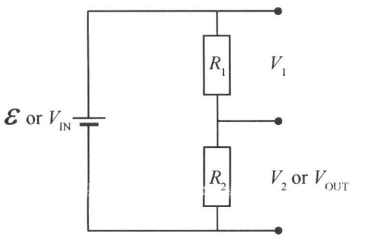
Energy = Power × time = Pt, $E = Pt$ (see P above)   Energy = area under P–t graph.
Voltage dividers – Used to obtain a "sub–voltage" from a supply.
With no load (usual situation):

$V_{OUT} = \frac{R_2}{R_1 + R_2} \times V_{IN}$ $\frac{R_1}{R_2} = \frac{V_1}{V_2}$ $\frac{R_1}{V_1} = \frac{R_2}{V_2}$

With load across V_{OUT}:

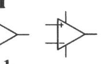
$V_{OUT} = \frac{R_2}{\frac{R_1 R_2}{R_L} + R_1 + R_2} \times V_{IN}$

Note: If R_L much bigger than $R_1 R_2$, may use "no–load equations" above



$V_1 + V_2 = V_{IN}$

Voltage amplifier/Transistor amplifier
Inverting: \ negative slope V–I graph
Non–inverting: / positive slope V–I graph



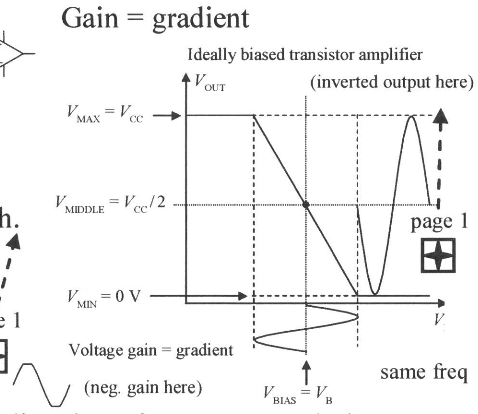
Gain = $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$, Gain = $\frac{V\ peak_{OUT}}{V\ peak_{IN}} \approx \frac{-R_C}{R_E}$

changes measured from middle point on graph.
negative gradient means negative gain, and inverted output

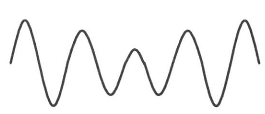
$V_{PEAK} = \sqrt{2} \times V_{RMS}$

Clipping occurs when bias too high / low or input ampl. too high. See bottom page 1.

Gain = gradient



Diode: Allows current flow one way only (in direction of arrow on symbol)
LED: Light emitting diode (emits light when forward biased) 75 ns response time
LDR – Light Dependant Resistor. More light, less resistance (less voltage)
Thermistor – More heat, less resistance (less voltage share)
Photodiode: semicond. – converts light into electrical signals. 1 ns response time
Phototransistor: Like photodiode, but more sensitive, not as quick (lower b/width)
Bandwidth: digital bps (bits per sec), analogue Hz –amt info per sec. or range of frequencies transmitted without **attenuation**: (dB) loss of power
Modulation: changing a beam/wave (carrier wave) to carry a signal.
Demodulation: extracting signal from beam/wave. **Analogue** = contin'ly variable



intensity modulation

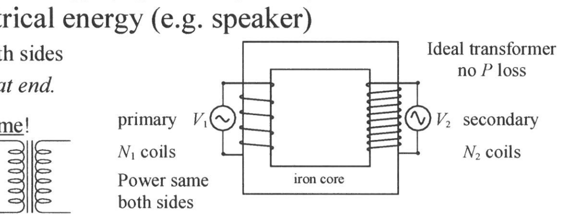
Voltage output of mike
→laser→phototransistor→current→speaker→sound

Cutoff: V_{OUT} maxes out. **Saturation**: V_{OUT} bottoms out
Input **transducers**: convert to electrical energy (e.g. microphone)
Output **transducers** convert from electrical energy (e.g. speaker)

Transformers: Iron core directs B field through both sides (primary V_1, secondary V_2) *See extended answer at end.*

Step up ($V_2 > V_1$), Step down ($V_2 < V_1$), Power same!

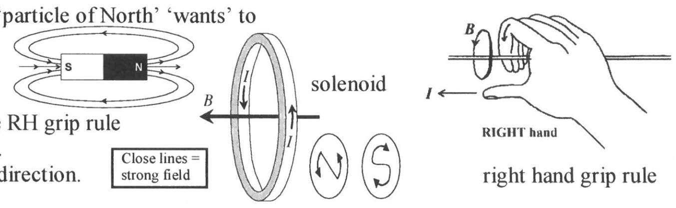
$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$ $P = IV$ $P_1 = P_2$ $I_1 V_1 = I_2 V_2$

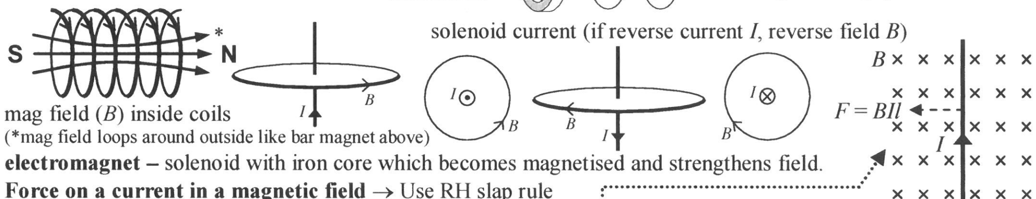


Power = constant at generator, and $P = IV$ so high voltage means low current.
Low current means low power loss since $P_{loss} = I^2R$, $P = V^2/R$, $P = IV$, Voltage drop in lines $V = IR$
Power at "house" = Power generated – Power loss, $V_H = V_{supply} - V_{loss}$

ELECTRIC POWER & MAGNETISM

Magnetic field, *B* direction a 'particle of North' 'wants' to go/out from N and into S
Units: Tesla (T) or Wb m^{-2}
⊙ = out of page, × = into page
Field due to a current → Use RH grip rule
Thumb gives current direction.
Fingers curl in magnetic field direction.

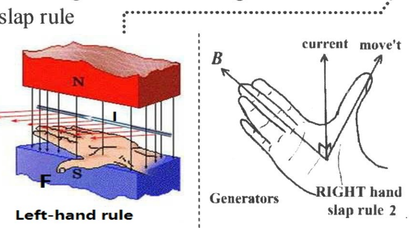




electromagnet – solenoid with iron core which becomes magnetised and strengthens field.
Force on a current in a magnetic field → Use RH slap rule
Current (I) = thumb
Field (B)= fingers
Force (F) = slap direction (out from palm)
n = number of loops/wires

$F = nBIl$ when current and field are ⊥

$F = nBIl\sin\theta$ where θ = angle b/w B and I.



no supply voltage

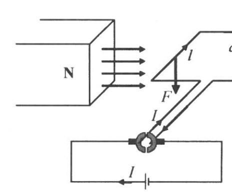
Force on a charge *q*   Note: θ = angle b/w B and v
$F = qvB$ if velocity and field are ⊥, $F = qvB\sin\theta$

Use when MOTION of a side is involved.

For + charge, use RH rule above. Thumb (I) gives charge velocity.

(For electron/negative charge, point right thumb in opposite direction to charge velocity.) Use RH slap rule 1.

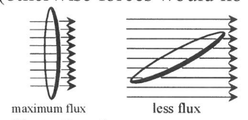
Motors, coils $F = nBIl$ on both l sides
torque (turning effect) $\tau = nBIld$ or $\tau = nBIA$
where loop length is l, width is d, A = area of loop
If B at angle θ to coil area:
$\tau = nBIld\sin\theta$ and $\tau = nBIA\sin\theta$
No force on sides parallel to B (side d)
See sample extended answer question.



MOTOR
Has existing current, voltage supply.

Split ring commutator reverses current every half turn so that Force pairs ("couple") also swap direction and continue to turn loop in the same continuous direction (otherwise forces would no longer turn loop).
Magnetic flux = number of field lines through an area.

$\phi = B_{\perp}A$ Units: Weber (Wb) or Tm^2



Flux ∝ no. of field lines through loop

Electromagnetic induction $\Delta\phi = \phi_f - \phi_i$
Faraday's Law for induced voltage:

$\varepsilon = -n\frac{\Delta\phi}{\Delta t}$ n = no. of loops, – for **Lenz's law**:

"Induced current is in direction to produce field which opposes original flux change"
Rod of length l cutting field lines at speed v: $\varepsilon = B_{\perp}lv$

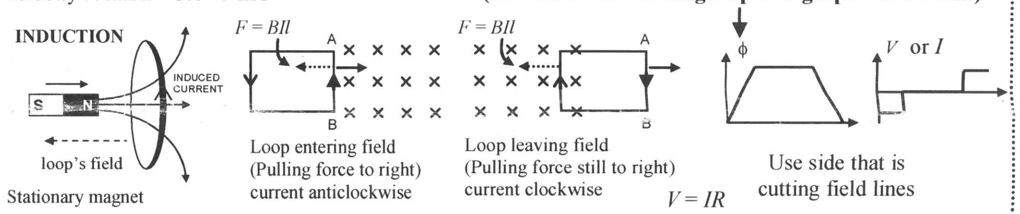
(see right, use RH rule 2 for current direction)
velocity v: km/h ÷ 3.6 → m/s

Rotating loop generators (1/4 or 1/2 turn etc) average magn. EMF: (f = freq'y, Hz)

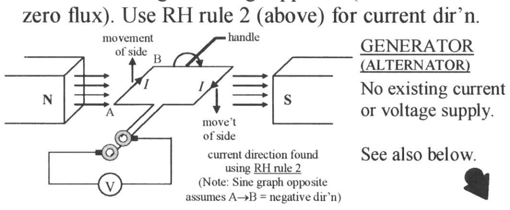
average $\varepsilon = 4nBAf$ or $\frac{4nBA}{T}$ or $4n\phi_{max}f$

or $\frac{4n\phi_{max}}{T}$ T = period (s) = $\frac{1}{f}$

Voltage graph = negative gradient of flux graph. (see below and rotating loop sine graphs below that)



Generation of AC (alternating current/voltage)
Slip rings allow contact whilst wires rotate, without twisting. See diag. opposite (starts with zero flux). Use RH rule 2 (above) for current dir'n.

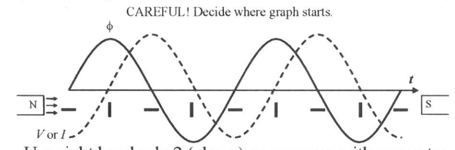


GENERATOR (ALTERNATOR)
No existing current or voltage supply.

See also below.

Note: Above diagram is for clockwise rotation.
When loop is in vertical position, current = 0 (instant)
Force due to BIL is opposite to movement direction
No force on sides parallel to magnetic field.
Current reverses each time loop passes vertical

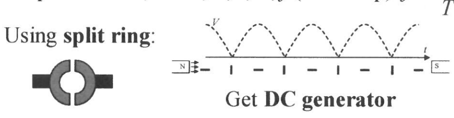
Rotating loop → AC current, voltage
(NOT loop moving in one direction – see above)



Use right hand rule 2 (above) or compare with generator diagram at left or below for current direction

Amplitude of V, $I \propto n, B, I, A, f$ (rotn freq.) $f = \frac{1}{T}$

Using **split ring**:

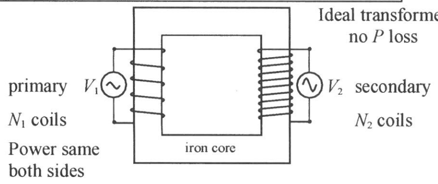


Get **DC generator**

Transformers: Iron core directs B field through both sides (primary V_1, secondary V_2) *See extended answer at end.*

Step up ($V_2 > V_1$), Step down ($V_2 < V_1$), Power same!

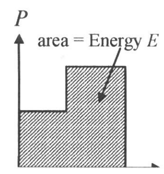
$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$ $P = IV$ $P_1 = P_2$ $I_1 V_1 = I_2 V_2$



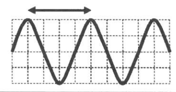
Supply of AC   Peak voltage = 390 V (peak to peak = 780 V)
RMS = equivalent DC that would provide the same power.

Power calcs: Use RMS values!!

$V_{RMS} = \frac{V_P}{\sqrt{2}}$, $I_{RMS} = \frac{I_P}{\sqrt{2}}$, $V_P = \sqrt{2} \times V_{RMS}$, $I_P = \sqrt{2} \times I_{RMS}$, $V_{PP} = 2V_P$, $V_{PP} = 2\sqrt{2}\, V_{RMS}$



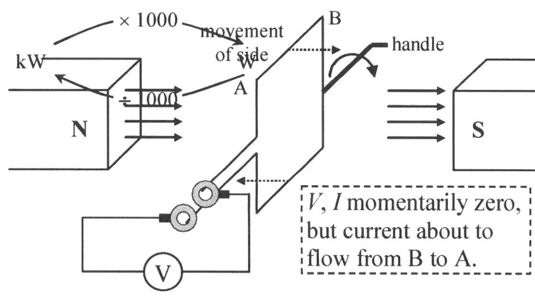
Power points left slot Active (240V RMS AC), right Neutral (0 V), bottom Earth (0 V)
Transmission lines (*See extended answer question on other side.*)
Power = constant at generator, and $P = IV$ so high voltage means low current.
Low current means low power loss since $P_{loss} = I^2R$, $P = V^2/R$, $P = IV$, Voltage drop in lines $V = IR$
Power at "house" = Power generated – Power loss, $V_H = V_{supply} - V_{loss}$
CRO display time base = x axis dist × scale e.g. period T = 4 cm × 5 ms per cm = 20 ms
$f = 1/T$ use seconds, note: 1 ms = 0.001 s, freq. in Hz.



$f = \frac{1}{T}$

Electrical energy: $E = Pt$, $E = IVt$, $E = I^2Rt$, $E = \frac{V^2t}{R}$, $P = \frac{E}{t}$

kilowatt hours = Energy
1 kWh = 3.6×10^6 J



V, I momentarily zero, but current about to flow from B to A.

Unit 4 Properties of mechanical waves

- $T = \frac{1}{f}$
- $v = f\lambda = \frac{\lambda}{T}$
- Doppler effect: $f = \frac{v_{sound}}{\left(\frac{v_{sound} \pm v}{f_0}\right)} = \frac{v_{sound} f_0}{v_{sound} \pm v}$ P219

- harmonics

  fixed at both ends:

  $\lambda = \frac{2L}{n} \rightarrow f = \frac{nv}{2L}$

  $n = 1, 2, 3, 4$

- fixed at one end

  odd $\lambda = \frac{4L}{n} \rightarrow f = \frac{nv}{4L}$ ($n = 1, 3, 5 \ldots$)

  n: number of harmonic (only odd-numbered harmonics)

  $\lambda = \frac{4L}{2n-1}$ $n = 1, 2, 3, 4 \ldots$

  n: the next harmonic in the sequence

  not harmonic number

- refractive index

  $n = \frac{c}{v}$

- Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$

- internal reflection.

  critical angel: $n_1 \sin\theta_c = n_2 \sin 90°$ ($n_1 > n_2$)

- constructive interference $Pd = n\lambda$ ($n = 0, 1, 2, \cdots$)

- destructive interference $Pd = n\lambda$ ($n = 0.5, 1.5, 2.5 \ldots$)

- fringe separation

  $\Delta x = \frac{\lambda L}{d}$

Planck's equation

- $E = hf \Rightarrow f = \frac{c}{\lambda}$
- $E = \frac{hc}{\lambda}$.
- $E_{max} = hf - \phi$

  $\phi = hf_0$.

→ stopping voltage $V \Rightarrow E = q_e V_{stopping}$ (↓ the charge on an electron)

$q_e V_{stopping} = E_K = \frac{1}{2} m v^2$ (v → speed)

- $\lambda = \frac{h}{p} = \frac{h}{mv}$
- $\Delta E = E_n - E_m = hf = \frac{hc}{\lambda}$

  (n, m Energe level)

- De Broglie wave

  $mvr = n\frac{h}{2\pi}$

  $C = n\lambda$

- Uncertainity.

  $\Delta x \Delta p \geq \frac{h}{4\pi}$

  $\Delta E \cdot \Delta t \geq \frac{h}{4\pi}$

- number of photon per second (1 second)

  $n = \frac{\text{Power of light} \cdot \Delta t}{\text{Energy of 1 photon}}$

- $F = \frac{\Delta p}{\Delta t}$ (p → momentum)

  $= \frac{P}{c}$ (P → power)

  if it is reflected $F = \frac{2P}{c}$