INDIAN ASSOCIATION OF PHYSICS TEACHERS

NATIONAL GRADUATE PHYSICS EXAMINATION 2012

Date of Examination : 22th January 2012

Time : 10 AM to 1 PM

Solution of part A

Q1. In polar coordinates the length element is
$dl = dr\, e_r + rd\theta\, e_\theta + r\sin\theta d\phi\, e_\phi$

Ans: **c**

Q2. The moment of inertia is $I = MR^2$ so $I_1 = I_2 = MR^2$ because each of the semi circular arc and the quadrant have equal mass and equal radius and the same axis of rotation.

Ans: **a**

Q3. According to Biot Savart's law

$$dB = \frac{\mu_0}{4\pi}\frac{idl\ \sin\theta}{r^2} = \frac{\mu_0}{4\pi}\frac{i\vec{dl}\ x\ \vec{r}}{r^3}$$

$$= \frac{\mu_0}{4\pi}\frac{\vec{J}dAdl\ x\ \vec{r}}{r^3} = \frac{\mu_0}{4\pi}\frac{\vec{J}\ x\ \vec{r}}{r^3}dV$$

Ans: **b & c**

Q4. The coherence time

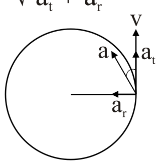
$$\tau = \frac{L}{c} = \frac{0.02945}{3\ x\ 10^8} = 0.1ns$$

Ans: **d**

Q5. The speed $v = ks$ and $a = \sqrt{a_t^2 + a_r^2}$

$$a_t = \frac{dv}{dt} = k\frac{ds}{dt} = k^2s$$

$$a_r = \frac{v^2}{R} = \frac{k^2s^2}{R}$$



Therfore $a = K^2s\sqrt{\left(1^2 + \left(\frac{s}{R}\right)^2\right)}$

Thus $\cos\theta = \frac{a_t}{a} = \frac{K^2s}{K^2s\sqrt{\left(1 + \left(\frac{s}{R}\right)^2\right)}}$

$$\cos\theta = \frac{1}{\sqrt{\left(1 + \left(\frac{s}{R}\right)^2\right)}} \text{ or } \tan\theta = \frac{s}{R}$$

Ans: **a**

Q6. The zero point energy of a harmonic oscillator is

$$E = \frac{1}{2}h\nu = \frac{h}{2T} = \frac{h}{2\ x\ 1} = \frac{h}{2}$$

Ans: **c**

Q7. Emission of light is a result of transition of an electron from higher energy state to lower state. When an electron jumps from state
s to p; sharp series is observed.
p to s; principal series is observed.
d to p; diffuse series is observed.
f to d; fundamental series is seen.

Ans: **b**

Q8. In a 6 dimensional space the volume element is $d\Gamma = dxdydz\ x\ dp_x\ dp_y\ dp_z$ or $d\Gamma = V\ x\ 4\pi p^2dp = V4\pi\sqrt{2mE}\,mdE$
The number of microstates therefore is

$$d\Omega = \frac{d\Gamma}{h^3} = \frac{2\pi V\,(2m)^{3/2}\,E^{1/2}\,dE}{h^3} \propto E^{1/2}$$

Ans: **b**

Q9. The induced emf across a rotating rod is

$\varepsilon = \frac{B\omega l^2}{2}$. So in the present case

$$\varepsilon = \frac{B\omega(31)^2}{2} - \frac{B\omega(21)^2}{2} = \frac{5B\omega l^2}{2}\ \text{volt}$$

Ans: **d**

Q10. The charge on a capacitor, after time t, is expressed as $q = q_0 e^{-\frac{t}{CR}}$. In the present problum $q = q_0 e^{-\frac{30}{CR_{self}}}$ & $q = q_0 e^{-\frac{10\,(4 + R_{self})}{4 \times R_{self} C}}$ comparing the two it yields $R_{self} = 8\ M\Omega$.

Ans: **c**

Q11. The opposite magnetising field reduces the residual magnetisation over the region BC of the B-H curve where the magnetising field $\vec{H}$ is directed opposite to $\vec{B}$.

Ans: **c**

Q12. Clausius Clapeyron equation(expression a) tells us that the Boiling / Melting point of a liquid changes with a change in pressure. Given Maxwell relation $\left(\frac{dP}{dT}\right)_v = \left(\frac{dS}{dV}\right)_T$ reduces to

$$\left(\frac{dP}{dT}\right)_v = \frac{dQ}{T\,(V_2 - V_1)} = \frac{L}{T\,(V_2 - V_1)}$$

which is again the same equation but there being a negative sign, d is not correct.

Ans: **d**

Q13. The transmission of a particle through a potential barrier, when its energy E is less than the barrier height V, is known as quantum mechanical tunnelling which applies to all the situations referred in the question which can be so examined when dealt quantum mechanically.

Ans: **a, b, c, & d**

Q14. Iso-spin is a property of nuclei which expresses the charge state of an elementary particle. Proton and neutron are the two iso-spin states (+ ½ and -½) of a nucleon. Iso-spin quantum number is conserved in strong nuclear interaction but not in E-M and weak interaction. However its Z-component is conserved in both the strong and electromagnetic interactions.

Ans: **a, b, c & d**

Q15. A group of stars forming a pattern in the sky is called a constellation. Ursa Major is a prominent constellation which has seven stars in a kite like pattern with pole star at the end of the tail.

Ans: **d**

Q16. Meissner observed that when a super conductor is cooled to its critical temperature or below, the lines of magnetic induction are pushed out of the material and pass no longer through it. The material loses all its magnetisation (M = 0) and behaves as a perfect dia magnet. This phenomenon is known as Meissner effect.

Ans: **b**

Q17. The given circuit is the realisation of AND gate. When both the inputs are 1, means high (5 V), none of the diodes is in the conducting state so no current flows through the load resistance R_L. A voltage of 5 volt therefore exists across the bulb, as a result it glows. When either of the input or both of them are zero means low (zero volt) the corresponding diode conducts resulting a voltage drop across R_L hence no voltage drop across the bulb, it then does not glow showing zero output.

Ans: **c**

Q18. The eigen values of a particle in a one dimensional potential well of specified width are expressed as $E_n = n^2 \frac{\pi^2 \hbar^2}{8ma^2}$ and the eigen functions are normalised by $|A|^2 \int_{-a}^{a} \sin^2\left(\frac{n\pi x}{2a}\right) dx = 1$ to give $\psi_n = \sqrt{\frac{1}{a}} \sin\left(\frac{n\pi x}{2a}\right)$

Ans: **a**

Q19. The proton electron hypothesis for the composition of an atomic nucleus accounts for the mass and energy of a nucleus as well as the charge neutrality. If, however, a nucleus say deuteron contains two proton and one electron the spin (angular momentum) in units of ħ will be S = ½+½+½ =3/2 means half odd integral value while the observed value is S = 1 a whole number as ½+½ =1 an integral value. Also the observed nuclear magnetic dipole moment is thousands time smaller than that of an electron.

Ans: **c & d**

Q20. Two plane polarised light waves when superimposed give rise to an elliptically polarised light represented by

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - 2\frac{x}{a}\frac{y}{b}\cos\phi = \sin^2\phi$$

with $a \neq b$ and phase angle $\phi \neq \frac{\pi}{2}$.

It becomes circularly polarised when a= b and $\phi = \frac{\pi}{2}$. In this problem

P is CP $\because a = b = E_0$ and $\phi = \frac{\pi}{3} - (-\frac{\pi}{6}) = \frac{\pi}{2}$

Q is CP $\because a = b = E_0$ and $\phi = 0 - (\frac{\pi}{2}) = \frac{\pi}{2}$

R is EP $\because a = E_0 \neq b = \frac{E_0}{\sqrt{2}}$ & $\phi = \frac{\pi}{4} - 0 = \frac{\pi}{4}$

S is LP $\because a = E_0 \neq b = \frac{E_0}{\sqrt{2}}$ and $\phi = 0$

Ans: **b, c & d.**

Q21. When the amount of heat conducted per second to the surface through the ice slab becomes equal to the heat conducted from bottom of the lake to the ice slab through water, the thickness of the ice slab stops growing and becomes constant.

Ans: **a & d**

Q22. When a p-n junction is formed, there is a diffusion of holes from p - region to n - region. Physically this means that some of the valence electrons in n - region may fill up the vacancies on the p - side similar to the diffusion of conduction electrons from n - region to p - region because of concentration difference. In fact the motion of an electron in the valance band is considered to be the motion of holes. The ions as such do not move because of their large masses.

Ans: **c**

Q23. The saturation of binding energy ≈ 8.3 MeV/nucleon for almost all the nuclei is a consequence of the fact that the strong nuclear forces are saturated.

Ans: **d**

Q24. The lowest energy state eigen function of a particle in one dimensional potential well between x = 0 & x= a, is $\psi \approx \sin\frac{\pi x}{a}$ for which the value of $|\psi|^2$ i,e the probability of finding a particle is maximum exactly at the centre between the walls of the well.

Ans: **c**

Q25. Construction and working of Ruby LASER can be seen in any text book e.g. Principles of LASERS by Svelto.

Ans: **a, b, c & d**

Part B -I

B1. The electrostatic force between two charges is given by $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ Correspondingly the electric field is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ and the electric flux at any point in the space is $\int d\phi = \int E.dS$ thereby $\phi = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}4\pi r^2 = \frac{q}{\varepsilon_0}$

This shows that the electric flux is the same in the space surrounding a charge and is independent of the distance r from the charge. If the denominator in the expression for the force is r^n with $n \neq 2$, the flux depends on r i,e the position, which indicates that the flux is being generated or terminated at points where there is no charge which is against the natural concept. This is why expression must have $r^n = r^2$.

B2. The differential equation for forced oscillations of a mechanical system under the influence of a periodic force is often expressed as $m\frac{d^2x}{dt^2} + r\frac{dx}{dt} + Kx = F_0 \sin pt$

using $\frac{r}{m} = 2\lambda$, $\frac{K}{m} = \omega^2$ and $\frac{F_0}{m} = f_0$

The steady state solution of this equation is

$$x = \frac{f_0}{\sqrt{(\omega^2 - p^2)^2 + 4\lambda^2 p^2}} \sin(pt - \theta)$$

while the particle velocity is expressed as

$$\frac{dx}{dt} = \frac{pF_0}{m\sqrt{(\omega^2 - p^2)^2 + 4\lambda^2 p^2}} \sin(pt - \theta)$$

Comparing with an electrical system where $i = \frac{dq}{dt} = \frac{V}{Z}$, the velocity $v = \frac{dx}{dt} = \frac{F}{Z_m}$

Thus the mechanical impedance Z_m is

$$Z_m = \frac{m}{p}\sqrt{(\omega^2 - p^2)^2 + 4\lambda^2 p^2}$$

$$Z_m = \sqrt{\left(\left(\frac{m}{p}\frac{K}{m} - mp\right)^2 + 4m^2 \frac{r^2}{4m^2} \right)}$$

$$= \sqrt{r^2 + \left(pm - \frac{K}{p}\right)^2}$$ Here r is mechanical resistance, p is the frequency of applied periodic force and K is the linear restoring force constant. As a conclusion, in an electrical circuit L is inertia factor and 1/C is spring factor.

B3. In a bent beam the longitudinal filaments above the neutral surface are elongated while those below are contracted. As a consequence longitudinal strain is caused and Young's modulus comes into play to describe its elastic behaviour in terms of a bending moment $BM = \frac{YI_g}{R}$ and not the modulus of rigidity (η) as there is no twist in this kind of deformation of the beam.

B4. For a gas obeying Vander Waal equation the temperature of inversion is $T_i = \frac{2a}{Rb}$ at which Joule Thomson coefficient $\left(\frac{dT}{dP}\right)_H = -\frac{1}{C_p}\left(\frac{2a}{RT} - b\right)$ vanishes while the boyle temperature $T_B = \frac{a}{Rb}$ at which a gas behaves ideally. Here a and b being the Vander Waal constants of the gas.

B5. According to the theory of relativity when the astronaut is moving with a velocity v=0.8c, the 8 light year distance appears contracted to $l = 8\sqrt{1 - \frac{(0.8c)^2}{c^2}} = 4.8$ ly

Hence the time taken for the trip is $t = \frac{4.8c}{0.8c} = 6y$

In other words the time t = 6 years in the frame of astronaut will be dilated to the extent that $\tau = \frac{t}{\sqrt{1 - \frac{(0.8c)^2}{c^2}}} = \frac{6}{0.6} = 10y$

which justifies the time $\tau = \frac{8c}{0.8c} = 10y$

Hence the result is reconciled.

B6. A wave function is a stationary state, if the probability density function $|\psi|^2$ is time independent. Let us first see if the given function is a solution of Schrodinger equation $-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} = E\psi$ for a free particle.

Substituting $\psi=\psi_0 e^{-i(kx-\omega t)}$, one obtains $-\frac{\hbar^2}{2m}(-ik)^2\psi = \frac{\hbar^2 k^2}{2m}\psi = \frac{p^2}{2m}\psi = E\psi$ that the given function is a solution of Schrodinger equation.We now find the probability density $|\psi|^2 = \psi^*\psi = |\psi_0|^2 e^{i(kx-\omega t)} e^{-i(kx-\omega t)} = |\psi_0|^2$ which is independent of time. Hence the given function is a stationary state

B7. Given that $L = 800 - 0.705T$

Thereby $\frac{dL}{dT} = -0.705$ and then

$$C_{vapour} = 1.01 - 0.705 - \frac{800}{373} = -1.145$$

The negative specific heat of saturated water vapours is explained as follows. In order to increase the temperature of a sample of water vapour by 1°C, a certain amount of heat is to be given to it. In doing so, though the vapours are heated yet become unsaturated. Now to saturate it again some heat is to be with-drawn from it. The amount of heat with-drawn is practically more than the heat added to raise the temperature. This indicates that overall the heat is with-drawn and the temperature rises which justifies the negative specific heat of saturated water vapours.

B8. Silicon is easily available in bulk, has a large band gap which results into a smaller reverse saturation current making device to function ideally. It can be operated at comparatively higher temperatures and can sustain temperature fluctuations. It is easy to create ohmic contact with silicon.

B9. In Young's double slit experiment, interference fringes are observed due to superposition of two coherent light beams. In case a broad source, and not a fine slit, is used before the two slits in the experiment, the interference fringes will not be seen. This is because of the fact that the light reaching any point on the screen will be incoherent and will not produce interference. In other words light beams reaching a particular point on the screen shall be originating at different points of the broad source and some will form maximum and some minimum at the same point resulting into a continuous illumination.

B10. The polarized light from polariser P is allowed to pass through analyser A. The analyser is given one full rotation, and the position of $I_{min} = 0$ (say θ_0) is noted. The given plate G (say) is now put (normal to optical axis of the system) between polariser & analyser.

(i) If all the orientations of the plate G yield same positions of $I_{min} = 0$ (i.e. θ_0) on rotating the analyser, then the given plate is plane glass plate.
Explanation: Plane glass plate does not affect the nature of polarization of the incident light.

(ii) If for all the orientations of the plate G, analyser on rotation yields some positions of $I_{min} = 0$ which for most of the cases will be different from θ_0, then given plate is half wave plate.
Explanation: The LP light remains LP on passing through HWP, only its plane of polarisation rotates by 2β if β is the angle between the incident vibrations & the optic axis of HWP. For $\beta = 0$ or 90°, there is no rotation of the vibration.

(iii) If most of the orientations of the plate G lead to NONZERO I_{min} on rotation of A, then the plate is QWP.
Explanation: LP becomes EP after passing through QWP. However if β = 45°, LP becomes CP and if $\beta = 0$ or 90°, LP remains LP.

Part B -II

P1. The differential equation for a damped harmonic oscillator can be written as

$$m\frac{d^2x}{dt^2}+r\frac{dx}{dt}+Kx=0$$

or $\frac{d^2x}{dt^2}+2\lambda\frac{dx}{dt}+\omega^2x=0$ Its solution can be written as $x=ae^{-\lambda t}\sin(\beta t+\phi)$

The first throw x_1 is observed at $t=\frac{T}{4}$

Thereby $x_1=ae^{-\frac{\lambda T}{4}}$ and $x_{201}=ae^{-\lambda(100T+\frac{T}{4})}$

As per the conditions of the problem

$$\frac{x_{201}}{x_1}=\frac{1}{10}=e^{-100\lambda T}\Rightarrow\lambda=\frac{1}{100T}\ln 10$$

or $\lambda=\frac{2.3026}{100\times1.15}=0.02s^{-1}$

The relaxation time τ is defined as the time during which the energy

$E=(\text{Amplitude})^2=a^2e^{-2\lambda t}$ decreases to $\left(\frac{1}{e}\right)$ times its initial value a^2 means when

$$t=\tau=\frac{1}{2\lambda}=\frac{1}{2\times0.02}\Rightarrow\tau=25.0\text{ s}$$

The undamped amplitude (a) is

$$a=x_1e^{\frac{\lambda T}{4}}=2\times e^{\frac{0.02\times1.15}{4}}=2.0115\text{ cm}$$

P2. (a) Using Stefan law $P=\varepsilon A\sigma T^4$

The wattage of the bulb is

$P=0.35\times0.25\times10^{-4}\times5.67\times10^{-8}(3000)^4$

Therefore $P=40$ watt

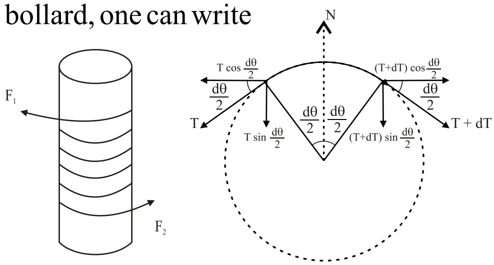
(b) The root mean square speed of the molecules of a gas is expressed as

$$v_{rms}=\sqrt{\frac{3RT}{M}}=\sqrt{\frac{3\times8.3\times300}{2\times10^{-3}}}=1932.6\text{ m/s}$$

The velocity of sound in a gas such as hydrogen is $v_{sound}=\sqrt{\frac{\gamma RT}{M}}$

Thus $\frac{v_{sound}}{v_{rms}}=\sqrt{\frac{\gamma}{3}}=\sqrt{\frac{1.4}{3}}=0.683$

P3. The rope is wrapped round the bollard. Let us consider a small segment of the rope in the shape of an arc that subtends an angle $d\theta$ at the centre. Because of the friction between the rope and the bollard, the tension at one end is T and T + dT at the other end of this arc. If N is the normal reaction on the surface of the cylindrical bollard, one can write



$$N-T\sin\frac{d\theta}{2}-(T+dT)\sin\frac{d\theta}{2}=0$$

For small values of $d\theta$, $\sin d\theta=d\theta$. Then one gets $N-T\frac{d\theta}{2}-(T+dT)\frac{d\theta}{2}=0$

Thereby $N=2T\frac{d\theta}{2}=Td\theta$. The small term $dT\,d\theta$ has been neglected.

Along the tangent, the state of equilibrium is achieved when

$$(T+dT)\cos\frac{d\theta}{2}-T\cos\frac{d\theta}{2}-\mu N=0$$

Using $\cos\frac{d\theta}{2}=1$, one obtains

$dT=\mu N=\mu T\,d\theta$ or $\frac{dT}{T}=\mu d\theta$

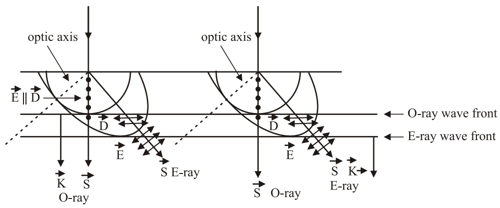
$$\therefore\int_{F_1}^{F_2}\frac{dT}{T}=\int_0^{2\pi n}\mu d\theta\text{ or }\ln\frac{F_2}{F_1}=\mu\times2\pi n$$

substituting the given values

$$\ln\frac{2.4\times10^6}{400}=0.4\times2\pi n\Rightarrow n=\frac{\ln 6000}{0.8\pi}$$

$n=3.4$ turns say 4 turns.

P4. The optic axis lies in the plane of incidence and subtends an angle $\theta\ (\neq 0, \frac{\pi}{2})$ with the surface of incidence. Calcite is a doubly refracting negative crystal with $v_O < v_E$ which means that the ordinary ray travels slower than the extraordinary ray and that the circular wave front for O-ray lies within the elliptical wave front for E-ray. The two waves travel with the same velocity along the optic axis and hence the two wave fronts touch in this direction. The situation is shown below



For O-ray: D || E but ⊥ K and S which are along the direction of propagation but ⊥ to the wave front. Further S is || K.

For E-ray: E is || to the optic axis and ⊥ to the ray-direction hence ⊥ to S. D is ⊥ to K and parallel to the wave front but not parallel to E. D is not perpendicular to ray- direction and K is not along the ray- direction.

In either case S is in the ray-direction whether O-ray or E-ray. E is perpendicular to the ray-direction. D is parallel to the wave front for both O-ray and E-ray.

P5. When a conductor, carrying current, is placed in a perpendicular magnetic field, an electric field is set up perpendicular to both the directions of the current density (J) as well as the magnetic field (B). Such an observation is known as Hall effect. In an experiment on Hall effect the force on the free charge carriers due to the applied magnetic field is balanced by the force due to the established Hall electric field E_H.

$$qE_H = qv \times B \Rightarrow E_H = vB = \frac{JB}{ne} = \frac{EB}{ne\rho}$$

$\Rightarrow \frac{E_H}{E} = \frac{B}{ne\rho}$. Now to calculate Hall voltage, we first estimate 'ne' for silver [density $d = 10.4\times10^3 \frac{Kg}{m^3}$ & Silver is mono atomic with mass number A=108]

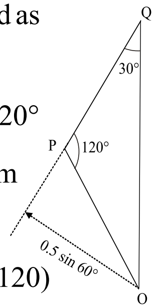
$$ne = \frac{6.023\times10^{23}\times10400}{108\times10^{-3}} \times 1.6 \times 10^{-19}$$

$= 9.28 \times 10^9$ coulomb/m^3 ∴ Hall Voltage

$$V_H = \frac{JbB}{ne} = \frac{iB}{tne} = \frac{5 \times 1.60}{0.10\times10^{-3}\,ne} = 8.62\ \mu V$$

Hall voltage across a metallic strip is quite low. It would be appreciable in case of a semi-conductor strip as 'n' will be less in that case.

P6. According to Biot Savart law the magnetic field produced by a current carrying straight conductor is expressed as



$$B = \frac{\mu_0 i}{4\pi R}(\cos\theta_1 + \cos\theta_2)$$

In this problem $\theta_1 = 30°$, $\theta_2 = 120°$

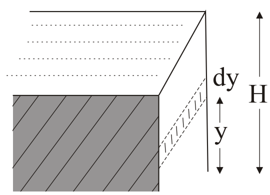
& $R = 0.5 \sin 60 = \frac{0.5\times\sqrt{3}}{2}$ m

$$B = \frac{10^{-7}\times 2}{0.5\times\sqrt{3}/2}(\cos 30 + \cos 120)$$

$B = 1.69 \times 10^{-7}$ T due to single side of the polygon. For 12 identical sides B is the same directed along the out ward normal. Hence the resultant $B = 12 \times 1.69 \times 10^{-7} = 2.03\mu T$. The magnetic dipole moment of the current loop is $\vec{\mu} = iA = 2\left[12\frac{(0.5)^2\sqrt{3}}{4}\right] = 2.6\ Am^2$

For an anticlockwise current μ is directed out of page normal to it.

P7. (a) The pressure at a height y is $\rho g(H-y)$. At this height, the force at a strip of width dy and length W (width of dam) is $dF = \rho g(H-y)W dy$



Thereby $F = \rho g W \int_0^H (H-y)dy = \frac{\rho g W H^2}{2}$

The torque exerted by this force against the dam is $\tau = \int_0^H \rho g\ (H-y)W dy \times y = \frac{\rho g W H^3}{6}$

Now using $\tau = h \times F \Rightarrow \frac{\rho g W H^3}{6} = h \times \frac{\rho g W H^2}{2}$

$\Rightarrow h = \frac{H}{3}$ Hence proved.

(b) Newton's second law of motion is

$$F = \frac{dp}{dt} = \frac{d(mv)}{dt} = \frac{d}{dt}\left(\frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}\right)$$

$$= m_0 \left[\frac{\sqrt{1-\frac{v^2}{c^2}}\frac{dv}{dt} - v\frac{1}{2}\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}\left(0-2\frac{v}{c^2}\frac{dv}{dt}\right)}{1-\frac{v^2}{c^2}}\right]$$

$$= \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}\left(\frac{1-\frac{v^2}{c^2}+\frac{v^2}{c^2}}{1-\frac{v^2}{c^2}}\right)\frac{dv}{dt} = \frac{m}{\left(1-\frac{v^2}{c^2}\right)}\frac{dv}{dt}$$

hence proved

P8. According to Rutherford Soddy law of radioactive disintegration $N = N_0 e^{-\lambda t}$ where λ is the disintegration constant. In a cumulative process such as in this problem,

$$\lambda = \lambda_1 + \lambda_2 = \frac{\ln 2}{T_1} + \frac{\ln 2}{T_2}$$

Given that $N = \frac{0.1}{100} N_0, T_1 = 7$ days & $T_2 = 8$ days

$$\therefore \frac{0.1}{100} N_0 = N_0 e^{-\left(\frac{\ln 2}{7}+\frac{\ln 2}{8}\right)t} \Rightarrow t = 37.2 \text{ days.}$$

P9. The plane indicated by broken lines cut intercepts a, 2a and ∞ on x, y and z axes where x & y axes lie in the plane of papaer while z-axis is taken perpendicular to the plane of paper. Hence the Miller indices of the plane will be obtained by $\frac{1}{1}:\frac{1}{2}:\frac{1}{\infty}::2:1:0$ Millers being (210), the inter-planer distance is $d = \frac{a}{\sqrt{h^2+k^2+l^2}} = \frac{5.63}{\sqrt{2^2+1^2+0^2}} = 2.52$ A°

The electrons are diffracted from this crystal lattice, then $2d \sin\theta = n\lambda$

From the given arrangement of atoms in the lattice $\tan\theta = 2 \Rightarrow \sin\theta = \frac{2}{\sqrt{5}}$

$$\Rightarrow 2 \times 2.52 \times \frac{2}{\sqrt{5}} = \lambda \Rightarrow \lambda = 4.504 \text{ A°}$$

Further the de Broglie wave length of an electron is $\lambda = \sqrt{\frac{150}{V}}$ $\therefore 4.504\text{A°} = \sqrt{\frac{150}{V}}$

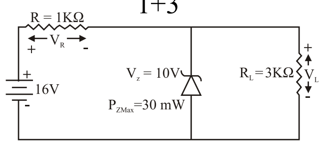
$$\Rightarrow V = \frac{150}{(4.504)^2} = 7.4V$$

P10. (a) According to Ohm's law $J = \sigma E$ or $nev_d = \sigma E$ or $ne\mu E = \sigma E$. Since both electrons and holes contribute to conduction $\sigma = e(n\mu_e + p\mu_p)$

The intrinsic carrier concentration is $n_i = 6\text{x}10^{19}$ e/m^3. After the sample is doped the electron concentration becomes $n = n_i + N_D = 2 \text{ x } 10^{23}$ electrons / m^3 (given). The law of mass action $n.p = n_i^2$ yields $p = 1.8 \times 10^{16}$ holes/m^3. The conductivity of the semiconductor material is then $\sigma = 1.6 \times 10^{-19}(0.39 \times 2 \times 10^{23} + 0.19 \times 1.8 \times 10^{16})$

Hence $\sigma = 1.248 \times 10^4$ ℧m^{-1}

(b) In the given circuit (when Zener is not conducting) $i_L = \frac{16}{1+3} = 4mA$ & $V_L = 3\text{x}4 = 12V$



Before the voltage reaches this value the Zener breaks down and the voltage across R_L remains only V_L =10 V. Then the voltage across R = 1KΩ is $V_R = 16 - 10 = 6$ volt. So the current from the source is

$$i_S = \frac{V_R}{R} = \frac{6}{1 \times 10^3} = 6 \times 10^{-3} A = 6 \text{ mA}$$

The current through the load is

$$i_L = \frac{V_L}{R_L} = \frac{10}{3 \text{ x } 10^3} = 3.33 \text{ mA}$$

Therefore current through Zener is $I_Z = 6 - 3.33 = 2.67$ mA & the power in Zener is $P_Z = 10 \text{ x } 2.67 = 26.7$ mW.