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FORMULA SHEET — PHYSICS

(1) $\boxed{\Delta\theta = \frac{s}{r}}$

- $\Delta\theta$ = angular disp. (rad)
- s = arc length (m)
- r = radius (m)

(2) $\boxed{w = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{T} = 2\pi f}$

- w = angular speed (rad s^{-1})
- Δt = time (s)
- T = time period (s)
- f = frequency (Hz)

(3) $\boxed{w = \frac{v}{r}}$ $\boxed{v = wr}$

- v = linear speed ($m s^{-1}$)

(4) $\boxed{a = \frac{v^2}{r} = rw^2}$

- a = centripetal acceleration ($m s^{-2}$)

(5) $\boxed{F = \frac{mv^2}{r} = mrw^2}$

- F = centripetal force (N)

(6) $\boxed{g = \frac{F_g}{m}}$ → grav. ~~field~~ strength at a point.

- g = grav. field strength ($N kg^{-1}$)
- F_g = force due to gravity / weight (N)
- m = mass (kg)

(7) $\boxed{F_G = \frac{G m_1 m_2}{r^2}}$ → Newton's law of gravitation

- F_G = grav. force btwn 2 point masses (N)
- r = distance btwn centres of 2 masses (m)
- G = Newton's grav. constant (6.67×10^{-11} $N m^2 kg^{-2}$)

(8) $\boxed{g = \frac{GM}{r^2}}$ → grav. field strength due to point mass

- M = mass of object producing grav. field (kg)

→ grav. field strength at a point due to object creating grav. field = F/m

→ grav. field strength due to a point mass placed in grav. field of bigger object = $\frac{GM}{r^2}$

(9) $\boxed{g \text{ on earth} = \frac{GM}{(R+h)^2} \sim \frac{GM}{R^2}}$

- M = mass of earth (kg)
- R = radius of earth (m)
- h = height of object from earth's surface (m)

(10) $\boxed{\phi = \frac{-GM}{r}}$

- ϕ = grav. potential ($J kg^{-1}$)
- r = distance from centre of mass to point mass (m)
- M = mass of object producing grav. field (kg)

(11) $\boxed{\Delta\phi = -\frac{GM}{r_2} - \left(-\frac{GM}{r_1}\right)}$

final − initial

(12) $\boxed{E_p = \frac{-GMm}{r}}$

- E_p = grav. potential energy (J)
- M = larger mass producing field
- m = mass moving within field of M
- r = distance btwn centres of M & m

(13) $W = \Delta E_p = GM\cancel{m}\left(\frac{1}{r_1 - r_2}\right)$ initial − final

~~initial~~ ~~final~~

- W = work done (J) ↳ against grav. field

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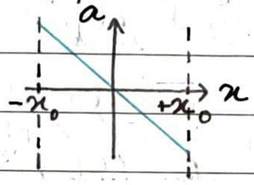
NOTE: x-t = sine curve

v-t = cosine curve, 90° out of phase w/ x-t; $\frac{dx}{dt}$

a-t = -ve sine curve, 90° out of phase w/ v-t; $\frac{dv}{dt}$

(14) $\boxed{a = -w^2 x}$

- a = acceleration ($m\,s^{-2}$)
- w = angular frequency ($rad\,s^{-1}$)
- x = displacement (m)

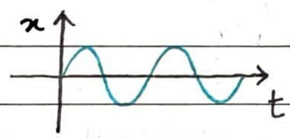


gradient = $-w^2$

a_{max} when x_{max}

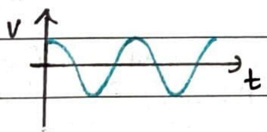
(15) $\boxed{x = x_0 \sin(wt)}$

- x = displacement (m)
- x_0 = amplitude (m)
- t = time (s)



(16) $\boxed{v = v_0 \cos(wt)}$

- v = speed ($m\,s^{-1}$)
- v_0 = max speed ($m\,s^{-1}$)



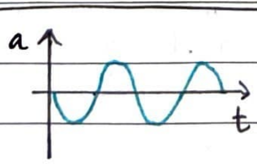
v_{max} at eq. ($x=0$)

$v_{min} = 0$ at x_{max}

(17) $\boxed{v = \pm w\sqrt{(x_0^2 - x^2)}}$

(18) $\boxed{v_0 = w x_0}$

(19) $\boxed{a = -a_0 \sin(wt)}$



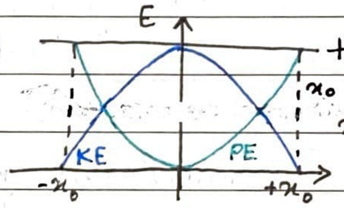
a_{max} at x_{max}

(20) $\boxed{PE = \frac{1}{2}kx^2 = \frac{1}{2}mw^2x^2}$

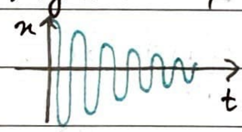
(21) $\boxed{KE = \frac{1}{2}mv^2 = \frac{1}{2}mw^2(x_0^2 - x^2)}$

(22) $\boxed{E = \frac{1}{2}mw^2x_0^2}$

(23)

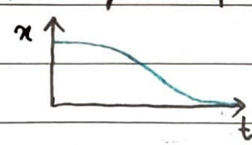


(24) light damping:

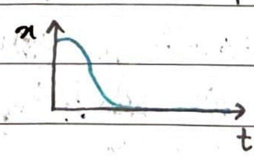


- amplitude dec. exponentially
- constant T

(25) heavy damping:



(26) Critical damping:



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(27) $\boxed{F = BIL\sin\theta}$

- F = force on current-carrying conductor in B field (N)
- B = magnetic flux density of applied B field (T)
- I = current in conductor (A)
- L = length of conductor <u>within</u> field (m)
- θ = angle btwn conductor & applied B field (°)

$F_{max} = BIL$; $\theta = 90°$ & $\sin\theta = 1$

$F_{min} = 0$; $\theta = 0°$ & $\sin\theta = 0$

(28) $\boxed{F = BQv\sin\theta}$

- F = magnetic F on particle (N)
- B = magnetic flux density (T)
- Q = charge of particle (C)
- v = speed of particle (ms^{-1})
- θ = angle btwn charge's velocity & B field (°)

$F_{max} = BQv$; $\theta = 90°$ & $\sin\theta = 1$

(29) $\boxed{r = \frac{mv}{BQ}}$

- r = radius of path (m)
- m = mass of particle (kg)
- v = linear velocity of particle (ms^{-1})
- B = magnetic field strength (T)
- Q = charge of particle (C)

(30) $\boxed{v = \frac{E}{B}}$ — v of particles that remain undeflected in velocity selector

- E = electric field strength (NC^{-1})
- B = magnetic field strength (T)

(31) $\boxed{\phi = BA\cos\theta}$

- ϕ = magnetic flux (Wb)
- B = magnetic flux density (T)
- A = cross-sectional area (m^2)
- θ = angle btwn magnetic field lines & the line ⊥ plane of area (°).

$\phi_{max} = BA$; $\cos\theta = 1$; $\theta = 0°$

$\phi_{min} = 0$; $\cos\theta = 0$; $\theta = 90°$

(32) $\boxed{N\phi = BAN\cos\theta}$

- $N\phi$ = flux linkage (Wb turns)

(33) $\boxed{E \propto \frac{N\Delta\phi}{\Delta t}}$ → Faraday's law

- E = induced e.m.f (V)
- N = no. of turns in coil
- $\Delta\phi$ = change in magnetic flux (Wb)
- Δt time interval (s)

(34) $\boxed{E = \frac{-N\Delta\phi}{\Delta t}}$ → Lenz's law

- external mag. field applied ⊥ direction of current through conductor.
- e^- experience mag. force.
- this makes them drift to one side of conductor = -ve charged
  opp side = +ve charged
- separation of charges causes p.d across conductor.

$$\boxed{V_H = \frac{BI}{ntq}}$$

- V_H = Hall voltage (V)
- B = mag. flux den (T)
- q = charge of e^- (C)
- I = current (A)
- n = number density of e^- (m^{-3})
- t = thickness of conductor (m)

smaller e^- density $\Rightarrow$ $V_H \uparrow$

↳ ∴ semiconducting material used for Hall probe

→ If e^- were replaced by +ve charge carriers, direction of V_H reversed. (+ve charge experiences F_{mag} force in opp direction)

→ equation derived from electric & magnetic forces on the charges.

→ charge separation → E field set up btwn the 2 opp sides of conductor; 2 sides treated as opp. charged parallel plates.

$$\boxed{E = \frac{V_H}{d}}$$

- E = electic field strength
- d = width of conductor slice

→ a single e^- has drift velocity v within conductor and mag field $\perp$ v.

$$\boxed{F_B = Bqv} \qquad \boxed{F_E = qE}$$

act in opp directions

$$\boxed{qE = Bqv}$$

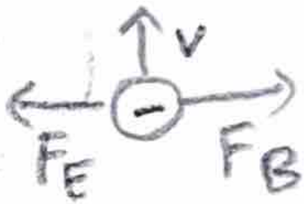
$$\frac{qV_H}{d} = Bqv \Rightarrow \boxed{\frac{V_H}{d} = Bv}$$

$\boxed{I = nAvq}$

- A = c/s area of conductor (m^2)
- n = no. density of e^- (m^{-3})

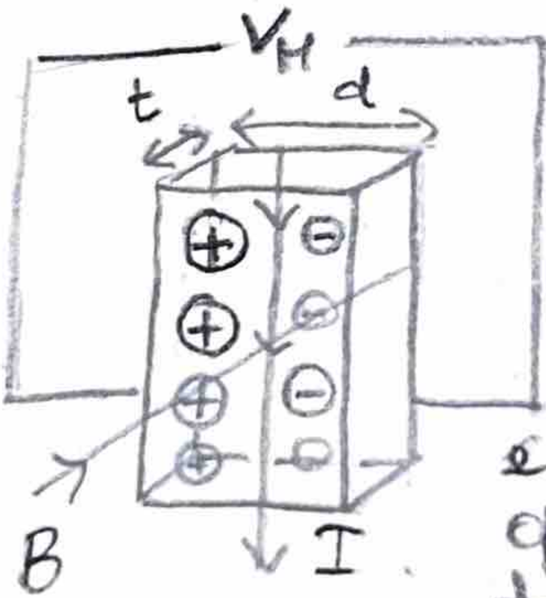
$$\frac{V_H}{d} = B \times \frac{I}{nAq}$$

$\boxed{A = dt}$



$$\therefore \frac{V_H}{d} = \frac{BI}{ndtq}$$

$$\Rightarrow \boxed{V_H = \frac{BI}{ntq}}$$



e^- flow opp dir to I.

(35) $\boxed{E = \frac{F}{q}}$ $\boxed{F = qE}$

- E = electric field strength (NC^{-1})
- F = electric force on charge (N)
- q = magnitude of charge (C)

(36) $\boxed{E = \frac{\Delta V}{\Delta d}}$ — uniform E field btwn parallel plates

- E = electric field strength (Vm^{-1})
- ΔV = p.d btwn the plates (V)
- Δd = distance btwn plates (m)

(37) $\boxed{F = \frac{Q_1 Q_2}{4\pi \varepsilon_0 r^2}}$ → Coulomb's law

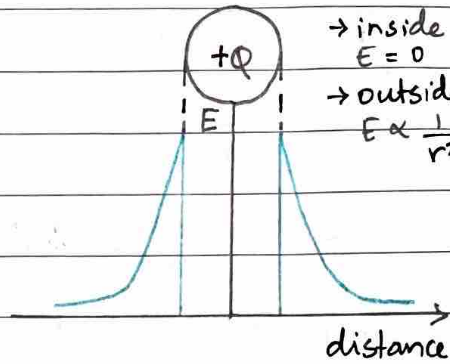
- F = electric force btwn 2 charges (N)
- Q_1 & Q_2 = mag. of charges (C)
- r = distance btwn centres of the 2 charges (m)
- ε_0 = permittivity of free space
  $= 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

$k = \frac{1}{4\pi \varepsilon_0}$ = Coulomb constant
$= 8.99 \times 10^9\ N m^2 C^{-2}$

(38) $\boxed{E = \frac{F}{q} = \frac{Q}{4\pi \varepsilon_0 r^2}}$ → electric field due to point charge

- q = small positive test charge (C)
- Q = point charge producing radial electric field (C)
- r = distance from centre of charge (m)

(39)



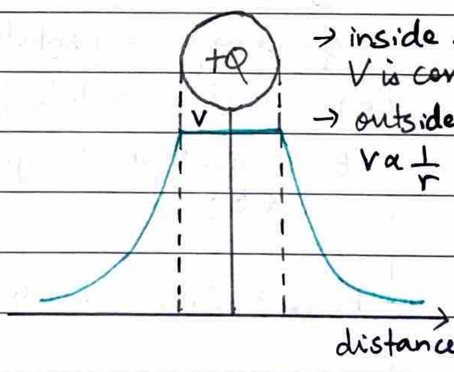
→ inside sphere, $E = 0$
→ outside sphere, $E \propto \frac{1}{r^2}$

(40) $\boxed{V = \frac{Q}{4\pi \varepsilon_0 r}}$ → electric potential due to a point charge

- V = electric potential (V)
- Q = magnitude of charge producing the potential (C)

+ve charge : V↑ as r↓
-ve charge: V↑ as r↑

(41)



→ inside sphere, V is constant
→ outside sphere, $V \propto \frac{1}{r}$

(42) $\boxed{E = \frac{-\Delta V}{\Delta r}}$ → electric potential gradient $\frac{\Delta V}{\Delta r}$

- E = electric field strength (Vm^{-1})
- ΔV = p.d btwn 2 points (V)
- Δr = displacement in direction of field (m)

Derivation of 36

$$\boxed{W = Fd}$$

- W = W done on charge when moving from 1 plate to the other (J)
- F = force on charge (N)
- d = distance btwn plates (m)

$$\boxed{W = qV}$$

- W = W done on charge in moving it through p.d. btwn plates

$$\boxed{Fd = qV}$$

$$\boxed{E = \frac{F}{q} = \frac{V}{d}}$$

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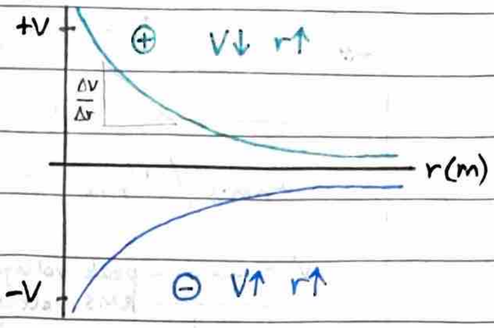
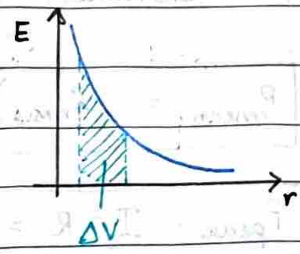
(43)


→ for +ve charge:
- all values of potential are +ve.
- $V \propto 1/r$

→ for -ve charge:
- all values of potential are -ve
- $V \propto -1/r$

(44)


→ for +ve charge: all values of field strength are +ve.

→ for -ve charge: all values of field strength are -ve.

→ $E \propto \frac{1}{r^2}$

→ area under = ΔV

→ steeper than corresponding V-r graph.

(45) $\boxed{\Delta W = q\Delta V}$ W done: - +ve charge against field lines (vice versa)

- ΔW = work done in moving charge through field (J).
- q = magnitude of charge (C)
- ΔV = p.d btwn 2 points (V)

(46) $\boxed{\Delta V = V_f - V_i}$

(47) $\boxed{E_p = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}}$

- E_p = electric potential energy (J)

$E_p = 0$ at ∞.

(48) $\boxed{\Delta E_p = q\,\Delta V}$

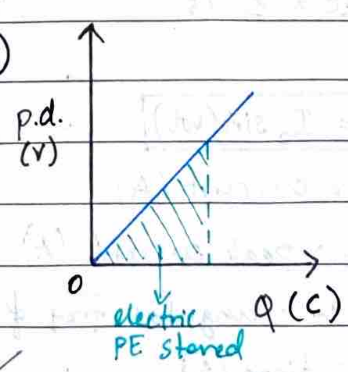
(49) $\boxed{C = \frac{Q}{V}}$

- C = capacitance (F)
- Q = charge (C)
- V = potential difference (V)

(50) $\boxed{C = 4\pi\varepsilon_0 r}$ → for spherical conductor

(51) Series: $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$

Parallel: $C_{total} = C_1 + C_2 + C_3 \ldots$

(52)


$V \propto Q$

(53) $\boxed{W = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{Q^2}{2C}}$

- W = work done / energy stored (J)

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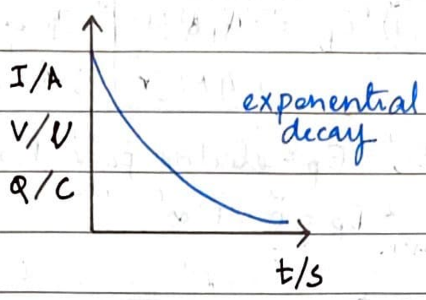
(54) discharging capacitor through resistor:



(55) $\boxed{\tau = RC}$

- τ = time constant (s)
- R = resistance of resistor (R)
- C = Capacitance of capacitor (F)

(56) $$\boxed{X = X_0 e^{-\left(\frac{t}{RC}\right)}}$$

- X = I/Q/V
- X_0 = Initial I/Q/V
- e = exponential function
- t = time (s)
- RC = τ (s)

$\frac{1}{e} = 0.37$

(57) $\boxed{I = I_0 \sin(\omega t)}$

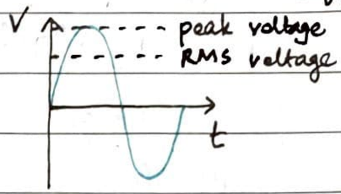
- I = current (A)
- I_0 = peak current (A)
- ω = angular freq. of supply (rad s^{-1})
- t = time (s)

(58) $\boxed{V = V_0 \sin(\omega t)}$

- V = voltage (V)
- V_0 = peak voltage (V)

(59) $\boxed{I_{r.m.s} = \frac{I_0}{\sqrt{2}}}$ (same for $V_{r.m.s}$)

$I_{r.m.s} / V_{r.m.s}$ = ~70% of I_0 / V_0



(60) $\boxed{P = IV = I^2R = \frac{V^2}{R}}$

- I = direct current (A)
- V = direct voltage (V)
- R = resistance (Ω)

(61) $\boxed{P_{mean} = (I_{r.m.s})^2 R}$

(62) $\boxed{P_{peak} = I_0^2 R = (\sqrt{2} I_{r.m.s})^2 R}$

(63) $\boxed{P_{mean} = \frac{P_{peak}}{2}}$

(67) $\boxed{Z = \rho c}$

- Z = acoustic impedence (kg m^{-2} s^{-1})
- ρ = density of material (kg m^{-3})
- c = speed of sound in material (m s^{-1})

(68) $$\boxed{\alpha = \frac{I_R}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}}$$

- α = intensity reflection coefficient
- I_R = intensity of reflected wave (W m^{-2})
- I_0 = intensity of incident wave (W m^{-2})
- Z_1 = acoustic impedience of material 1
- Z_2 = acoustic impedence of material 2 (kg m^{-2} s^{-1})

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(69) $\boxed{I = I_0 e^{-\mu x}}$ — ultrasound

- I_0 = intensity of incident beam (Wm^{-2})
- I = intensity of reflected beam (Wm^{-2})
- μ = absorption coefficient (m^{-1})
- x = distance travelled through material (m)

(70) $\boxed{E_{max} = eV = hf_{max} = \frac{hc}{\lambda_{min}}}$

(71) $\boxed{f_{max} = \frac{eV}{h}}$ → maximum frequency

(72) $\boxed{\lambda_{min} = \frac{hc}{eV}}$ → minimum wavelength

- e = charge of electron (C)
- V = voltage across anode (V)
- h = Planck's constant (Js)
- ~~s~~ c = speed of light ($m s^{-1}$)
- E_{max} = max. energy X-ray photon can have (J)

(73) $\boxed{I = I_0 e^{-\mu x}}$ — X-ray

- I_0 = intensity of incident beam (Wm^{-2})
- I = intensity of emergent beam (Wm^{-2})
- μ = linear absorption coeff (m^{-1})
- x = distance travelled through material (m)

(74) $\boxed{E = hf = m_e c^2}$

- E = energy of photon (J)
- h = Planck's constant (J s)
- f = freq. of photon (Hz)
- m_e = mass of e^- or e^+ (kg)
- c = speed of light in vacuum

(75) $\boxed{p = \frac{E}{c}}$

- p = momentum of photon (Ns)
- c = speed of light ($m s^{-1}$)

(76) $\boxed{A = \frac{\Delta N}{\Delta t} = -\lambda N}$

- A = activity of sample (Bq)
- ΔN = no. of decayed nuclei
- Δt = time interval (s)
- λ = decay constant (s^{-1})
- N = no. of nuclei remaining in sample

(77) $\boxed{N = N_0 e^{-\lambda t}}$

- N_0 = initial no. of undecayed nuclei (when $t = 0$)
- N = no. of undecayed nuclei at time t.
- λ = decay constant (s^{-1})
- t = time interval (s)

(78) $\boxed{A = A_0 e^{-\lambda t}}$

- A_0 = initial activity (Bq)
- A = activity at time t (Bq)

(79) $\boxed{C = C_0 e^{-\lambda t}}$

- C_0 = ~~count~~ initial count rate (cpm)
- C = count rate at t (cpm)

(80) $\boxed{\lambda = \frac{0.693}{t_{1/2}}}$

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(81) $\boxed{\Delta Q = mc\Delta\theta}$

- ΔQ = change in thermal energy (J)
- m = mass of substance being heated (kg)
- c = specific heat capacity of substance ($J\ kg^{-1}\ K^{-1}$ or $J\ kg^{-1}\ {}^{\circ}C^{-1}$)
- $\Delta\theta$ = change in temp (K or °C)

(82) $\boxed{Q = Lm}$

- Q = thermal energy required to change state (J)
- L = latent heat of fusion / vaporisation ($J\ kg^{-1}$)
- m = mass of substance changing state (kg)

(83) $\boxed{n = \frac{N}{N_A}}$

- n = no. of moles
- N = no. of molecules
- N_A = avogadro constant

(84) $\boxed{n = \frac{m}{M_r}}$

(85) $\boxed{pV \propto T}$ – ideal gases

(86) $\boxed{pV = nRT}$

- n = no. of moles
- R = molar gas constant ($8.31\ J\ K^{-1}\ mol^{-1}$)
- T = temperature (K)
- p = pressure (Pa)
- V = volume (m^3)

(87) $\boxed{pV = NkT}$

- N = no. of molecules
- k = Boltzmann constant ($1.38 \times 10^{-23}\ J\ K^{-1}$)

(88) $\boxed{k = \frac{R}{N_A}}$

(89) $\boxed{pV = \frac{1}{3}Nm\langle c^2\rangle}$

- m = mass of 1 molecule (kg)
- $\langle c^2\rangle$ = mean square speed of molecules ($m^2\ s^{-2}$)

(90) $\boxed{p = \frac{1}{3}\rho\langle c^2\rangle}$

- p = pressure (Pa)
- ρ = density ($kg\ m^{-3}$)

$c_{r.m.s} = \sqrt{\langle c^2\rangle}$

(91) $\boxed{E_k = \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT}$

- E_k = KE of a molecule (J)
- k = Boltzmann constant
- T = temp of gas (K)

(92) $\boxed{W = p\Delta V}$

- W = work done (J)
- p = pressure (Pa)
- V = volume of gas (m^3)

Derivation of 89

(i) $\Delta p = p_f - p_i = -mc - (+mc)$
$= -2mc$

(ii) t btwn collisions $= \frac{\text{distance}}{\text{speed}}$

$= \frac{2l}{c}$

(iii) F on wall by 1 molecule:

$F = \frac{\Delta p}{\Delta t} = \frac{2mc}{\frac{2l}{c}} = \frac{mc^2}{l}$

(iv) P exerted by 1 molecule:

$P = \frac{F}{A} = \frac{\frac{mc^2}{l}}{l^2} = \frac{mc^2}{l^3}$

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(93) $\boxed{\Delta U = q + W}$ — first law of thermodynamics

- ΔU = inc. in internal energy (J)
- q = energy transferred to system by heating (J)
- W = work done on system (J)

(94) $\boxed{E = hf}$

- E = energy of photon (J)
- h = Planck's constant (Js)
- f = frequency (Hz)

(95) $\boxed{E = \frac{hc}{\lambda}}$

- c = speed of light (ms^{-1})
- λ = wavelength (m)

(96) $\boxed{p = \frac{E}{c}}$

- p = momentum of photon ($kg\ ms^{-1}$) or (Ns)
- E = energy of photon (J)
- c = speed of light (ms^{-1})

(97) $\boxed{1\,eV = 1.6 \times 10^{-19}\,J}$ eV = electronvolt

↳ derived from $E = QV$

- E = energy (J)
- Q = charge (C)
- V = potential difference (V)

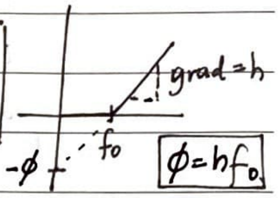
(98) $\boxed{eV = \frac{1}{2}mv^2}$ $\boxed{v = \sqrt{\frac{2eV}{m}}}$

- e = charge of e^- (C)
- V = potential diff (V)
- m = mass of particle (kg)
- v = velocity of particle (ms^{-1})

(99) $\boxed{E = hf = \phi + \frac{1}{2}mv^2_{max}}$

- h = Planck's constant (Js)
- f = freq. of incident EM rad (Hz)
- ϕ = work function of material (J)
- $\frac{1}{2}mv^2_{max}$ = max. KE of photoelectrons (J)

$$\boxed{\begin{aligned} E_{Kmax} &= hf - \phi \\ y &= mx + c \end{aligned}}$$



$\boxed{\phi = hf_0}$

- f_0 = threshold freq (Hz)

(100) $\boxed{E_k = \frac{1}{2}mv^2 = eV}$ — e^- diffraction

- E_K = kinetic energy (J) of e^-
- m = mass (kg) of e^-
- v = velocity (ms^{-1}) of e^-
- e = charge of e^- (C)
- V = p.d. (V) btwn cathode & anode

(101) $\boxed{\lambda = \frac{h}{p}}$ — de Broglie equation

- λ = de Broglie wavelength of particle (m)
- p = momentum of particle ($kg\ ms^{-1}$ OR Ns)

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

(102) $E = \frac{1}{2} \times \frac{p^2}{m}$ (from $E = \frac{1}{2}mv^2$)

$\Rightarrow p = \sqrt{2mE}$

$\boxed{\lambda = \frac{h}{\sqrt{2mE}}}$

- λ = de Broglie wavelength (m)
- h = Planck's constant (Js)
- E = KE of particle (J)
- p = momentum of particle ($kg\ ms^{-1}$)
- m = mass of particle (kg)
- v = speed of particle (ms^{-1})

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(103) $\boxed{\Delta E = hf = E_2 - E_1}$

- E_1 = energy of lower level (J)
- E_2 = energy of higher level (J)
- f = freq. of photon (Hz)

(104) $\boxed{\lambda = \frac{hc}{E_2 - E_1}}$

- λ = wavelength of light absorbed/emitted (m)

(105) $\boxed{F = \frac{L}{4\pi d^2}}$ → Inverse square law of flux.

- F = radiant flux intensity / observed intensity on earth ($W m^{-2}$)
- L = luminosity of source (W)
- d = distance btwn star & earth (m)

(106) $\boxed{\lambda_{max} \propto \frac{1}{T}}$ → Wien's displacement Law

- λ_{max} = max. wavelength emitted by the star at the peak intensity (m)
- T = thermodynamic temp. at surface of star (K)

$\lambda_{max} T = 2.9 \times 10^{-3}$ m K

↳ constant of proportionality

(107) $\boxed{L = 4\pi r^2 \sigma T^4}$ → Stefan-Boltzmann Law

- L = luminosity of star (W)
- r = radius of star (m)
- σ = Stefan-Boltzmann constant
- T = surface temp. of star (K)

(108) $\boxed{\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}}$

- $\Delta\lambda$ = shift in wavelength (m)
- λ = wavelength emitted from source (m)
- Δf = shift in frequency (Hz)
- f = frequency emitted from source (Hz)
- v = speed of recession ($m s^{-1}$)
- c = speed of light in vacuum ($m s^{-1}$)

(109) $\boxed{v \approx H_0 d}$ → Hubble's Law

- v = galaxy's recessional velocity ($m s^{-1}$)
- d = distance btwn galaxy & earth (m)
- H_0 = Hubble's constant / rate of expansion of universe (s^{-1})

$T_0 = \frac{1}{H_0}$ → age of universe

↳ 13-14 billion years

(110) $\boxed{E = mc^2}$

- E = energy (J)
- m = mass (kg)
- c = speed of light ($m s^{-1}$)

(111) $\boxed{\Delta m = Zm_p + (A-Z)m_n - m_{total}}$

- Z = proton no.
- A = nucleon no.
- m_p = proton mass (kg)
- m_n = neutron mass (kg)
- m_{total} = measured mass of nucleus (kg)