OAU PHY 102 Class Notes

Electromagnetic Oscillations - Radioactivity

Note Credit : Adebayo Zainab
(OAU CHM DEPARTMENT)

Intecnum

Electromagnetic Oscillation

Current & Voltage are in phase (resistor only)

$X_C = \frac{1}{\omega_d C}$

capacitive reactance

Current leads voltage by 90° (capacitor only)

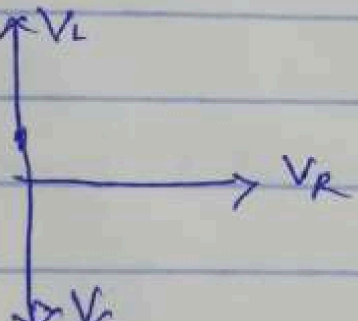
$X_L = \omega_d L$

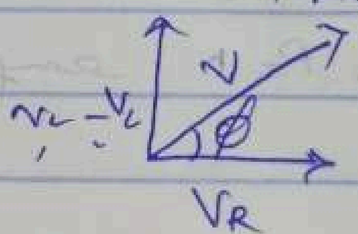
inductive reactance

voltage leads the Current by 90° (inductor only)

Current lags the voltage

RLC Circuit





$\Rightarrow V^2 = V_R^2 + (V_L - V_C)$

$v = V \sin \omega_d t$

$V = Z I$

Resistor

$v = V_R \sin \omega_d t$

$i = I \sin \omega_d t$

inductor

$v = V_L \sin \omega_d t$

$i = I \sin (\omega_d t - \pi/2)$

Capacitor

$V = V_C \sin \omega_d t$

$i = I \sin (\omega_d t + \pi/2)$

$V_R = IR$, $V_C = IX_C$, $V_L = IX_L$

$$Z^2 I^2 = I^2 R^2 + I^2 (X_L - X_C)^2$$

$$Z^2 = R^2 + (X_L - X_C)^2$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

driving potential

$$V_{RLC} = IZ \Rightarrow I = \frac{V_{RLC}}{Z} = \frac{\mathcal{E}_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

If we're left with only X_L

$\tan\phi = \infty$, $\phi = \pi/2$

If it's X_C only

$\tan\phi = -\infty$, $\phi = -\pi/2$

If it's only R

$\tan\phi = 0$, $\phi = 0$

$$\cos\phi = \frac{V_R}{V} = \frac{R}{Z}$$

Resonance

$I = \frac{V}{Z}$, when I reaches its maximum we say it's in resonance

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$X_L = X_C$, when $\omega d = \frac{1}{\sqrt{LC}} = \omega$

$X_L = \omega d L$, $X_C = \frac{1}{\omega d C}$

when we only have LC, the sinusoidal continues when the driving angular frequency = natural angular frequency

$\omega d = \omega$

<u>Power in AC Circuit</u>

$P = i^2 R = [I \sin(\omega d t - \phi)]^2 R = I^2 R \sin^2(\omega d t - \phi)$

r.m.s. current

<> is used to denote means

$\langle i^2 \rangle = I^2 \langle \sin^2(\omega t - \phi) \rangle$

$\sin^2\theta = \frac{1}{2}(1 - \cos 2\theta) \Rightarrow \langle \sin^2\theta \rangle = \frac{1}{2}$

$\langle i^2 \rangle = I^2 \langle \sin^2(\omega t - \phi) \rangle$

$\langle i^2 \rangle = I^2 \times \frac{1}{2} = I^2/2$

$I_{r.m.s} = \sqrt{i^2} = \frac{I}{\sqrt{2}}$

$V_{r.m.s} = \frac{V}{\sqrt{2}}$

$P_{avg} = I_{r.m.s}^2 R = \left(\frac{V_{r.m.s}}{Z}\right)^2 R = I_{r.m.s} \frac{V_{r.m.s}}{Z} \times R$

↑ Power factor for RLC circuit

$P_{avg} = I_{rms} V_{rms} \frac{R}{Z} = I_{rms} V_{rms} \cos\phi$

capacitive reactance depends on the driving frequency

Transformers

Primary – generator

Secondary – where the power is to be used

Whatever happens depend on – No of turns is essential to transformer it is either step up or step down

$$V_S = V_P \frac{N_S}{N_P}$$

If $N_S > N_P$, $V_S > V_P$, which means the transformer is stepped up & vice versa.

$$I_P V_P = I_S V_S, \quad I_S = \frac{I_P V_P}{V_S}$$

Maxwell's eqn: All electromagnetic eqn are governed by maxwell's eqn.

Electromagnetic Wave

Infrared ray is what is used in remote to control TV

Electric wave travels ⊥ to magnetic wave

direction of d motion is also ⊥

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$ wave speed

$$\frac{E_m}{B_m} = c$$ (amplitude ratio)

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$ poynting vector

$$S = \frac{1}{c\mu_0} E^2$$

$$u = \frac{1}{2} \varepsilon_0 E^2$$ (energy density)

$$u_E = \frac{B^2}{2\mu_0}$$

$$I = \frac{P}{4\pi r^2} = \frac{E_{rms}^2}{C}$$ Light intensity

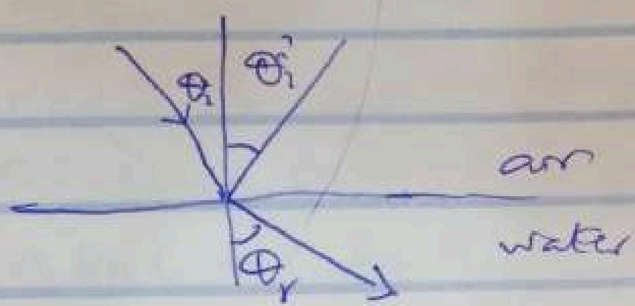
Polarization is a property of transverse wave

Specifying d ... ,

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

Snell's law

$\theta_r = \theta_i'$



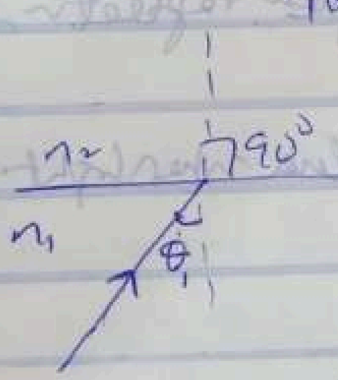
$n = \frac{c}{v}$ — refractive index; c = speed of light in vacuum; v = speed of light in a given medium

Same medium - no refraction, $n_1 = n_2$

$n_2 > n_1$. Bending to d normal, $\theta_1 > \theta_2$

$n_2 < n_1$ away from d normal $\theta_2 > \theta_1$

Total internal reflection

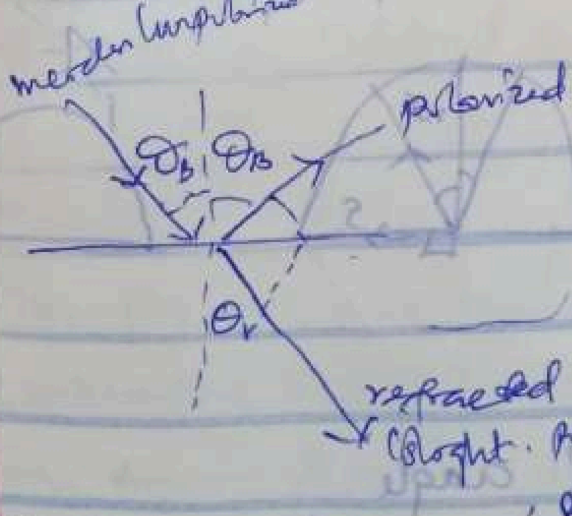


$n_1 \sin\theta_c = n_2 \sin 90$

$\sin\theta_c = \frac{n_2}{n_1}$

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

Polarization by Reflection



$\theta_r + \theta_B = 90°$

$\theta_r = 90° - \theta_B$

$n_1 \sin\theta_B = n_2 \sin\theta_r$
$= n_2 \sin(90 - \theta_B)$

$n_1 \sin\theta_B = n_2 \cos\theta_B$

$\tan\theta_B = \frac{n_2}{n_1}$

, Brewster angle

Geometric Optics

Reflection & Reflective Surface [Mirrors]

{eclipse & shadows}

reflected

absorbed

tr.

2 laws of reflection

&

Surfaces

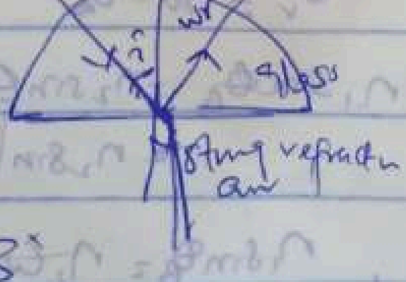
Specular reflection or regular reflection – when light strike smooth plane surface

Diffuse reflection produce when light strikes unsmooth surface

both obey reflecting law

Total internal reflection

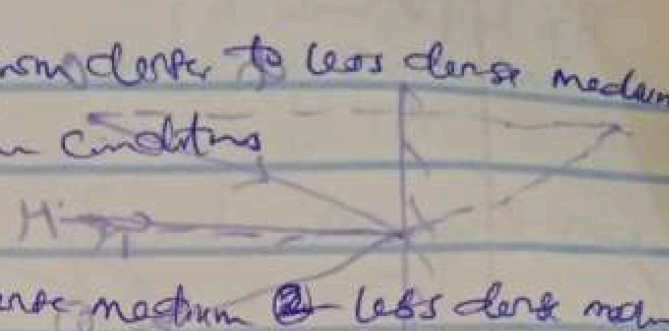
weak reflection & strong refraction



④ incident > critical angle

(critical angle when refracted ray make 90° with the n)

(ii) Light must be travelling from denser to less dense medium
total internal reflection conditions



$n = \frac{\sin\theta_1}{\sin\theta_2}$

angle of incident in first medium — 1 – dense medium (2) – less dense medium

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ — angle of refraction in 2nd medium

$n_1 \sin C = n_2 \sin 90$

$n_1 \sin C = n_2$

$n_1 = \frac{n_2}{\sin C}$, $\frac{n_1}{n_2} = \frac{n_1}{\sin C}$ => $\frac{n_2}{n_1} = \sin C$

$_2n_1 = \sin C$

refractive index of medium 1 w.r.t. m 2

Application of total internal

(2) Mirage (unreal) (occurrence of mirage) — because hot air has lower n than cold air

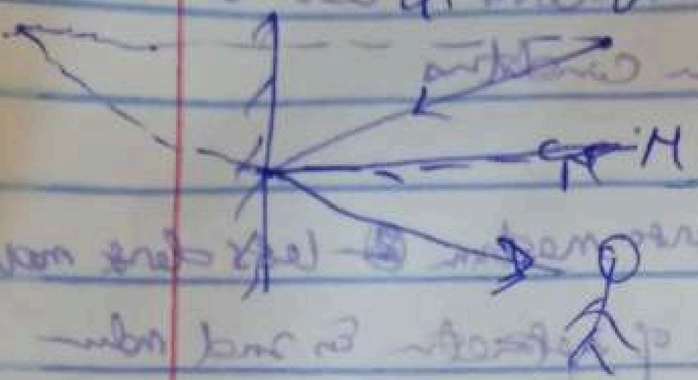
(1) fish ability to see outside fireside water (field of fish underwater)

Q: What's the critical angle for light travelling from diamond to air, $n_d \sin d = n_a \sin 90$, $\theta = 24.4°$

Mirrors

@ Plane Mirror — formed at the back of the screen

(i) Laterally inverted, virtual, same size, same distance from mirror & you, erect (upright)



Real or virtual
Enlarged or reduced
Erect or inverted

Types of image

Flat Mirror

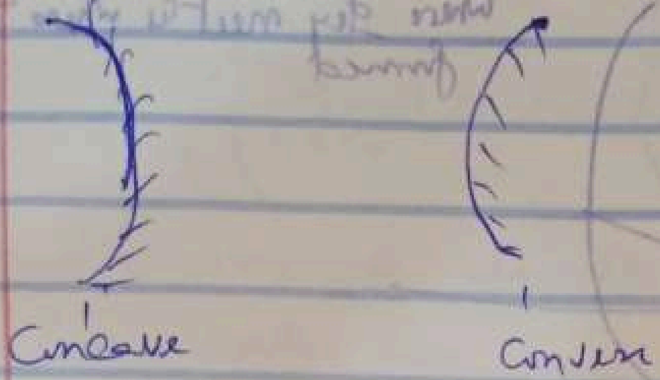
P → object distance to d mirror
q - distance from d mirror to d image
virtual image
does not exist, - made by our eye

Ray diagram
Used to predict d location of d image of an object

trace d top, trace d base

Spherical / Curved Mirrors

Concave mirror - reflected
Convex mirror



Centre of a sphere of which d mirror is part of it

Centre of Curvature

radius .. C1

focus, principal axis

Pole

midpoint of d mirror

dist. btw Centre of Curvature & pole, related to focal length

↓

$\frac{1}{2}R$

line from pole to Centre of Curvature

Convex has -ve principal focus gives virtual image, cuz Centre of Curvature & principal axis are on diff side.

all rays that are parralel diverge after reflection

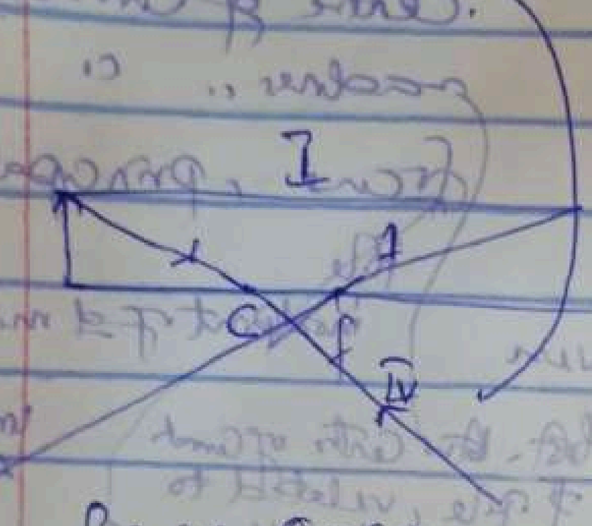
Concave: all rays that are parralel converge after reflection has real principal focus

image are also formed on same side

Locating Image by Drawing Rays (4 ways)

1. A ray that is parralel to d central axis reflects thru d focal point
2. A ray that reflect from d mirror after passing thru d focal point emerges point parralel.

→ where they meet is where they're formed



f = +ve concave mirror

-ve convex mirror

u is -ve for

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Magnification +ve - image orientation is upright. virtual

-ve - inverted image real image

$m = \frac{h_i}{h_o}$ $m = -\frac{h_i}{h_o}$

Spherical abberation

Concave mirror

Parabolic mirror

$2pr - r^2 - 2pr \quad \left(\frac{r^2}{2p-r}\right)^2$

 $r_1 = r_2$

 $r_1 = -r_2$

Lens maker eqn

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$ – thin lens

for a Convex (converging) lens

$r_1 = +ve$, $r_2 = -ve$, $f = +ve$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

for a Concave (diverging) lens

$r_1 = -ve$, $r_2 = +ve$, $f = -ve$.

- frequency is fixed & it determines colour.

Destructive, $\Delta L = m(\lambda/2)$ $m = 1, 3, 5, 7, \ldots$

$\Delta L = (n + \frac{1}{2})\lambda$, $n = 0, 1, 2, \ldots$

Constructive, $\Delta L = n\lambda$, $n = 0, 1, 2, 3, \ldots$

<u>Phase Change</u>

- from higher to 180

$n_{oil} > n_{water}$ – no phase shift

air – oil interface, $180°$ phase shift, $n_{air} < n_{oil}$

$\Delta L = n\lambda'$, $n = 0, 1, 2, \ldots$

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

Relativity

- A study of measure of events

Postulates

- Law of physics are the same for observers in all inertial reference frames
- Speed of light in vacuum has the same value c in all directions & in all inertial reference frames

Relativity of light : $\Delta t = \frac{\Delta t_0}{\sqrt{1-(v/c)^2}}$

Lorentz factor, γ, $= \frac{1}{\sqrt{1-\beta^2}} = \frac{1}{\sqrt{1-(v/c)^2}}$

$\Delta t = \gamma \Delta t_0$ (time dilation)

β = speed parameter $= v/c \times 1$

$L = L_0 \sqrt{1-\beta^2} = \frac{L_0}{\gamma}$, length contraction

$\gamma > 1$, $L < L_0$

$u = \frac{u' + v}{1 + u'v/c^2}$: relativistic velocity

$u = u' + v$ (classical velocity transformation)

Doppler's effect

$f = f_0 \sqrt{\frac{1-\beta}{1+\beta}}$ — source moves away from detector, $\beta = v/c$

$f = f_0 (1 - \beta + \frac{1}{2}\beta^2)$.

Photon

$E = hf$ (photon energy), h = Planck's constant $= 6.63\times10^{-34}$ Js

Rate of emission = $\frac{\text{rate of energy emission}}{\text{energy per emitted photon}} = \frac{P_{emit}}{E} = \frac{P_{emit}}{hf}$

$R_{emit} = \frac{P_{emit}\lambda}{hc}$

$1\,eV = 1.6\times10^{-19}$ J

work function is a characteristic of target metal.

At cut off frequency, kinetic energy is minimum.

Compton shift is not a function of wavelength, is a function of phase shift ϕ (which is a function of metal target angle).

$\lambda = \frac{h}{p}$ (de Broglie wavelength)

Schrodinger's Eqn

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}[E - U(x)]\psi = 0$$ [Schrodinger equation one dimensional motion]

$$\frac{d^2\psi}{dx^2} + k^2\psi = 0$$ [Schrodinger's eqn free particle]

$$\psi(x) = Ae^{-ikx} + Be^{-ikx}$$

$$\hbar = \frac{h}{2\pi}$$ (heisenberg uncertainty principle.

$$b = \sqrt{\frac{8\pi^2 m (U_0 - E)}{h^2}}$$

More about Matter waves

Confinement of wave leads to quantization

$h = \frac{E}{f}$, $E = \frac{1}{2}mv^2$, $E = \frac{1}{2}\frac{m^2v^2}{m} = \frac{1}{2}\frac{p^2}{m}$

$L = \frac{n\lambda}{2}$, n = quantum no = 1, 2, 3, ...

$$y_n(x) = A\sin\left(\frac{n\pi}{L}x\right) = A\sin\left(\frac{n\pi}{\frac{n\lambda}{2}}\right) = A\sin\left(\frac{2\pi}{\lambda}\right)$$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$, $E_n = \left(\frac{h^2}{8mL^2}\right)n^2$, for n = 1, 2, 3, ...

$\Delta E = hf = E_{high} - E_{low}$

$\lambda = \frac{hc}{\Delta E}$

$E_n = \frac{-13.61\, eV}{n^2}$ for n = 1, 2, 3, ... Bohr's model

$L = n\hbar = \frac{nh}{2\pi}$

Nuclear Physics

Problems on Rutherford's theory [the particle emitted]

- Predicts that light will be of continuous wavelength.
- Predicts that atom is unstable.

Neil's Bohr [Proposed H model]

- explains line spectrum
- Predicts electron are orbiting round of nucleus [the excitation]
- ensures of stability of atom by stating discovery of ground state
  $E = h\nu - \phi = \frac{1}{2}mv^2 - \emptyset$, $\emptyset = hf = hc/\lambda$.
- Predicts ionization energy of H.
  $E = E_n - E_0$

mass of nucleus is at the centre of of nucleus.

Nucleon → addition of proton & neutron

Au has 32 isotopes [$^{173}Au - ^{204}Au$] only ^{197}Au is stable.

Binding energy is of minimum energy required by an electron to excite from its orbit to a higher state.

$\emptyset = -\Delta mc^2 \Rightarrow \Delta m = \frac{-\emptyset}{c^2}$

speed of light

$M = \Sigma m_p + \Sigma m_n$

$E = m_p c^2 + m_n c^2$

$\Delta E = \Sigma mc^2 - Mc^2 =$

$= \Sigma (m_p + m_n) c^2 - Mc^2$

$\Delta M = (2 \times p + 2 \times n) - M(\text{element})$

$p = 1.007825u$

$n = 1.008665u$

For He, $\Delta M = (2 \times 1.007825u) + (2 \times 1.008665u) - M_{He}$

$1u = 931.5 MeV$

$B.E = \Delta mc = (ZM_p + NM_n - {}_Z^A M) c^2$

Given that the mass of Na is 21.994435u &

${}_{11}^{22}Na$, 11 protons, 11 neutrons

$B.E = \Delta mc^2 = (ZM_p + NM_n - {}_Z^A M) c^2$

$= [(11 \times 1.007825u) + (11 \times 1.008665u) - 21.994435u] 931.5 MeV$

$= 174.148582 5 MeV$

C is not used cause, the u has been converted to eV

So, we can say, $\Delta B = \Delta M$

Energy atom mass

The bom

Radioactivity

Independent of temp & pressure - Can be natural eg U or induced (artificial), Gives out a large amount of energy

fission — splitting of nucleus into 2 lighter nuclei. ^{235}U

fusion — Combination of lighter nuclei to form a single nucleus

Radioactive element - elements that can spontaneously emit radiation, radon, thorium, polonium, Uranium & it is Independent of external control - can't be affected by Chemicals, pressure or temp. Is random process, these elements has a definite time rate of decay characterised by the ½ life

$N - 2\bar{T}$

$-\frac{dN}{dt} \propto N$

$\frac{dN}{dt} = -kN$

$\int_{N_0}^{N} \frac{dN}{N} = \int -k\,dt$

$\ln\frac{N}{N_0} = -kt \Rightarrow \frac{N}{N_0} = e^{-kt}, \quad k = \lambda$

1st $T \rightarrow \frac{1}{2}N$ - remain

2nd $\frac{1}{2}T \rightarrow \frac{1}{2}(\frac{1}{2}N) = \frac{1}{2^2}N$ remain

3rd $\frac{1}{2}(\frac{1}{2}T) = \frac{1}{2}(\frac{1}{4}N) \rightarrow$ remain $= \frac{1}{2^3}N$

nth $\frac{1}{2^{n-1}}T = (\frac{1}{2^n})N$ remain

At any time t, $N = N_0 e^{-\lambda t}$

At halflife, $N = \frac{N_0}{2}$, $t = T$

$\frac{N_0}{2} = N_0 e^{-\lambda T}$

$\frac{1}{2} = e^{-\lambda t} \Rightarrow \ln\frac{1}{2} = -\lambda T \Rightarrow \ln 1 - \ln 2 = -\lambda t$

$f \ln 2 = t \times T$, $\lambda = \frac{\ln 2}{T} = \frac{0.693}{T}$

$N = R$, $N_0 = R_0$

1 becquerel = 1 Bq = 1 decay per second

1 Curie = 1 Ci = 3.7×10^{10} Bq

$^{226}_{88}Ra \longrightarrow ^{222}_{86}Rn + ^{4}_{2}He + Q$

$^{238}_{96}U \longrightarrow ^{230}_{90}Th + 2\,^{4}_{2}He + 8\,^{0}_{-1}e + Q$

artificial $^{4}_{2}He + ^{14}_{7}N \longrightarrow ^{18}_{9}F \longrightarrow ^{17}_{8}O + ^{1}_{1}H + Q$

Original material not normally radioactive.

A nucleus of an element $^{202}_{84}X$ which emits an alpha particle and then a Beta particle, the final nucleus formed has an atomic no of ?

$^{202}_{84}X \longrightarrow ^{0}_{-1}e + ^{4}_{2}He + ^{198}_{83}Y$

A radioactive element has a count rate of 600Hz. If the ½ life of this element be 3min. How many mins will it take for the count rate to diminish to 150Hz

$\lambda = \frac{\ln 2}{3min} = 0.231/min$

$N = N_0 e^{-\lambda t} \Rightarrow \frac{N}{N_0} = e^{-\lambda t} \Rightarrow \ln\left(\frac{N}{N_0}\right) = -\lambda t$

$\ln\left(\frac{150}{600}\right) = -0.231t$

$-1.386 = -0.231t$

$t = 6.00$ mins

At a certain instant, a piece of radioactive material contains 10^{12} atoms. The ½ life of the material is 30 days.

2.7×10^{5} - (a) Calc the no of disintegration in the first second.

64 days - (b) How long will it elapse before 10^{4} atoms remain.

9.6 - (c) What's the count rate at this time?

A substance has a ½ life of 3 min. After 6 min, the count rate was observed to be 400. What was its count rate at zero time. 1600

Particle physics

- All new particles are unstable when they can transform to other particles
- Intrinsic angular momentum

$$\text{Spin } \vec{S} = m_s \hbar \quad \text{where } m_s = s, s-1, s-2, \ldots, -s$$

$$\hbar = \frac{h}{2\pi}, \quad \vec{S} = \tfrac{1}{2}\hbar \text{ (spin up)}$$

$$\vec{S} = -\tfrac{1}{2}\hbar \text{ (spin down)}$$

Gravitational force applies to all particles

electromagnetic " act upon all electrically charged particles

Hadron -> when strong force act on a particle

Lepton -> when weak force " " " "

electron with same mass but diff charge is called positron

Proton and anti-proton with gauge charge called pion (are unstable) it can decay in its own

$p + p^- \rightarrow 4\pi^+ + 4\pi^-$ — unstable

electron & antielectron gives gamma

$e^+ + e^- \rightarrow \gamma + \gamma$

$N = N_0 e^{-\lambda t}$ $\pi^+ \rightarrow \mu^+ + \nu$ — also unstable, ν = neutrino

Exercise

1:8 2 radioactive elements P & Q have ½ lifes 10 & 20 min respectively. If they started off with same no of atoms what's d ratio of d remaining atom of P to that of Q

$N_0 = \frac{N}{e^{-\lambda t}}$

$\frac{N_p}{e_p^{-\lambda t}} = \frac{N_q}{e_q^{-\lambda t}}$ $\frac{N_p}{N_q} = \frac{e_p^{-\lambda t}}{e_q^{-\lambda t}} = e^{-10\lambda} - e^{-20\lambda} = e^{-\lambda}($

antimeson $\mu^+ \rightarrow e^+ + \nu + \nu^*$ = 105.7 MeV

μ, μ-meson: Pion & meson decays spontaneously (i.e naturally) with d release of energy

$e^+ \rightarrow 0.511$ MeV 1.0×10^{-n} J

10^{-6}

Lepton (Meson & lepton)

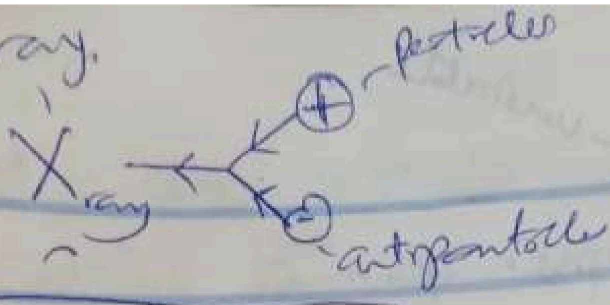
$\mu^+ \rightarrow e^+ + \nu_e^{(+)} + \nu_\mu^{(+)}$ LM

Hadron / proton

$P \rightarrow e^+ + \nu_{(e)}^-$

Every known particle have antiparticle, when they come together, they'll annihilate with d production of 2 γ (gamma).

ray.



Pair production

In pair production, electromagnetic (EM) radiation is transformed into matter. The reverse of pair production is called annihilation.

$e^- + e^+ \to \gamma + \gamma$

annihilation.

- A student makes the following statement about an electron
  (i) an electron is a boson (ii) an electron is a lepton
  (iii) an electron is a fermion
  Which of the following is/are correct?
  (a) I only (b) II only (c) III only (d) I & II only (e) II & III only
- Particles that participate in the strong nuclear interaction are called (a) neutrinos (b) hadrons (c) leptons (d) electrons (e) photon.
- The conservation law violated by the rxn $p \to \pi^- + e^+$ is the conservation of (a) charge (b) energy (c) linear momentum (d) lepton number & baryon no (e) angular momentum.
- The rxns $\mu^- \to e^- + \nu^- + \nu^+$ conserves (e) when
  (a) μ^- lepton no but not e^- lepton no (b) electron lepton no but not

μ^- Lepton no ✓(c) both μ^- & e^- lepton no (d) neither μ^- lepton no nor e^- lepton no (e) all of the above.

- $^{A}_{Z}P \rightarrow {}^{A}_{Z-1}D + \_\_\_ + \_\_\_$. The blanks should contain (a) β^+ and n (b) β^- and ν ✓(c) β^+ and ν (d) β^- and P (e) β^+ & β^-

- A certain radioactive element has a ½ life of 20 days. Calc the time it will take for 7/8 of the atom originally present to disintegrate. (a) 20 days (b) 40 days ✓(c) 60 days (d) 80 days (e) 100 days.