

Theory & Formulae in Ghatge chapter 21 - Holography.

SCU - pg 414

and pg 417/418

~~$$\Delta EDC \sim \Delta CBA$$

 $\rightarrow m\angle 2 \sim m\angle 2$
 $\rightarrow m\angle 1 \sim m\angle 1$~~

→ Inverse square law force

we will solve in same manner!

phase part we get
combining $C_1 \cos \theta + C_2 \sin \theta$
 $= C' \cos(\theta - \phi)$

derivation $\rightarrow$ DIAS (11 - 64, 65, 36, 37)

$$\sigma = \int \sigma(r) d\Omega = \int_0^\pi \sigma(r) \underline{2\pi r \sin\theta d\theta}$$

(b) $v = \sqrt{\frac{T}{\mu}}$ → Tension
→ mass per unit length (speed on string)

speed of sound in solid = $\sqrt{\frac{Y}{\rho}}$

4. 4. " - líquido: $\sqrt{\frac{B}{\rho}}$

$$u = \sqrt{\frac{7P}{5}} = \sqrt{\frac{7RT}{M}}$$

04(c) → Mol Prism → AJG pg 22.9

Q4(a) $\rightarrow$ For such overhorn, we use Fresnel diffraction $\rightarrow \sqrt{nb\lambda} = 91_n$

odd HPZ $\rightarrow$ bright
even HPZ $\rightarrow$ dark.

Q5 (a) In such questions $\rightarrow$ The current has to be same through lamp.

Now $R = \frac{V}{I} = 20$ and then $I = 10A = \frac{250}{Z} \rightarrow Z = \sqrt{R^2 + (\omega L)^2} = 25$
 $\omega = 2\pi f = 2\pi \times 50$

(b) Gauge transformation $\rightarrow$ SPEM pg 437

Coulomb Gauge & vector potential $\vec{A}$ in coulomb gauge $\rightarrow$ pg 439-441 SPEM

(c) & (d) $\rightarrow$ Easy

Q6 (a) $\rightarrow$ simple LR in DC circuit

(b) $\rightarrow$ search for answer of resistor & amplification in SPEM-AC

(c) conducting sphere in uniform Electric field using Method of Images
 pg 145 $\rightarrow$ SPEM

Q7 (a) SPEM $\rightarrow$ pg 433-435

(b) SPEM $\rightarrow$ pg 302-305

(c). Easy.

Q8 (a) either use DIAS Method $\rightarrow n(\mathbf{E})d\mathbf{E} \rightarrow n(\mathbf{r})d\mathbf{r}$
 and then $f(\mathbf{r}) = \frac{n(\mathbf{r})}{N} = f(v_x)f(v_y)f(v_z)$ and $d^3v_x d^3v_y d^3v_z = 4\pi v^2 dv$

or use GBG method 1.17-1.22 using undetermined multiplied B

(b) Easy

(c) Saha Thermal Ionization Equation $\rightarrow$ GBG pg 13.53-13.55

$\rightarrow$ Abhijeet Agarwal (AA Notes) $\rightarrow$ Thermo part 2 pg 1

Q1(a) Explanation of Natural phenomena in contemporary physics using Quantum theoretical methods $\rightarrow$ Blackbody Radiation, stability of orbitals of e^- in atom, biology (protein structure, photosynthesis). Superfluidity (frictionless flow of liquid at 0 Kelvin), Superconductivity, Quantum entanglement, Quantum Hall effect

Application $\rightarrow$ Quantum computing, Cryptography (Qubits), Quantum Teleportation, MRI, lasers, integrated circuits, superconducting magnets, electron microscopy, LED, Transistors, explanation of chemical Bond & DNA.

(ii) Anions of OM $\rightarrow$ Easy $\rightarrow$ DIAS (4) - 80 or Hyperphysics (HP)

(iii) Boundary condition on $\Psi \rightarrow$ finite, single valued, square-integrable and Ψ & $\partial\Psi/\partial x$ must be continuous

Q1(b) (i) use $L_z = -i\hbar \frac{\partial}{\partial \phi} \rightarrow \phi(\phi) = \frac{1}{\sqrt{2\pi}} e^{im_z \phi}$

(ii) Properties of Pauli Spin Matrices $\rightarrow$ Wikipedia * and DIAS (6) - 9 to 13

(c) Franck-Condon Principles $\rightarrow$ RSK pg 362-366 $\rightarrow$ for $n=2.8$ 0.0105 cm^{-1} $n=3$

(d) Lamb Shift $\rightarrow$ DIAS (51) - 37-38 $\rightarrow$ 0.034 cm^{-1} $\sim 2S_{1/2}$ higher than $2P_{1/2}$

$\hookrightarrow$ observed in Hydrogen & other Hydrogen-like atoms in Lamb & Retherford experiments

(ii) 21cm-line in Hydrogen Astronomy $\rightarrow$ DIAS (5) - 80-81

(eg: He, Na)

Q2(a) 2 ways $\rightarrow$ use a_+ & $a_- \rightarrow$ DIAS (5) $\rightarrow$ 141, 142 (easy)

Use $y = \left(\frac{\mu m}{\pi}\right)^{1/2} x$ ~~DIAS (5) - 119~~ $\rightarrow$ DIAS (5) - 119 < very long & complicated >

(b) Matrix representation of operator: $\hat{F} = \begin{bmatrix} F_{11} & F_{12} \\ F_{21} & F_{22} \end{bmatrix} = \begin{bmatrix} \langle \phi_1 | \hat{F} | \phi_1 \rangle & \langle \phi_1 | \hat{F} | \phi_2 \rangle \\ \langle \phi_2 | \hat{F} | \phi_1 \rangle & \langle \phi_2 | \hat{F} | \phi_2 \rangle \end{bmatrix}$

$\hookrightarrow$ similar to Spin

(+ + + -) in 2nd row

thus in Matrix form: $H = \hbar\omega \begin{bmatrix} 1/2 & 0 & 0 & \dots \\ 0 & 3/2 & 0 & \dots \\ 0 & 0 & 5/2 & \dots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$ energy operator of linear oscillator.

extra learning: $\rightarrow$

similarly $a_- = \frac{1}{\sqrt{2}} \left(\begin{bmatrix} 0 & \sqrt{1} & 0 & 0 & 0 \\ 0 & 0 & \sqrt{2} & 0 & 0 \\ 0 & 0 & 0 & \sqrt{3} & 0 \\ 0 & 0 & 0 & 0 & \sqrt{4} \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix} \right)$ basically raising/lowering operator

and $a_+ = \frac{1}{\sqrt{2}} \left(\begin{bmatrix} 0 & 0 & 0 & \dots \\ \sqrt{1} & 0 & 0 & \dots \\ 0 & \sqrt{2} & 0 & \dots \\ 0 & 0 & \sqrt{3} & \dots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix} \right)$ lowering/raising operator

since $a_- |n\rangle = \sqrt{n} |n-1\rangle$ insert a and $a^\dagger$ in place of F in here.

since $a_+ |n\rangle = \sqrt{n+1} |n+1\rangle$

P to 3

Now since: $a^+ = \text{raising} = \frac{1}{\sqrt{2m\hbar\omega}} (-ip_x + m\omega x)$ and $a^- = \frac{1}{\sqrt{2m\hbar\omega}} (ip_x + m\omega x)$ (2)

we have $\hat{x} = \sqrt{\frac{\hbar}{2m\omega}} (a^+ + a^-) = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & \sqrt{2} & 0 \\ 0 & \sqrt{2} & 0 & \sqrt{3} \\ 0 & 0 & \sqrt{3} & 0 \end{pmatrix}$ and similarly for $\hat{p}_x$

Q2(b) (i) Easy. $\langle \Psi | H | \Psi \rangle$

$$\begin{bmatrix} \Psi_1^* & \Psi_2^* & \Psi_3^* \end{bmatrix}_{1 \times 3} \begin{bmatrix} H \end{bmatrix}_{3 \times 3} \begin{bmatrix} \Psi_1 \\ \Psi_2 \\ \Psi_3 \end{bmatrix}_{3 \times 1}$$

$$\hat{p}_x = \sqrt{\frac{m\hbar\omega}{2}} \begin{pmatrix} 0 & -i & 0 & 0 \\ i & 0 & -i\sqrt{2} & 0 \\ 0 & i\sqrt{2} & 0 & -i\sqrt{3} \\ 0 & 0 & i\sqrt{3} & 0 \end{pmatrix}$$

Q3(a)(i) Historical development of concept of e^- spin $\rightarrow$ Bohr-Sommerfeld Model $\rightarrow$ Stern Gerlach experiment (1922)
 Dirac included spin in 1928 in his relativistic quantum mechanics $\leftarrow$ Pauli introduced 3 spin matrices

(ii) All WFs & unsolved HCV spin are IMP $\sim$ HCV pg 267-271

$$S^2 \chi = S(S+1)\hbar^2 \chi, S_z \chi = m\hbar \chi, \text{ where } \chi = |S, m\rangle \sim \text{DIAS(6) pg 6}$$

Now $\Psi_{x+} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ $\Psi_{y+} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ i \end{pmatrix}$ $\Psi_{z+} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ $\Psi_{x-} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -1 \end{pmatrix}$ $\Psi_{y-} = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -i \end{pmatrix}$ $\Psi_{z-} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ derivation in HCV W-E.

spin commutation
 $\vec{S} \times \vec{S} = i\hbar \vec{S}$

Pauli Matrix $\rightarrow \sigma_x = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}, \sigma_y = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}, \sigma_z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

Q3(b) LS $\rightarrow$ RSK: 140-142

SS $\rightarrow$ RSK: 155-157

Li diagram on 157 imp *

and DIAS(S) pg 39

and Vector Model of

Atom $\rightarrow$ RSK pg 76 (pg 79 diagram)

(iii) RSK pg 114

NO LS in ^{80}Hg $\rightarrow$ SS preferred in heavier atoms

Q4(a) BNW pg 31

selection rule is $\Delta J = \pm 1$ for both rigid & non-rigid diatomic rotator

(ii) requirement for pure rotational spectra $\rightarrow$ permanent electric dipole moment (since $\epsilon = p \times E$)
 no emission spectra for rotational due to population of ground level mostly,
 and no excitation mechanism for population inversion.

(iii) Easy

Q4(b) Raman Effect $\rightarrow$ RSK pg 336

Rayleigh $\rightarrow$ same frequency (elastic)
 Raman $\rightarrow$ inelastic scattering.

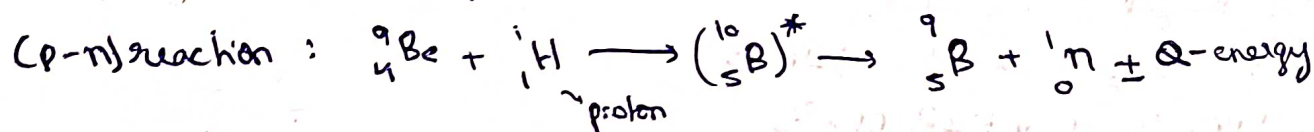
(c) defn + Quantum theory
 (ii) explanation

(i) Application of Raman Effect $\rightarrow$ RSK pg 342

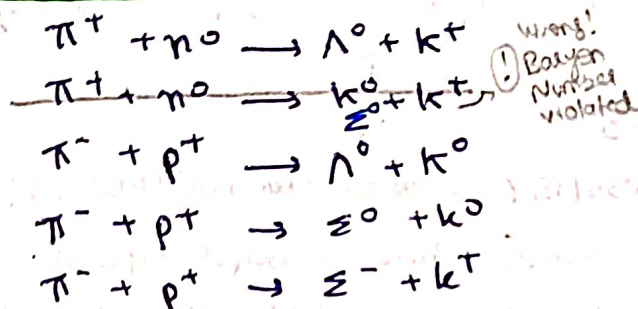
(iii) RSK pg 342 & 343

(iv) Easy.

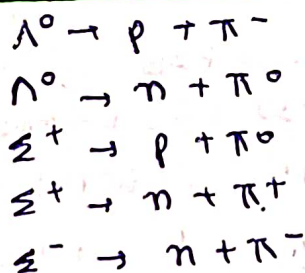
Q5(a) Nuclear Transmutation $\rightarrow$ when particle energy is not too high ($< 50 \text{ MeV}$)
 $\downarrow$
 DCT pg 406 $\rightarrow$ when incident particle overcomes coulomb barrier and forms compound nucleus, which immediately disintegrates



(b) production of strange particles



Decay of strange particles



Easy to remember $\rightarrow$ one side only and other has Λ, K, Σ only $>$
 has n or p & π

(c) Primitive lattice to BCC $\rightarrow$ vertex as origin to 3 Body centers $\rightarrow$ reciprocal lattice is FCC primitive
 $a^* = 2\pi \frac{(b \times c)}{[a \cdot (b \times c)]}$ - pg 51 P8B

(i) Josephson Jn, SQUID & applications of SQUID $\rightarrow$ DIAS(S) - 164 bottom part onwards
 (ii) easy

(d) FET vs BJT $\rightarrow$ P8B pg 420

Q6 (a) liquid drop model $\rightarrow$ Fission Barrier, excitation energy and Activation Energy
 $U_{235} \rightarrow 0.7\%$ (fissile) $\rightarrow$ odd-A nuclei are less stable $\rightarrow$ DIAS(S) - 148 & 149
 $U_{238} \rightarrow 99.3\%$ (fertile) $\rightarrow$ even-A $\rightarrow$ not fissile bcoz B.E released is less than critical energy reqd for fission. For U_{235} B.E is greater than critical energy
 $\rightarrow$ only fissionable by fast neutrons (not thermal neutrons)

(b) BWR $\rightarrow$ Boiling Water Reactor $\rightarrow$ Enriched uranium fuel due to light water $\rightarrow$ Tarapur (only BWR in India, remaining are PHWR)
 PHWR $\rightarrow$ Pressurized heavy water Reactor $\rightarrow$ Natural uranium fuel with D_2O moderator
 FBR $\rightarrow$ Fast Breeder Reactor $\rightarrow$ Fuel is U_{238} which is fertile & converted to fissile Plutonium 239 $\rightarrow$ No FBR in India, currently prototype being built at Kalpakkam

(c) Easy

(d) DIAS(S) - pg 145 & 146

Q7 (b) Pauli's Neutrino Hypothesis $\rightarrow$ P8146 SBP

$\rightarrow$ must have zero charge, $1/2$ spin and almost massless

Q7 (a) Gellmann Nishyima reln $\rightarrow Q = T_3 + \frac{1}{2}(S+B)$

pg 330 SBP

storage particle production, decay

and 's' by Gellmann-Nishyima $\rightarrow$ pg 327 SBP

Quark Quantum Number

using modified $Y = S+B+T+T+B$

$(Q = T_3 + \frac{1}{2}Y) \sim$ last pg of DIAS(S).

(c) (i) BCS theory $\sim$ P&B pg 295

(ii) Given: $n_i = \frac{2(2\pi kT)^{3/2}}{h^3} (m_n^* m_p^*) e^{\frac{-E_g}{2kT}} \sim \sigma = n_i e (\mu_n + \mu_p)$

pg 206 P&B

(iii) pg 222 P&B Example 7.3

Q8 (a) Binary Addition $\rightarrow$ DIAS(S) pg 156/157 $\sim$ also includes half/full subtractor

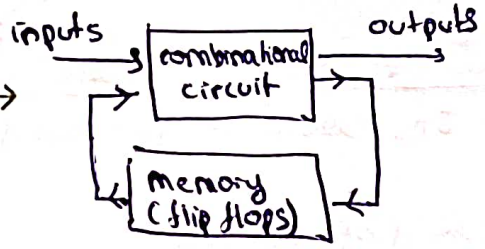
(b) Sequential circuits are logic circuits where the output depends on present value of input signal as well as sequence of past inputs.

combinational circuit $\sim$ Time-independent circuit which don't depend on previous input.

Sequential circuit $\sim$ dependent on clock cycle & prev. input. eg $\rightarrow$ Flip-flop, counters, registers, clocks.

(ii) simple sequential circuit

(iii) clocked RS flip flop & JK flip flop $\rightarrow$ VK Mehta pg 769



(iv) ROM $\rightarrow$ Read-only memory

Easy: (use internet)

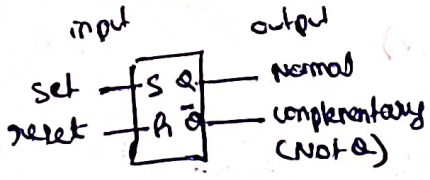
RAM $\rightarrow$ volatile memory that temporarily stores files (eg: 4GB RAM)

ROM $\rightarrow$ non-volatile memory that stores permanently (phone - 128GB...)

RAM $\rightarrow$ faster, more expensive, can be retrieved & altered, large size of chip

ROM $\rightarrow$ slower, cheaper, can only be read, small chip size

RS Flip Flop



used to temporarily

hold or store information until it is needed. single RS flip flop will store one binary digit - either 0 or 1.

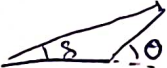
Mode of operation	S	R	Q	Q̄
Prohibited	0	0	1	1
Set	0	1	1	0
Reset	1	0	0	1
disabled	1	1	No change	No change

VK Mehta & internet is showing app. for this...
(?)

Q8(c) solar cell $\rightarrow$ DIAS (6) - pg 22

Q1 (a) Easy: $v = v_0 - gt + v_e \ln\left(\frac{M_0}{M_0 - \dot{m}t}\right)$ Note: v_e is wrt Rocket frame always
→ PIAS(1) - 29

(b) $v_{2/1} = \frac{v_2 - v_1}{1 - \frac{v_1 v_2}{c^2}}$ (Velocity Addition theorem) → PIAS(1) - 122

(c) Easy, simple interference  $\tan \theta = \frac{a_2 \sin \theta}{a_1 + a_2 \cos \theta}$; $A^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos \theta$

(d) DIAS(2) - 118, 119 (Resolving Power of Gratings) $\sim \frac{\lambda}{d} = m\lambda$ using Rayleigh criteria

Q2 (b) $b = \frac{k}{2E_x} \cot \frac{\phi}{2}$ → DIAS(11) - 64/65

here E is kE since we used $J = b\sqrt{2mE}$ but also the same

E which is also used in $E = \sqrt{1 + \frac{2EJ^2}{mk^2}}$ is Total E as shown on DIAS(11) - 57.

Q3 (a) Fermat principle defn → ASG 3.4

(b) Easy

(c) derivation of Lorentz → DIAS(1) - 108

we can choose which to use as per convenience.

In the question → we can use any of the 4 transformations $\begin{matrix} x' = \dots & t' = \dots \\ x = \dots & t = \dots \end{matrix}$

All 4 are linked in $x'^2 - c^2 t'^2 = x^2 - c^2 t^2$ anyways

Easier way is $\Delta t' = \Delta t \sim v = \frac{\sqrt{3}c}{2} \rightarrow$ Then $\Delta x' = -\Delta v \Delta t = -520 \text{ m}$

(or) use $\Delta x'^2 - c^2 \Delta t'^2 = \Delta x^2 - c^2 \Delta t^2$ directly also.

(-ve is allowed)

Q4 (a) Polarization of light demonstrates Transverse Nature

(b) QWP → ASG 22.19

→ DIAS(6) pg 26

(b) Fresnel diffraction by straight edge using Cornu spiral → ASG pg 20.10

(c) Ray diagrams for Michelson-Morley → ASG pg 15.23 (iii) explain shifting of fringe inward/outward.

(i) extended source of light because interference only occurs for light incident on plate at angle θ . perfectly coll beam won't produce fringes (also for more area)

We use monochromatic in Michelson. If we use white light → ASG 15.25

(ii) Refer pg 84 - DIAS(2) → sheet for 3 Amazing Ray diagrams of Michelson explaining All.

(iii) we $2\cos \theta = (m + 1/2)\lambda$ → ASG 15.23

Q5 (a) Easy

(b) Easy

(c) cannot cycle → Also draw schematic, piston, etc. → GBG 6.4

(d) B.E distribution → GBG 12.32 / DIAS(4) - 20, 21

Q6 (a) Easy → KVL (Kirchoff voltage Law) and sum of current at junctions law

Q6(b) Easy $\sim E = \frac{\lambda}{2\pi\epsilon_0 r} \sim V = -\int \vec{E} \cdot d\vec{r}$ and $C = \frac{Q}{V} \rightarrow C = \frac{2\pi\epsilon_0 L}{\ln(\frac{r_2}{r_1})}$ (2)

(c) ϕ -value of series LCR $\rightarrow$ DIAS(4) - SG - S8.

$Q =$ $\frac{1}{\omega R}$ - went $\frac{1}{\omega R}$ in parallel
 $\rightarrow$ SPBM(2) pg 454
 Volts $\frac{1}{\omega R}$ in series
 AC

~~Max. value of ϕ is $\frac{1}{\omega R}$ when $\omega = \frac{1}{RC}$~~

★ Q8(a) GBG $\sim$ 15.1 to 15.5
 $\rightarrow$ complete soln RGTSI $\rightarrow$ pg 109-111 BEST to do
 (BE condensate)

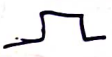
2002 - Paper 2 < v. Fast ~ 1st Iteration >

①

Q1(b)(i) ~~Q1(b)(i)~~ $S = 1/2 \rightarrow |\vec{S}| = \sqrt{S(S+1)}\hbar$
 3 particles: e^-, n, p
 lowest non-zero ang. mom.

Q4(d)(i) Barely asking for term symbol for diatomic molecule.

Q1(d)(i) (?) either give MOT or something from RSK pg 393 or BNW pg 182

Q2(a) → potential Barrier  → may both possibilities of $E < V_0$ & $E > V_0$

refer pg 233 of Princeton PPT internet lecture 7: electronic spectra.

Q2(c) → HCN pg 113 & pg 341

Q3(a) Formula: $\Delta T = \frac{5.842 \times 10^{-6}}{n^3 l(l+1)}$ for spin orbit diff. b/w $j = l + 1/2$ & $j = l - 1/2$, RSK pg 93
 (Derivation RSK from pg 90-93)

Q3(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 4f^{14} 5d^{10} 6s^2$
 normal state → $1S_0$
 1st excited state → $6s^1 6p^1 \rightarrow 1P_1, 3P_{0,1,2}$ (RSK pg 146)

Q3(c) $v_d = a \times \tau = \frac{eF}{m} \times \tau \sim \gamma = ne v_d = \sigma E \rightarrow \sigma = ne^2 \tau / m$

Q5(a)(i) neutron has magnetic moment → explained by Gell-Mann model → Quarks have individual charges (plus - Schmidt Model)
 -ve due to π^- meson cloud also an explanation

$\mu_{quark} = \frac{e \hbar}{2m_{quark}}$ - p - $4/3 \mu_B - 1/3 \mu_d \sim 2.793 \mu_N$
 Bohr magneton term. just like μ_B - μ_N method to measure μ → Stern Gerlach, Zeeman effect, NMR (SBP pg 129)
 $n \sim 4/3 \mu_d - 1/3 \mu_u \sim -1.91 \mu_N$ } from wikipedia Nucleonic magnetic moment

Q5(b)(i) SBP pg 162 → reiner Brown expt

(ii) $\vec{n} = \frac{\vec{S}}{|\vec{S}|}$ where $f = \frac{\vec{S} \cdot \vec{a}}{|\vec{S}| |\vec{a}|}$ and $d = \vec{n} \cdot \left(\frac{\vec{a}}{|\vec{a}|} \right)$
 $\frac{x}{a^2 \hbar} \times \gamma \mu_B \times 3/4 \times 1$ (pg 19 PDB)

Q5(c)(i) PDB 206, 213, 219, 216 (equations)

Analytical one → ↑ in Temp causes n to ↑ as thermal vibration causes bonds to break

negative logic → $\frac{\text{high voltage} = 0}{\text{low voltage} = 1}$

★ To convert from the logic 10 -ve logic or vice versa just invert all 0 & 1 in the truth table

Q6(a) observation law in Nuclear reaction → DCT pg 402

Q7(b) - Antiparticle - opp charge & opposite of any mom wrt spin
 discovery → pg 318 SBP - Andre & Serge, Chamberlain (e⁺) (p⁺)

7(c) → DAS(5) - pg 119 - only TSCPT covered in All.

AND in +ve			→ -ve (invert)		
			AND		
0	0	0	1	1	1
0	1	0	1	0	1
1	0	0	0	1	1
1	1	1	0	0	0

equivalent to OR in the logic

Q4(a) Gabor on-line holographic, Limitation of Gabor exp't, how overcome by Leith & Upat? ~ Internet Research

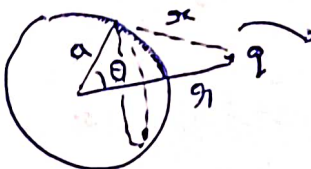
Q4(c) Self-focusing of laser beam $\rightarrow$ ASG 18-32 (check BJS?)

Q8(c) Fermi Energy is a concept in Quantum Mechanics that usually refer to energy difference b/w the highest & lowest occupied single-particle states in a quantum system of non-interacting fermions at Absolute zero Temp.

Q8(b) $\eta_{\text{otto}} = 1 - \frac{1}{(\rho_1 + 1)}$ $\rho = \frac{v_1}{v_2} = \left(\frac{T_2}{T_1}\right)^{1/\gamma-1}$

Then $\eta_{\text{otto}} = 1 - \frac{T_1}{T_2}$ and $\eta_{\text{carnot}} = 1 - \frac{T_1}{T_3}$ $\sim$ since $T_3 > T_2 \rightarrow \eta_{\text{carnot}} > \eta_{\text{otto}}$



Q7(a) 
$$V_{\text{avg}} = \frac{\int_0^\pi \frac{kq}{x^2} \cdot 2\pi a \sin\theta d\theta}{4\pi a^2}$$
 where $x = \sqrt{a^2 + r^2 - 2ar\cos\theta}$
$$V_{\text{avg over sphere}} = \frac{kq}{r^2}$$

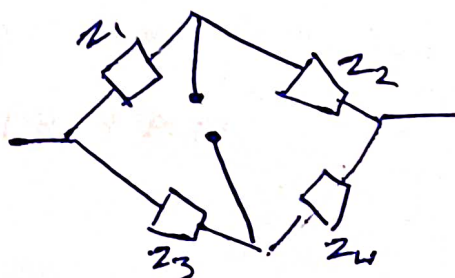
Laplace eqn ~~is used~~ $\rightarrow$ used in uniqueness theorem as well

$\rightarrow$ Property of Laplace eqn in 3 dimensions: if we consider the value of soln of Laplace eqn at a point ζ , then the avg value of soln over any sphere centered at ζ is equal to value of soln at ζ .

i.e. if we integrate V over surface of sphere of R centered at ζ , we must have:

$$\frac{1}{4\pi R^2} \oint_R V da = V(r) \quad \sim \text{This is hard to prove, requires heavy duty maths, } \circledast$$

Q5(b)



$\sim$ For Balanced: $E_1 = E_3 \rightarrow I_1 Z_1 = I_3 Z_3$
also $I_1 = I_2 = \frac{V}{Z_1 + Z_2}$

$$\text{and } I_3 = I_4 = \frac{V}{Z_3 + Z_4}$$

(Just like wheatstone bridge)

condition for Balanced AC bridge: $Z_1 Z_4 = Z_2 Z_3$ (magnitudes balanced)
 $\theta_1 + \theta_4 = \theta_2 + \theta_3$ (phase angle balance)

Both eqn are combined into:

$$\underline{\underline{Z_1 Z_4 = Z_2 Z_3}} \rightarrow \underline{\underline{Z_1 e^{i\theta_1} Z_4 e^{i\theta_4} = Z_2 e^{i\theta_2} Z_3 e^{i\theta_3}}}$$

2003 - Paper 2 (V. Fort 1st iteration)

(3)

Q1(a)(iii) $\sim E$ is total Energy
 so $KE = E - V \quad \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$

Q1(b)(ii) "show" means put values and demonstrate

Q1(c)(ii) $2B(5+1)$ $\begin{matrix} 8B & 10B & 12B & 14B \\ | & | & | & | \\ \leftarrow & \leftarrow & \leftarrow & \leftarrow \\ 2B & 2B & 2B & \end{matrix}$ equidistant spacing

Q3(a) $E_F = \frac{\hbar^2}{2m} \left(\frac{3\pi^2 N}{V} \right)^{2/3}$ for non-interacting fermions

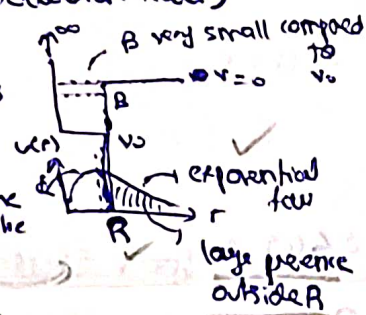
Q7(a) 2 characteristic properties:

(i) They are produced in pairs (strong interaction)

(ii) They are decay by weak but produced in strong reaction

Their decay lifetime is very long (decay rate is 10^{-13} of the production rate)

Q6(a) loosely bound $\rightarrow$ BE is much lower than avg B.E/A = 8 MeV (2.25 MeV)
 $\rightarrow$ Nucleons spend more time separated by distance larger than range of force ($2a \approx 2R$)



Particle has no excited state because any excitation will easily make the system break apart.

first soln $x = -y \sim$ first soln at $\pi/2$, $a = \pi/2$, 2nd soln is $k_1 a = 3\pi/2$ (for $l=0$)

Now $k_1 = \frac{\sqrt{2m(E-V)}}{\hbar} = \frac{\sqrt{2m(KE)}}{\hbar}$ This for 2nd soln $\rightarrow KE = 9(KE)_0$ ($E = V_0 = 9V_0$)
 $KE = 9 \times 32 - 8 \text{ MeV} = 295.2 \text{ MeV}$
 This makes total Energy positive & system is no longer bound

If we take $l=1$, Then potential is increased by $\frac{5}{2} = \frac{2(1+1)\hbar^2}{2\mu R_0^2} \approx 18.75 \text{ MeV}$ (for $l=1$)

The potential becomes shallower & narrower. Thus in this case also the state is no longer bound.

Q5(a)(i) YBCO $\rightarrow$ Yttrium Barium copper oxide $\rightarrow T_c = 93 \text{ K}$

BSCCO $\rightarrow$ Bismuth Strontium calcium copper oxide $\rightarrow T_c = 110 \text{ K}$

High T_c superconductor $\rightarrow T_c$ above 77 kelvin

$\rightarrow$ don't follow BCS theory

small isotope effect, small coherence length

3d-4d f-d
 Based copper oxides

we use liquid N₂ for high T_c superconductor but need to use liquid He (very expensive) for conventional superconductors.

Band $\rightarrow \Delta V = \pm 1, \Delta V = \pm 2 \dots$

projections $\rightarrow v'' = 0 \rightarrow v' = 0, 1, 2, 3 \dots$

Branch $= 0.5 = -2, -1, 0, 1, 2$ (g: P, O, R)

V-R spectra $\rightarrow \Delta S = \pm 1, \Delta V = \pm 1, \pm 2, \pm 3$ (Both Branch & Band)

Gross structure Electronic $\rightarrow \Delta V$ unrestricted $\rightarrow$ Both Band & projection

Q4(a) $\rightarrow$ Branches in electronic spectra of Diatomic $\rightarrow$ pg 172 BNW

Q4(b) $\rightarrow$ Formula in SBP pg 204 only Branch: Rot. Band & Branch: VR

$\Delta F(5) = 0$

2004 - Paper 1 (U. Fast 1st iteration)

(4)

Q1(b) DIAS (2) pg 10

Q2(a) MoI $\rightarrow$ Amount of Force or Torque used to change rotation rate.

moment $PoI \rightarrow$ Feature of an object which describes an imbalance relative to defined set of coordinate axes.
Product of Inertia ($I_{xy}, I_{yz}, \dots$)

Q2(b) easy - DIAS (11 - 48)

Q3(b) $\rightarrow$ Use Matrix Method. $\rightarrow$ pg 5.10 ASG Example 5.4

Q4(c) $\rightarrow$ easy - DIAS (2) - pg 99

Q4(b) $\rightarrow$ use $2\mu B\theta = \lambda \rightarrow$ where assume $\cos\theta \rightarrow 1$

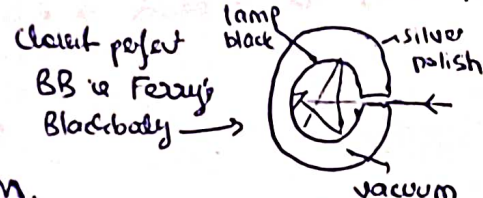
(DIAS (2) pg 75)

Q5(a) $\rightarrow$ use ∇^2 in cylindrical coordinates $\sim (r, \theta, z) \Rightarrow \nabla^2 = \frac{1}{r} \frac{\partial}{\partial r} (r \frac{\partial \psi}{\partial r}) + \frac{1}{r^2} \frac{\partial^2 \psi}{\partial \theta^2} + \frac{\partial^2 \psi}{\partial z^2}$
($x = r \cos\theta, y = r \sin\theta$)

Q8(b) $\rightarrow$ condition for FD $\sim$ MB : $E - \mu \gg kT$ (Then we can neglect ± 1 in the denominator)

Basically $FD \& BE \rightarrow MB$ at high Temp & low particle densities. [FD/BE $\rightarrow$ Quantum (low Temp)
MB $\rightarrow$ classical (high Temp)
(at high Temp $\sim E$ will be very high)]

Q7(b) Perfect BB can't be realized. Lampblack Lamp Block $\sim$ absorbs 96-97%.



Proof of Kirchhoff's Law $\rightarrow$ GBC 11.7

Q7(c) Poynting Theorem $\rightarrow$ 302 SPAM & Poynting Vector $\rightarrow$ 305 SPAM.

Q6(c) Magnetic Shield DIAS (6) - pg 24

2004 - Paper 2 (U. Fast 1st iteration)

Q1(b)(ii) Ground state wave fn of H atom $\sim \psi(r) = \frac{1}{\sqrt{\pi} a_0^{3/2}} e^{-r/a_0} \sim P(r) = 4\pi r^2 \frac{d\psi}{dr}$

Q1(c) $\rightarrow$ Chegg (or) refer below.

Q1(a)(i) $\rightarrow$ Thermal motion $\sim kE = kT$ (d.o.f = 2)

(Note in Stern Gerlach expt $\sim$ we used Neutral neutral silver atoms $\sim$ they had d.o.f = 4)

Q2(a) Generalized uncertainty Principle

$\rightarrow$ Griffiths QM pg 112-117

Q2(c) $\rightarrow$ similar question pg 36 Griffiths QM Example 2.2

Q4(a) High resolution spectroscopy through LASERS which were prev. not possible. Eg $\rightarrow$ 7 lines

of H_α , 4/6 lines of D_1, D_2 of Sodium, 2 emission, branches of VR and Raman spectroscopy.

This has allowed in depth knowledge of internal structure of universe and as well as at fundamental level.

Q1(c) According to AG soln: $\bar{\omega}_c = \frac{1}{514.5 \text{ nm}} = 19436.3 \text{ cm}^{-1}$

Raman shift like $= \bar{\omega}_c - \omega_r$

$\rightarrow$ Thus

- (i) $19436.34 - 1595 = 17841 \text{ cm}^{-1} \Rightarrow \lambda_1 = 560.5 \text{ nm}$
- (ii) $15784 \text{ cm}^{-1} \Rightarrow \lambda_2 = 637.5 \text{ nm}$
- (iii) $15686 \text{ cm}^{-1} \Rightarrow \lambda_3 = 637.7 \text{ nm}$

Q5(b)(iii) DIAS (5) pg 175, 176

Q5(d)(iii) B.E = $(m_{\text{HeI}} - 2m_p - 2m_n) c^2$

Q7(b) Helicity of Neutrinos determined by Goldhaber experiment. DCT pg 237 (tough) use internet/wikipedia.

Q7(c) Proof of Block Theorem (?). refer Block fn in DIAS (5) pg 176

2005 - Paper 1 CV. Part 1st iteration

(5)

Q1 (a) Don't overcomplicate $\rightarrow$ Force derived from potential means conservative internal force $\rightarrow$ Force not from potential include friction, etc

Now if $V = V(r) \rightarrow E = -\nabla V = f(r) \rightarrow$ Then $\tau = r \times F = 0 \rightarrow S = \text{const.}$

(d) $n_1 = 1.48$
 $n_2 = 1.5 \rightarrow N.A. = \sqrt{n_1^2 - n_2^2} = 0.244$ significant $\rightarrow$ how resistant fibre is to bend - induced loss
 $\rightarrow$ how strongly fiber guides light.

Q2(b) JCU $\sim$ pg 30, 31 $\rightarrow$ holonomic constraint $\rightarrow$ can be expressed as $f(r_1, r_2, t) = 0$
 $N.A. = n_0 \times \sin i_m \rightarrow$ core angle.

non-holonomic $\rightarrow$ can't be expressed as above. eg: $|r| \geq a$
 Q3(a) $\dot{y} = 2a \omega \sin \alpha \sin \omega t$
 $E = \frac{1}{2} m \dot{y}^2$

Q5 (a) SPEM pg 127

(b) It is the simple normal soln (don't overcomplicate) Law of corresponding states is actually for d, B, Y in van der Waals but here

(c) Plot of CV vs $T/T_0 \rightarrow$ pg 140 P2B

reduced Temp.

it means that while CV vs T may be diff. for different metals, the CV vs T/T_0 is strikingly similar for almost all metals. This is because both Debye & Einstein have from $C_V = f(T/T_0)$. Thus for solid with diff Temp T_1, T_2 , C_V is same if $\frac{T_1}{\Theta_1} = \frac{T_2}{\Theta_2}$

Q7 (a) Microscopic set of Maxwell eqn uses total charge & total current which includes difficult to calculate atomic level charge & current (since total = bound + free).

macroscopic set introduces 2 new auxiliary fields that can sidestep knowledge of these atomic sized charge & current

Microscopic eqn (total charge & current)

$$\nabla \cdot E = \rho_{\text{total}}$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times B = \mu_0 \left(\frac{\partial E}{\partial t} + J_{\text{total}} \right)$$

(Macroscopic) (in terms of free charge & current)

$$\nabla \cdot D = \rho_{\text{free}} \rightarrow \oint D \cdot d\vec{s} = Q_{\text{free}}$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J_{\text{free}} + \frac{\partial D}{\partial t} \rightarrow \oint H \cdot d\vec{s} = I_{\text{free}} + \frac{\partial}{\partial t} \left(\oint D \cdot d\vec{s} \right)$$

similar *

We introduced $D = \epsilon_0 E + P = \epsilon E$

$$H = B/\mu_0 - M = B/\mu$$

pg 220 SPEM

$$\text{when } \rho_b = -\nabla \cdot P \text{ and } J_b = \nabla \times M + \frac{\partial P}{\partial t}$$

$\frac{1}{3}$ bound

magnetization current

polarization current

for inhomogeneous medium

$$P = \epsilon_0 \int \chi_e(r,t) E(r,t) d^3r$$

$$M(r,t) = \frac{1}{\mu_0} \int \chi_m(r,t) B(r,t) d^3r$$

Q8 $\rightarrow$ Best Notes for B-E is for 2002 paper 1 Q8(a) soln in RGTS1 - pg 109 - 111

(also soln for 2005 paper 1 Q8(a) & (b))

Q8 (c) $\mu \rightarrow$ rate of change of free energy of thermodynamic system wrt change in number of atom/molecule added to system

$$\mu = \frac{\Delta G}{\Delta n} \rightarrow \text{extensive} = \text{intensive}$$

$$\mu = G_m = \frac{G}{n} \rightarrow \text{now } d\mu = dG_m = -S_m dT + v_m dp$$

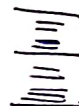
$$\text{molar Gibbs energy} \quad \text{Thus } \mu = \mu(T, P) \rightarrow \left(\frac{\partial \mu}{\partial T} \right)_P = -S_m \text{ and } \left(\frac{\partial \mu}{\partial P} \right)_T = v_m$$

2005 - Paper 2 (v. Fort 1st Iteration)

6

Q1(c)(i) ~ Fluorescence & Phosphorescence ~ pg 388 RSK

(ii) $S=0$ starts at beginning of v-level for each gap



Q2(b) OM Griffiths. Discuss WKB ~

pg 323 is sufficient explanation

(just my formula, no need for derivation)

WKB for infinite well ~ pg 324

WKB for Tunneling ~ 326, 327 } OM Griffiths

Q3(a) Refer Griffiths & DIAS (1) for Radial equation & Energy eigen values.

Q1(d)(ii) Pure rotation spectrum of H_2 ~ Rot. Raman Spectra

since H_2 has no permanent dipole.

$$B = \frac{h}{8\pi^2 \mu r^2 c} = 60.90 \text{ cm}^{-1} \quad \text{spacing in Raman Spectra} = 4B = 243.6 \text{ cm}^{-1}$$

Q4(a) Application of Raman in Molecular spectroscopy ~ RSK pg 342

LASER Raman ~ RG (6) pg 92, 93

Q5(d)(i) significance of -ve effective mass of e^- ~ P8B pg 191

Q5(a)(ii) 1 curie = 1 Ci = 3.7×10^{10} disintegration/sec

1 Rutherford = 1 rd = 10^6 disintegration/sec

1 Bq = Becquerel
= 1 disintegration/sec.

use $\frac{dN}{dt} = \lambda N$ and $E_{1/2} = \frac{0.693}{\lambda}$ (SBP pg 65)

Q6(a) wu expt ~ SBP 166, 167

(experimental detection set-up & observation)

Q7(a)(iii) Anderson: position discovery - SBP pg 318

Q5(d)(ii) In solids, molecules are closely arranged together, due to this, the atoms and molecules tend to move into the orbitals of neighbouring atoms.

Hence, the electron orbitals overlap when atoms come together. Thus several bands of energy levels are formed as atomic wave functions overlap & intermix leading to merging of energy levels forming a continuum of states called band.

Q6(c) shell levels ~ DCT pg 368

Q5(b)(i) Easy ~ Hall Effect DIAS(6) pg 28

(Note lengthwise Resistance not same as R_H - I don't think we need lengthwise Resistance here)

2006 - Paper 1 (V. Fast 1st iteration)

(7)

Q1(c) ~~at~~ convergent spiral & Fresnel Integral ~ DIAS (6) pg 26

Q1(b) let $x' = \gamma_1 (x - v_1 t)$, $t' = \gamma_1 (t - \frac{v_1 x}{c^2})$

$$x'' = \gamma_2 (x' - v_2 t'), \quad t'' = \gamma_2 (t' - \frac{v_2 x'}{c^2})$$

we want x & x'' rel. put x', t' in x'', t'' .

$$\text{we get } x'' = \gamma_1 \gamma_2 \left[x \left(1 + \frac{v_1 v_2}{c^2}\right) - (v_1 + v_2) t \right]$$

$$t'' = \gamma_1 \gamma_2 \left[t \left(1 + \frac{v_1 v_2}{c^2}\right) - \frac{(v_1 + v_2) x}{c^2} \right]$$

now comparing with $x'' = \frac{1}{\gamma_1 \gamma_2} \left[x - v^* t \right]$

and $t'' = \frac{1}{\gamma_1 \gamma_2} \left[t - \frac{v^* x}{c^2} \right]$

we can compare and see that $v^* = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}$ even $\gamma_1 \gamma_2$ will come out as:

$$\gamma_1 \gamma_2 = \gamma^* = \frac{1}{\sqrt{1 - \frac{(v^*)^2}{c^2}}}$$

Q1(d) chiral molecule has non-super-imposable mirror image. optical activity is rotation of plane of polarization (POP) of PPL, as it travels through soln of chiral molecules. Rotation is proportional to conc. of molecules in soln. $\theta = \theta_c \times l \times c$.

Also chirality of molecule determines dirn: i.e. dextro or leavo.

The property of optical activity arises from interaction of EM radiation of polarized light with unsymmetrical electric fields generated by e^- in chiral molecule.

Q6(c) non-stationary case $\rightarrow$ time varying field. Generalised Ampere Law ~ Maxwell correction.

Generalized $\oint \vec{H} \cdot d\vec{l} = I + \dot{I}_D \sim \vec{I}_D = \int \vec{J}_D \cdot d\vec{S} = \epsilon_0 \int \frac{\partial \vec{E}}{\partial t} \cdot d\vec{S} = \epsilon_0 \frac{d\Phi_E}{dt}$ where $\Phi_E = \int \vec{E} \cdot d\vec{S}$

Q5(b) Derivation of Biot-Savart Law:

we $dB \propto I dl$
 $dB \propto \sin \theta$
 $dB \propto \frac{1}{r^2}$

SPFM pg 177:
 (or) Ampere law of force
 b/w current elements.
 (pg 175)

$$dF_{12} = \frac{\mu_0}{4\pi} \frac{(I_1 dl_1) \times (I_2 dl_2 \times \vec{r}_{12})}{r_{12}^3}$$

From Lorentz Force: $dF_{12} = I_2 d\vec{l}_2 \times d\vec{B}_1$

$$\text{Thus } d\vec{B}_1 = \frac{\mu_0}{4\pi} \frac{(I_1 d\vec{l}_1) \times \vec{r}_{12}}{r_{12}^3}$$

Q6(b) Separation of variables and solution in cylindrical coordinates $\rightarrow$ DIAS (3) pg 12

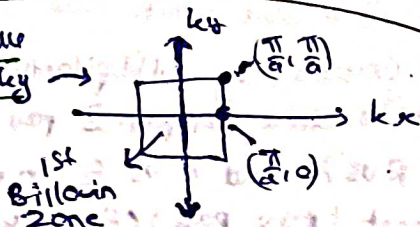
~~Popo-2-2006~~

Q7(c) Brillouin zone of rectangular lattice ~ P&SB pg 55

Brillouin lattice relation to energy of e^- in metal ~ P&SB pg 186

$$E = \frac{\hbar^2 k^2}{2m} = \frac{\hbar^2 (k_x^2 + k_y^2)}{2m} \sim \text{put value of } k_x \text{ & } k_y$$

in relation $\sim a = 2\pi (\text{given})$



energy of Brillouin zone

$k = \frac{2\pi}{a}$ is discontinuity in E vs k graph
 Boundary of reduced zone scheme.

due to Bragg reflection

Q1 (b) (i) $(\vec{a} \cdot \vec{\sigma})(\vec{b} \cdot \vec{\sigma}) = (\vec{a} \cdot \vec{b})I + i(\vec{a} \times \vec{b}) \cdot \vec{\sigma}$ where $\vec{a}, \vec{b}$ commute with $\vec{\sigma}$

proof in wikipedia is shown by me below.

now $\vec{\sigma}, \vec{p}$ will commute with $\vec{\sigma}$

$$\vec{L} = \vec{r} \times \vec{p}$$

$$(\vec{\sigma} \cdot \vec{r})(\vec{\sigma} \cdot \vec{p}) = (\sigma_x x + \sigma_y y + \sigma_z z)(\sigma_x p_x + \sigma_y p_y + \sigma_z p_z)$$

Now $\sigma_x^2 = \sigma_y^2 = \sigma_z^2 = 1 \rightarrow$ thus we get $\vec{L} \cdot \vec{p}$ term.

Now $\sigma_x x \sigma_y p_y + \sigma_y y \sigma_x p_x \rightarrow$ we can interchange x_i or p_i with σ_i but we can't exchange x_i or p_i with σ_j since these both don't commute

$$\text{Also } \sigma_x \sigma_y + \sigma_y \sigma_x = 0$$

$$\sigma_x \sigma_y - \sigma_y \sigma_x = 2i\sigma_z$$

$$\text{Thus } \sigma_x \sigma_y = i\sigma_z$$

$$\sigma_y \sigma_x = -i\sigma_z$$

$$\begin{aligned} \text{Thus } \sigma_x \sigma_y x p_y + \sigma_y \sigma_x y p_x \\ = i\sigma_z x p_y - i\sigma_z y p_x \\ = i\sigma_z L_z \end{aligned}$$

Q1(d) spin-orbit coupling Energy $= \alpha(\vec{L} \cdot \vec{S})$

$$\Delta T = \frac{5.8424}{n^3(2l+1)} \text{ cm}^{-1}$$

convert to energy unit (x hc)

$$\text{also } \begin{cases} +\frac{1}{2} \mu_B B \\ -\frac{1}{2} \mu_B B \end{cases} \sim \Delta E = \mu_B B$$

$$2p \rightarrow n=2, l=1$$

Q4(a) spinning $e^- \rightarrow g_s = 2$, free proton: $g_p = 5.56$ (2x2.793)

orbiting $e^- \rightarrow g_l = 1$

(b) principle of NMR + SBP pg 291

(c) BNU pg 203 $\rightarrow$ Magnitude of Applied Field: 2.34 T (2.5 Tesla) (or) 0.1 T

$\rightarrow$ Rough range of frequency: 1-100 MHz.

$$\Delta E = h\nu_L = \mu_B B g_s = 2\mu_B B \quad (\text{Here there are two transitions } m_j = 1/2 \rightarrow m_j = -1/2)$$

$$\text{For proton: } \nu_L = \frac{\mu_B B g_p}{h} = \frac{(5.05 \times 10^{-27}) \times 2.5 \times 5.56}{h} = 100 \text{ MHz} \rightarrow \text{other large nuclei have smaller 'g' and hence spectroscopy will be more difficult. 1 MHz also,}$$

Reason why deuteron is stable:

Q5 (a) SBP 277 $\rightarrow$ depth of well = 25 MeV much greater than Coulomb repulsion (0.6 MeV).

Also refer pg 203 Q 6(a)

$$\text{corresponding to } R = 2.4 \text{ Fermi} \quad (\text{Use } E = \frac{ke^2}{R})$$

(Physical calculations)
(Note data given in paper for deuteron in 2006)

Hypothetical: Decay of Deuteron: $n \rightarrow p + e^- + \bar{\nu}_e$

Then $D \rightarrow 2p + e^- + \bar{\nu}_e$

Now $M(\text{reaction}) = 1875.6 \text{ MeV}$

Mass reaction: $2(938.27)$

$+ 0.511 \text{ MeV}$

$= 1877.05 \text{ MeV}$

$$Q5(c) f = B(C+D)$$

1/2 - map refer DIAS (6) - 31

Q5(d) (i) Field of quark of E (coloured) & electro-strong interactions. (?) - not available anywhere.

Q7(b) DIAS (5) pg 119 and DCT pg 763, 765

Q5(d) (ii) $DL \sim 2 \text{ FCC}$ filling $1/2$ (alternate fcc) $\rightarrow$ interpenetration of (0,0,0) and $(1/2, 1/2, 1/2)$

SCP $\rightarrow$ Pseudo BCC $\rightarrow$ it is 2 interpenetrating primitive cubic (one of cc cubic & other of cc cubic which look like BCC $\rightarrow$ (0,0,0) and $(1/2, 1/2, 1/2)$)

Q6 (c) DIAS (5) pg 139 $\rightarrow$ Gamma Ray Multipolarity classification.

Q6 (a) DIAS (5) pg 141 $\rightarrow$ photo-electric, Compton & pair production.

Q6 (b) Geiger-Nuttall law $\rightarrow R$ vs λ and λ vs E in α -decay $\rightarrow$ pg 134 SBP

Q7 (c) refer pg 7 of PTO sheet (prev. page) flip back

2007 - Paper 1 CV. Fast 1st Iteration)

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Q4(a) Fabry-Pérot fringes are sharper because they involve interference of many reflected beams of light. Max sharper when $R \approx 1 \rightarrow F \uparrow$.

Q4(c) $R \cdot P = \frac{\lambda}{\Delta \lambda} \approx nN$

→ Reflectivity of the individual surfaces.

Dispersive power of grating: $\frac{d\theta}{d\lambda} = \frac{n}{\sqrt{(e+d)^2 - n^2 \lambda^2}}$

Q5(c) ~~use~~ $V = V_0 e^{i\omega t} \rightarrow$ everything becomes easy.

Q8(b) $E_{f0} = \frac{\hbar^2}{2m} (3\pi^2 n)^{2/3} \sim$ we can put directly we got same result....

$E_{f0} = p_f^2 / 2m$

or do ~~the messy integral~~ $N = 2 \int_0^{p_f} f(p) g(p) dp = 2 \int_0^{p_f} 4\pi p^2 dp \cdot V$

Now $E = 2 \int_0^{p_f} E g(p) dp = 2 \int_0^{p_f} \frac{p^2}{2m} g(p) dp \rightarrow$ now it is easy.. (complete soln on DIAS (4) pg 56)

Q7(a) Rayleigh scattering $\propto 1/\lambda^4$ (proof ASG 7-16)

$\vec{p} = \frac{e^2}{m(\omega^2 - \omega_0^2)} \vec{E}$

now for oscillating dipole $p = p_0 e^{-i\omega t}$

energy rate radiated $\frac{P}{P} = \frac{\omega^4 p_0^2}{12\pi\epsilon_0 c^3}$

put value of p_0 . Then use $I = \frac{1}{2} \epsilon_0 E_0^2$ & replace E_0^2 with I .

Then $dI = -N \bar{P} dx \sim \frac{dI}{I} = -\gamma dx \sim I = I_0 e^{-\gamma x}$. since $\omega \ll \omega_0$ we get $\gamma \propto 1/\lambda^4$

Q5(a) Law of increase of Entropy: GBG 7.16

($\Delta S_{\text{total}} \geq 0$)

Now $\Delta S_{\text{total}} = -\frac{\Delta G}{T} > 0 \rightarrow$ Thus $\Delta G < 0$ and the system will evolve to one where the Gibbs free energy is minimal, since this is where total entropy is greatest. Basically G will keep falling till equilibrium is established & then G will be minimum

proof that at const P & T , $\Delta G = -T \Delta S_{\text{total}}$

$\Delta S_{\text{total}} = \Delta S_{\text{sur}} + \Delta S_{\text{system}}$: Now $\Delta S_{\text{system at const } P} = \Delta H$ This is of system

$= -\frac{\Delta H}{T} + \Delta S$

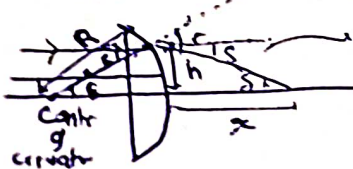
Then $\Delta S_{\text{sur}} = -\Delta S_{\text{sys}} = -\Delta H/T$

$\Delta S_{\text{sur}} = -\Delta H/T$

$\Delta S_{\text{total}} = (-\Delta H/T + \Delta S)_{\text{system}} = -\frac{\Delta G}{T}$ ΔG is of system

source: SSG Lehman college Q55
hyper. com.
plane-conver lens
(n=1.6)

Q1(b) Not sure of soln $\rightarrow$ use question of 2 rays ~ one at 0.5 cm & other at 12 cm for aberration
in all soln we consider a random marginal ray, we already have paraxial at 0.1 cm



$\sin \theta = \frac{h}{R}$

now $\frac{\sin \theta}{\sin \theta} = \frac{n_1}{n_2}$

we get r

now $\delta = r - i$
we get x using $\tan \delta$.

Find x_1 & x_2 for both marginal & paraxial ray

$\Delta x \rightarrow$ longitudinal aberration.

2007 - Paper 2 (V. Part 1st Iteration)

(6)

Q1(a)(i) use relativistic Energy formula: $E^2 = p^2 c^2 + m_0^2 c^4$ ~ use $\Delta r \Delta p, \geq \hbar/2$

Also for e^- ~ $\Delta \tau_f = r$, for oscillator ~ $\Delta x = 2x$

Q5(a)(i) The observed values agree mostly for light nuclei (~~especially even-odd~~ on odd-even) (deviation occurs at heavy nuclei)
exception - certain nuclei like ^{23}Na predicted spin '0' $\leq 1/2$, but observed is $3/2$.

Q5(b)(i) PSB pg 7 - $2T \cos \theta + T = mT \rightarrow \cos \theta = \frac{m-1}{2}$ ~ $m = 3, 2, 1, 0, -1$ &
~ demonstration that 5-fold symmetry cannot fill all space.
 $\theta = \frac{2\pi}{n}$

Quasi-crystal $\rightarrow$ it is ordered, but not periodic. Quasi-crystal can continuously fill all available space, but lacks translational symmetry.

Quasi-crystal are semi-crystalline & show 5-fold rotational symmetry.

Q6(a) SBP pg 190-195.

Q7(a) strangeness of strange particles:

(i) produced in pairs

(ii) decay lifetime is very high (rate of production 10^{13} times rate of decay)

(iii) produced by strong interaction but decay by weak.

Q6(b) Mirror Nuclei: $Z_1 = N_2$ and $Z_2 = N_1$. (Mass no. $A = N_1 + Z_1 = N_2 + Z_2$)

e.g. ^{14}C and ^{14}O ~ Mirror Nuclei have equal spin & same Parity.

Charge independence of Nuclear Force is manifested in properties of mirror nuclei ($F_{np} \approx F_{pn} \approx F_{nn}$)

Due to charge independence of Nuclear Forces, $\rightarrow$ the Masses, B.E. & excitation spectra, when corrected for coulomb terms are very similar in light mirror nuclei

Q8(c) solar cell working - PIAS(6) pg 32

(Not in heavy mirror nuclei ~~also~~)

2008 - Paper 1 (V. Fort 1st Iteration)

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Q1(f) ~ ASG Best for HeNe & Ruby laser ~ 27.12 - 27.14 ASG

Q2(b) ~ I (rotational analogue of Mass) ~ $K.E = \frac{1}{2}mv^2 = \frac{1}{2}(mr^2)\omega^2$

$$I = \int r^2 dm$$

$$\text{or use } J = r \times p = r \times (m\omega \times r) = (mr^2)\omega$$

Q2(c) Critical Velocity ~ speed at which fluid transitions from streamline to turbulent.

$$Re = \frac{\rho v D}{\mu} \sim \text{Diameter of pipe}$$

$$v_{\text{critical}} = \frac{\mu \times Re}{\rho \times D}$$

$0 < Re < 2000 \rightarrow$ laminar / streamline

$2000 < Re < 3000 \rightarrow$ turbulent

$Re > 3000 \rightarrow$ highly unstable

kinematic viscosity = $\frac{\eta}{\rho}$ $\mu \rightarrow$ dynamic viscosity (same as η)

$$Re = \frac{\text{Inertial Force}}{\text{Viscous Force}}$$

Q3(c) Intensity of Beam = $\frac{1}{2} c \epsilon_0 E_0^2$

Q4(b) Normal & Anomalous Dispersion ~ SPEN pg 413 & 414 $\sim$ Intensity = $\langle u_B \rangle + \langle u_E \rangle = 2 \langle u_E \rangle = 2 \times \frac{1}{2} c \epsilon_0 E_0^2$ (HCV pg 335)

Q6(b) $d\phi_m = \frac{\mu_0 I}{4\pi} d\Omega = \frac{\mu_0 I}{4\pi} \frac{dA \cos \theta}{r^2} = \frac{\mu_0 I}{4\pi} \frac{m \cos \theta}{r^2} \sim$ configuration for stable equilibrium

(magnetic shell)

DIAS pg 22-23

Q7(a) Avg Intensity = $\frac{1}{2} c \epsilon_0 E_0^2$ (refer HCV pg 335) or Q3(c) above.

always induced $\vec{B}$ in circle

Q5(b) Either use simple: $E = \frac{d\phi}{dt}$ and $E = E \times 2\pi R$ we get $E = \frac{B_0 d R}{2}$

or use $\nabla \times E = -\frac{\partial B}{\partial t} \sim$ use (cylindrical) coordinates $\nabla \times E = \frac{1}{r} \begin{vmatrix} \hat{r} & r\hat{\theta} & z\hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial z} \end{vmatrix} E_r \hat{r} + E_\theta \hat{\theta} + E_z \hat{z}$

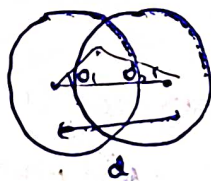
take $\hat{\theta}$ component $\frac{1}{r} \frac{\partial}{\partial r} (r E_\theta) - \frac{1}{r} \frac{\partial}{\partial \theta} (E_r) = -\frac{\partial B}{\partial t}$ in circular we had $\frac{\partial}{\partial \theta} = 0$ (uniform in circle)

Now $\frac{\partial E_r}{\partial \theta} = 0$ since E_r is constant along all θ

Then $\frac{1}{r} \frac{\partial}{\partial r} (r E_\theta) = B_0 \dot{\theta} \rightarrow E_\theta = \frac{B_0 d r}{2} + \frac{C}{r} \sim C \rightarrow 0$ as $r \rightarrow 0$ we want finite.

$E_\theta = \frac{B_0 d r}{2}$ (same as from simple method above)

Q6(a)



Now $E(r) = \frac{\mu_0 I}{3\epsilon_0} \hat{r}$ Basically $\vec{r}_1 - \vec{r}_2 = \vec{d}$

$E = E_1 \cos \theta_1 + E_2 \cos \theta_2 = \frac{\mu_0 I}{3\epsilon_0} (r \cos \theta_1 + r \cos \theta_2) = \frac{\mu_0 I}{3\epsilon_0} \times d$

Q8(a) 2nd law ~ Entropy of isolated system can never decrease with time

~ 2 Statements: Kelvin-Planck & Clausius.

cannot Theorem proof: GBG pg 6.20

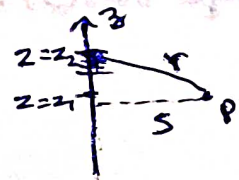
Q6(c) Griffiths ED Q5.22 Soln ~ vector potential due to line segment.

$$\vec{A} = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{r}}{r} = \frac{\mu_0 I}{4\pi} \int_{z_1}^{z_2} \frac{\hat{z} dz}{\sqrt{z^2 + s^2}} = \frac{\mu_0 I}{4\pi} \ln \left| \frac{z_2 + \sqrt{z_2^2 + s^2}}{z_1 + \sqrt{z_1^2 + s^2}} \right| \hat{z}$$

Doing $\vec{B} = \nabla \times \vec{A}$ we get $\frac{\mu_0 I}{4\pi s} (\sin \theta_1 + \sin \theta_2) \hat{\phi}$ (in cylindrical coordinates) (s, θ, z)

$= -\frac{\partial A_z}{\partial s} \hat{\phi}$

put $z = s \cos \theta$



Q5(f) PTO ~

Q5(f) Microcanonical Ensemble $\rightarrow$ Represents possible states of system whose total (12)
 Now $N_1 + N_2 = N$ (fixed) Energy is exactly fixed.

$$N_1(+E) + N_2(-E) = \text{Total } E \text{ (Fixed)} = \pm \epsilon_i$$

Now given $f = \frac{\pm \epsilon_i}{NE}$
 (Fixed)

if we have $N_1 = 6$
 $N_2 = 4$ Then $\frac{\pm \epsilon_i}{E} = 2$

if $N_1 = 8$
 $N_2 = 2$ Then $\frac{\pm \epsilon_i}{E} = 6$

Now $N_f = \frac{\pm \epsilon_i}{E} = N_1 - N_2$

Solving: we get $N_1 = \frac{N + N_f}{2}$

and $N_2 = \frac{N - N_f}{2}$

Now $\Omega = \frac{N!}{N_1! N_2!}$
 (giving N_1, N_2 are fixed)

$S = k_B \ln \Omega$

put in value of Ω & further simplify using string formula.

2008 - Paper 2 CV-Fat (1st Iteration)

Q6(a) Kurie Plot: SBP pg 156 & 157. 3 Example of β^- decay: $^{60}_{27}\text{Co} \rightarrow ^{60}_{28}\text{Ni}$ | $^3_1\text{H} \rightarrow ^3_2\text{He}$

For β^- : $X \rightarrow X' + e^- + \bar{\nu}_e$
 2mc ejected $\rightarrow$ Net: (one e^- & one e^+)

$Q = [m(X) - m(X')]c^2$

For β^+ : $X \rightarrow X' + e^+ + \nu_e$
 e^- mandant cancel out in β^+ (positron emission)

$Q = [m(X) - m(X') - 2m_e]c^2$

For $K-e^+$ capture: $X + e^- \rightarrow X' + \nu_e$

$Q = [m(X) - m(X')]c^2 - B_{\text{electron}}$
 Brie Binding energy of captured electron.

example of β^+ decay: $^{23}_{12}\text{Mg} \rightarrow ^{23}_{11}\text{Na} + e^+ + \nu_e$

$^{11}_6\text{C} \rightarrow ^{11}_5\text{B} + e^+ + \nu_e$

$^{26}_{13}\text{Al} + e^- \rightarrow ^{26}_{12}\text{Mg} + \nu_e$

$^{59}_{28}\text{Ni} + e^- \rightarrow ^{59}_{27}\text{Co} + \nu_e$

Q5(a) $p \rightarrow n$ not observed since $m(n) > m(p)$ and hence energetically impossible

for positron decay to occur: $m(\text{Parent}) - m(\text{daughter Nuclei}) > 2m_{\text{electron}}$

Q5(c) Islands of Isomerism: OCT pg 377. 2 ex of Nuclear Isomers: ^{111}In and ^{27}Co

Q7(c) $\lambda_L \propto \frac{1}{\sqrt{n_s}}$, now $n_s = n_0 [1 - (\frac{T}{T_c})^4]$ $\sim \lambda_L = \lambda_0 [1 - (\frac{T}{T_c})^4]^{-1/2}$
 Superconducting e^- density total e^- density below 28 below 20

Q4(c) EPR $\rightarrow$ BWW pg 245 (Electron Paramagnetic Resonance)

Q4(a) Exponential set-up of Raman effect $\rightarrow$ RSK pg 337

Q1(di) Example of Zeeman of Alkali $\rightarrow$ Sodium D, $3P_{3/2}$ lines further splitting into 4 & 6 components

Q3(b) Hamiltonian $\rightarrow$ 287 RSK $\rightarrow$ solve further to get rotational energy levels (pg 288 RSK)

Q5(e) $\omega_A = k_A (\frac{A}{A-4})$ $\rightarrow$ pg 137 SBP

Q1(e) $a(p) = \frac{1}{\sqrt{2\pi\hbar}} \int_{-\infty}^{\infty} \psi(x) e^{-\frac{ipx}{\hbar}} dx = \frac{1}{\sqrt{2\pi\hbar}} \times \frac{1}{\sqrt{2a}} \int_{-\infty}^{\infty} e^{-\frac{ipx}{\hbar}} dx = \frac{1}{p} \sqrt{\frac{\hbar}{\pi a}} \sin(\frac{pa}{\hbar})$

Now $\langle p \rangle = \int_{-\infty}^{\infty} p |a(p)|^2 dp = 0$ (odd fn) and $\langle p^2 \rangle = \int_{-\infty}^{\infty} p^2 |a(p)|^2 dp = \infty$

then $\Delta p_x = \sqrt{\langle p^2 \rangle - \langle p \rangle^2} = \infty$

we can split like this either before or after integration

Q2(b) Refer DIAS(6) pg 12/13 for 2 methods $\rightarrow$ Matrix operator $S_x = S_+ + S_-$

2009 - Paper 1 (V. Fast 1st Iteration)

(13)

Q1(a) Bernoulli Theorem

Q2(b) D.O.F = 6 & role of Euler angle - SCU 328, 329, 331

Q3(c) Relativistic aberration is basically $\tan \theta' = \frac{\sin \theta \sqrt{1-v^2/c^2}}{\cos \theta + v/c}$

For $\frac{d\vec{L}}{dt}$ when $\rightarrow$ prove for $\vec{r}$, since $\vec{r}$ is generic vector, we can replace with $\vec{L}$.

stellar aberration derivation

Q3(d) $v = \frac{\partial \phi}{\partial t}$; $K.E = \frac{1}{2}mv^2 \sim$ DIAS(2) pg 32

Q4(c) $\alpha = \frac{1}{L} 10 \log_{10} \frac{P_{in}}{P_{out}}$ (unit is dB/km)

Q4(b)(ii) Just give expression/formula - Not asking for values

Q4(c) Poynting vector + Intensity (Flux) $\sim R = \frac{S_r}{S_i}$, $T = \frac{S_t}{S_i}$

Q8(a) $S = k \log \Omega \sim$ GBG 12.18, $k \sim k_B \sim$ GBG 12.20, $\Delta S \geq \frac{\Delta Q}{T} \sim$ GBG pg 7.14

Q8(c) put $\alpha(E) dE \propto \sqrt{E}$ and $\langle E \rangle = \frac{3}{2}kT$ will give $\beta = \frac{1}{kT}$. Refer DIAS(4) pg 28 and 36

Q5(c) Use $\mathcal{E} = -\frac{d\phi}{dt} = 2\pi R \times E_{induced}$ $\rightarrow E_{induced} \sim$ always in circle.

Q5(b) specific Gibbs function is constant during phase change: $dG = v dP - S dT = 0$

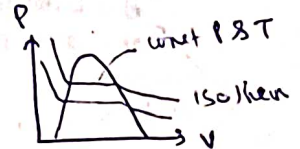
At equilibrium $dG = 0$ < Thermal & mechanical equb: $dP = dT = 0$

since P & T are constant during first order phase transition

Q5(a) (?) My Attempt $\rightarrow$ Assume cylinder to be infinite.

for $r < R \rightarrow A \propto r^2$

for $r > R \rightarrow A \propto \ln r$ } PDF stated in DIAS(3) - ESM vector potential



2010 - Paper 1 (V. Fast 1st Iteration)

Q3(a) Compton effect: Step 1 - eliminate ϕ , Step 2 - eliminate E $\sim$ put $(1 - \cos \theta) = 2 \sin^2 \theta/2$

Q1(d) $\Delta \nu = \frac{c}{2a} = 1.5 \text{ GHz}$, No. of axial modes: $\frac{\Delta \nu}{\Delta \nu_{mode}} = \frac{7.5}{1.5} = 5$

Q1(e) for unpolarized light: $I = I_0 \langle \cos^2 \theta \rangle = \frac{I_0}{2}$ (irrespective of orientation of polarizing axis)

Q3(c) DIAS(2) pg 87-89

Q4(c) $r = \frac{f \lambda}{\alpha}$ (where α is gradient of light beam on lens) $\sim$ 18.6 pg 18.14 ASG

Q5(b) ~~if v not $\perp$ to $\vec{B}$: $\vec{v} \times \vec{B}$ is not along $\vec{B}$~~ $\rightarrow$ use take $B \sin \theta$ (if $\sin \theta$ is effective length)

in our question $\vec{v}$ is $\perp$ to $\vec{B}$ $\rightarrow$ No need for $\sin \theta$ as $\vec{v}$ is in $\vec{B}$ plane

take $\mathcal{E} = r(\vec{v} \times \vec{B})$ $\rightarrow \vec{v} \times \vec{B}$ gives component of $\vec{v}$ which is not along $\vec{B}$.

Motional EMF formula: $\mathcal{E} = (\vec{v} \times \vec{B}) \cdot \vec{l}$

Q6(a) $\vec{P} = n \vec{p}_m$. Expression for potential in term of polarization vector: $V = \frac{1}{4\pi\epsilon_0} \left[\int \frac{(\vec{P} \cdot \vec{n}) dA}{r} + \int \frac{-(\vec{P} \cdot \vec{r}) d\tau}{r^3} \right]$

Q7(c) skin depth = $\sqrt{\frac{2}{\mu \omega}}$ (pg 328 SPEM)

Q8(a) DIAS(3) pg 127 $\rightarrow$ Tredov question

Q6(b) No Time constant for LCR-DC circuit is defined

Q2(c) Eulerian Angles $\rightarrow$ SCU 331-333

Q1 $\rightarrow$ Heavy symmetric Top $\rightarrow$ SCU pg 353 353 only

~~part of answer to Q1 part~~

Pending?

2011 - Paper 1 (V. Fast 1st Iteration)

Photon Gas

(14)

Q7(c) $\frac{1}{8} \times \frac{4\pi k^2 dk}{(\pi/L)^3} = \frac{V}{2\pi^2} k^2 dk \rightarrow \text{put } \frac{v}{k} \rightarrow \frac{c}{k} \Rightarrow D(\omega) d\omega = \frac{V}{2\pi^2} \frac{\omega^2 d\omega}{c^3}$ (Rayleigh Jeans)
 < Note in g(p)dp ~ we can put $p = \hbar k$, $p = \frac{h}{\lambda} = \frac{h\nu}{c}$, etc
 but $E = h\nu = \hbar\omega$ is NOT correct
 For $E \rightarrow \nu$, take p intermediate: $E \rightarrow p \rightarrow \nu$
 we can't directly put $E = \frac{p^2}{2m} = \hbar\omega$ do $g(E) \rightarrow g(p)$ then $g(p) \rightarrow g(\nu)$
 Identical to $\frac{8\pi}{\lambda^4} d\lambda$ if we put $\omega = \frac{2\pi c}{\lambda}$ and put $g_i = 2$.

Q6(a) $E_r = \frac{\sigma}{\epsilon_0} = \frac{\partial V}{\partial r} |_{r=R}$ since $E_{in} = 0$ in conducting sphere. also note $q_{tot} = \int \rho \times 2\pi R^2 \sin\theta d\theta$ doesn't have to be zero because the sphere is grounded and can take a net charge. For dielectric sphere however $q_{tot} = 0$.

Q5(b) $\nabla \times B = \mu_0 \frac{\partial D}{\partial t} = \mu_0 \frac{\partial}{\partial t} (\epsilon_0 E) = \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$
 Now $\nabla \times (\nabla \times B) = -\frac{\partial^2 E}{\partial t^2} = -\frac{\partial^2}{\partial t^2} (\mu_0 \epsilon_0 \frac{\partial E}{\partial t}) = -\mu_0 \epsilon_0 \frac{\partial^2 E}{\partial t^2}$
 $\frac{\partial^2 E}{\partial x^2} = \frac{\partial^2}{\partial t^2} (\nabla \times B) = \mu_0 \frac{\partial^2 D}{\partial t^2} + \mu_0 \frac{\partial^2 D}{\partial t^2} = \mu_0 (\frac{\partial^2 D}{\partial t^2} + \frac{\partial^2 D}{\partial t^2}) = \mu_0 (\frac{\partial^2 D}{\partial t^2} + \frac{\partial^2 D}{\partial t^2})$
 Q1(f) $E_y = b \cos \omega t$
 $E_x = a \cos(\omega t - \delta)$ Lissajous figure (DIAS (2) pg 128) here take $\delta = \beta - \alpha$
 Q1(b) $T = \frac{1}{2} \dot{\vec{w}} \cdot \vec{I} \cdot \dot{\vec{w}} = \frac{1}{2} I_1 \omega_1^2 + \frac{1}{2} I_2 \omega_2^2 + \dots$ Now $\frac{dT}{dt} = \frac{1}{2} I_1 \frac{d}{dt} (\omega_1 \cdot \omega_1) = \frac{1}{2} I_1 2\omega_1 \cdot \frac{d\omega_1}{dt}$
 $\rightarrow \frac{dT}{dt} = \omega_1 \cdot \frac{d}{dt} (I_1 \omega_1) + \omega_2 \cdot \frac{d}{dt} (I_2 \omega_2) + \dots = \omega_1 \cdot \frac{dI_1}{dt} \omega_1 + \omega_2 \cdot \frac{dI_2}{dt} \omega_2 + \dots = \omega_1 \cdot G_1 + \omega_2 \cdot G_2 + \omega_3 \cdot G_3 = \dot{\vec{w}} \cdot \vec{G}$

Q2(a) P.O.F ~ SCU pg 34 $\rightarrow$ free rigid motion - DOF = 6
 1 point fixed - DOF = 3
 2 point fixed - DOF = 2
 Q3(b) $n = \frac{c}{v_p} = \frac{ck}{\omega}$ (since $v_p = \frac{\omega}{k}$). Now $\frac{1}{v_g} = \frac{dk}{d\omega} = \frac{1}{c} \frac{d(n\omega)}{d\omega} = \frac{1}{c} [n + \omega \frac{dn}{d\omega}]$
 Thus $v_g = \frac{c}{n + \omega \frac{dn}{d\omega}} = \frac{c}{n - \lambda \frac{dn}{d\lambda}}$

Q5(c) $f(E) = \frac{1}{e^{\frac{E-E_F}{kT}} + 1}$ always less than 1. ~ every cell has (occupancy less than one) and hence all can't have 2 fermions. Every fermion in unique energy state.

Q7(b) with $\rho = \vec{J} = 0 \rightarrow$ symmetry exists: $\nabla \cdot E = 0$ $\nabla \times E = -\frac{\partial B}{\partial t}$
 $\nabla \cdot B = 0$ $\nabla \times B = \frac{1}{c^2} \frac{\partial E}{\partial t}$
 for $\rho \neq 0, \vec{J} \neq 0 \rightarrow$ symmetry broken. $\nabla \cdot E = \rho/\epsilon_0$ $\nabla \times E = -\frac{\partial B}{\partial t}$
 $\nabla \cdot B = 0$ $\nabla \times B = \frac{1}{c^2} \frac{\partial E}{\partial t} + \mu_0 \vec{J}$
 (we add moving electric charge)

This symmetry can be restored by adding (Maxwell's charge) new terms due to magnetic monopoles to restore symmetry
 $\nabla \cdot E = \rho/\epsilon_0$, $\nabla \cdot B = \mu_0 \rho_m$, $\nabla \times E = -\frac{\partial B}{\partial t} + \mu_0 \vec{J}_m$, $\nabla \times B = \frac{1}{c^2} \frac{\partial E}{\partial t} + \mu_0 \vec{J}_e$
 Q1(e) we get $I = \frac{T_0 \lambda^2}{\pi d} \int_{-\infty}^{\infty} \frac{\sin^2 y}{y^2} dy = \pi$ (standard result) ~ Then $I = \frac{T_0 \lambda^2}{d}$

Q6(a) oscillatory: $c < \omega_0 \rightarrow \frac{R\epsilon}{2\pi L} < \frac{1}{\sqrt{LC}}$
 Now $Q = \frac{2\pi E}{2CE\Delta T} = \frac{2\pi E}{2CE\lambda \frac{2\pi}{\omega_0}} = \frac{\omega_0}{2C} = \frac{\omega_0 L}{R}$
 Now they have given some thing.
 $Q = \frac{2\pi E}{2CE\Delta T} = \frac{\pi}{CT} \sim (\frac{Q}{\pi}) T = \frac{1}{C}$
 Now $a = a_0 e^{-ct} = a_0 e^{-t/\tau}$ putting $t = 1/\tau = (\frac{Q}{\pi}) T$

2012 - Paper 1 (V. Fast 1st Iteration)

(15)

Q4(a) $\frac{dq(\text{inside volume } V)}{dt} = I_c dt - I_c' dt$ (I_c is conduction current entering volume V)

Now $\Phi_E = \int \vec{E} \cdot d\vec{s} = q/\epsilon_0 \rightarrow \frac{dq}{dt} = \epsilon_0 \frac{d\Phi_E}{dt} = I_d = I_c - I_c' \Rightarrow I_c = I_d + I_c'$ $I_c' + I_d = \text{const}$

loss of conduction current appears as displacement current.

Q4(c) Electrostatic properties of conductors:

- (i) $E_{\text{inside}} = 0$ (ii) Interior of conductor contains no charge ($\rho_{\text{in}} = 0$) ~ use Gauss law in conductor (all charge only on surface)
- (iii) $\vec{E}$ field lines are normal to surface (iv) constant potential in volume ($V_{\text{in}} = \text{const}$)
- (v) Equipotential surface (vi) Electrostatic shielding in cavity.

All these properties arise from $E = 0$.

Q7(b) use $\Delta V = \sqrt{(\Delta V_1)^2 + (\Delta V_2)^2}$ (ASG 28.15) if $g(E) \propto E^{1/2} \rightarrow \langle E \rangle = \frac{3}{2} kT$
 Q7(c) use $g(E) \propto \sqrt{E}$ ~ No k if $g(E)$ const $\rightarrow \langle E \rangle = \frac{1}{2} kT$ E from 0 to ∞
 Q8(c)(i) $\langle v \rangle_{\text{avg}}$ vs T ($\theta_F \rightarrow$ GBG pg 13.30) px from $-\infty$ to ∞ used in equipartition theorem

Q1(a) Now $T = \frac{1}{k \cdot E} \left(\frac{1}{\sqrt{1-v^2/c^2}} - 1 \right) m_0 c^2$ rel. velocity $\vec{v}$
 Now $v' = \frac{2v}{1+v^2/c^2}$ (2) Then $T' = \frac{1}{k \cdot E} \left(\frac{1}{\sqrt{1-v'^2/c^2}} - 1 \right) m_0 c^2$ (3)

putting value of v' in $T' \rightarrow T' = \frac{2v^2/c^2 (m_0 c^2)}{1-v^2/c^2}$ (4) Now write $\frac{v^2}{c^2}$ in terms of T from (1) and insert in (4)

we get $T' = \frac{2T(T + 2m_0 c^2)}{m_0 c^2}$ if $m_0 c^2 \gg T$ (non-relativistic)
 we get $T' = 4T$ ~ correct since $v' = 2v$ so kE is 4 times

Q2(a) $\oint \vec{D} \cdot d\vec{s} = Q_{\text{free}} \rightarrow \vec{D} = \frac{Q}{4\pi r^2} \hat{r}$ (b) Now $\vec{E} = \frac{\vec{D}}{\epsilon} = \frac{Q(1+\epsilon r)}{4\pi \epsilon_0 r^2}$
 Now $C = \frac{Q}{V} = \frac{4\pi \epsilon_0}{\left[\frac{1}{a} - \frac{1}{b} + k \ln b/a \right]}$ $V = \int_a^b \vec{E} \cdot d\vec{s} = \frac{Q}{4\pi \epsilon_0} \left[\frac{1}{a} - \frac{1}{b} + k \ln \frac{b}{a} \right]$

(c) Now $\vec{P} = \chi \epsilon_0 \vec{E} = (\epsilon_r - 1) \epsilon_0 \vec{E} \rightarrow \vec{P} = -\frac{Qc}{4\pi r^2}$ Now $P_p = -\vec{r} \cdot \vec{P}$ < Note: Formula for Divergence in SPHM pg 28 >

then $P_b = -\frac{1}{r^2} \frac{\partial}{\partial r} (r^2 P_r) = -\frac{1}{r^2} \frac{\partial}{\partial r} (r^2 (-\frac{Qc}{4\pi r^2})) = \frac{Qc}{4\pi r^2}$

(d) $\sigma_b = \vec{P} \cdot \hat{n} : \sigma_{r=a} = -\frac{Qc}{4\pi a^2} ; \sigma_{r=b} = \frac{Qc}{4\pi b^2}$ see Q1(c) on pg 17

Q6(b) Now min at $n\lambda + \frac{\lambda}{2}$ and $n\lambda - \frac{\lambda}{2} \sim n\lambda$ is max (central has twice width of normal maxima)
 width of principal maxima ($\theta \approx 0$): $(\epsilon + d) \sin \theta = \pm \frac{\lambda}{N} \rightarrow \Delta \theta = \frac{2\lambda}{N(\epsilon + d)}$ [Note $\frac{\lambda}{N(\epsilon + d)}$ is angular half-width]

2009 - Paper 2 (V. Fast 1st Iteration)

Q2(a)(iv) Antineutrino is $1/2$ -spin just like electron. Thus $S_y = \frac{1}{2} \hbar \sigma_y$

Q1(d) $N \sim 1s^2 2s^2 2p^3 \sim \boxed{\uparrow \uparrow \uparrow}$ (Hund's Rule) $S = 3/2$ and $L = 0$
 $L = S m_L = -1 + 0 + 1 = 0$

1st excited state $He : 1s^1 2s^1$

Ground state $He : 1s^2 : 1S_0$

1st excited state: $1s^1 2s^1 : 1S_0, 3S_1$

2nd excited state: $1s^1 2p^1 : 1P_1, 3P_{0,1,2}$

Q2(b)(iii) $E_f = \frac{1}{2} m v_f^2 \Rightarrow \frac{v_f}{c} = \sqrt{\frac{2E_f}{m c^2}}$ put $m c^2 = 0.51 \text{ MeV}$

Q3(b) simple: $g(p) dp = g(E) dE \rightarrow$ get $g(E) dE$ using $E^2 = \frac{p^2 \hbar^2}{2m} \sim \frac{1}{8} \frac{4\pi p^2 dp}{(2\pi)^3} \dots g(E) \propto \int \frac{1}{p} dp$
 $g(p) \propto p^2 dp$

Q5(c) Note: $(\vec{A} + \vec{B}) \cdot \vec{A} = \vec{A} \cdot \vec{A} + \vec{B} \cdot \vec{A} = \vec{A} \cdot \vec{A} + \vec{A} \cdot \vec{B} = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{A} = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{B} = 2\vec{A} \cdot \vec{B} \sim (\vec{A} + \vec{B}) \cdot \vec{A} \sim (\vec{A} + \vec{B}) \cdot \vec{A} \sim (\vec{A} + \vec{B}) \cdot \vec{A} \sim (\vec{A} + \vec{B}) \cdot \vec{A}$
 < Further proof is easy > use de Morgan 2nd line also same as X

Q4(b)(iii) $\vec{E} = -\vec{\mu}_S \cdot \vec{B} = \mu_B B g_{sm} = \pm \mu_B B \sim$ Thomson precession $\times \frac{1}{2} \sim \pm \frac{1}{2} \mu_B B$ (spin-orbit coupling) (16)

Q5(a) Field quantum of weak: $W^\pm, Z^0 \rightarrow R = \frac{\hbar}{2mc} \approx 10^{-18} \text{ m}$ (putting $m = 80 \text{ GeV}/c^2$)

" " EM: photon $\rightarrow R = \infty$ since photon massless

Q5(b) Yukawa Potential in SBP (not in DCT) pg 283, 323 $\rightarrow V = -C \frac{e^{-r/R}}{r}$ (Yukawa interaction distance R is Range of Force)

Q5(c) Refer soln in HCP PDF - reciprocal of HCP & HCP with rotation

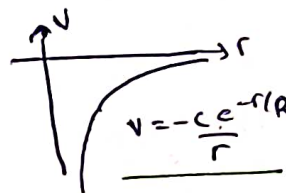
Q5(d) Reasons for Silicon: (i) cheap (ii) Abundant ($\text{SiO}_2 \rightarrow$ silicon sand)

(iii) can be used at high Temp (iv) can be operated at high voltages

(v) used in MOSFET as it easily oxidizes to Silicon Dioxide (SiO_2)

(vi) High Forward B Voltage (0.7V) compared to Germanium making it more stable

(vii) low reverse saturation current, (viii) Moderate Energy Gap $\sim$ more stable



Q5(b) Si & Ge not used because of low temp coeff & variable with Temp. Metal oxides are preferred due to layer, stable & more predictable temp coefficient. $\text{NiO} \rightarrow \text{MnO} \rightarrow$ commonly used (MnO is Manganese oxide)

Q5(c) HCP $\rightarrow$ PDF in DIAS (6)

Q6(b) 10^{14} GeV (corresponds to 10^{27} Kelvin) $\rightarrow$ GUT on RG notes pg 115 NPP

All coupling constant become equal. $\sim$ Annu- to Min annihilation $\rightarrow$ RG hit soln 2 pg 273

GUT $\rightarrow$ indicate decay of proton & existence of leptoquark $\rightarrow$ refer RG hit soln-2 pg 273

2010 - Paper 2 CV. Fault 1st Iteration

Q1(a) Use $2\pi r = n\lambda$ (standing waves) and $\lambda = h/mv$

Q2(a) solve as we do for Harmonic oscillator. $\sim$ after pulling $y = (\frac{m\omega}{\hbar})^{1/2} x$, we get:

$(-\frac{d^2}{dy^2} + y^2)\psi = \frac{2E\hbar}{m\omega} \psi$ (DIAS (4) pg 119), here we have $(-\frac{d^2}{dx^2} + x^2)\psi = \lambda \psi$. same soln: for $Axe^{-x^2/2}$ clearly $n=1$, $E = \frac{3}{2}\hbar\omega$ and eigenvalue = 3

Q2(b) Alpha decay Paradox $\rightarrow$ Barrier Penetration $\rightarrow$ SBP pg 139-144

Q5(d) under certain circumstances, the Cooper pairs move from one superconductor to the other across the thin insulating layer, such motion of pair of e^- constitute Josephson current and process by which pairs cross the insulating layer is called Josephson tunneling.

Q5(b) Reduced zero scheme E vs k $\rightarrow$ P&B pg 186 and figure on pg 188

Q7(c) Paramagnetism $\rightarrow$ classical theory: P&B pg 235

$\rightarrow$ quantum theory: P&B pg 238

Q5(a) For B/E (nucleon) $\rightarrow$ use M_{nucleus} (given) & $M_p, M_n \rightarrow$ find B/E

and divide by A for B/E per nucleon.
 $P.F. = \frac{M}{A} \rightarrow$ Isotopic mass } Both are given data
 $A \rightarrow$ mass number

2011 - Paper 2 CV. Fault 1st Iteration

Q8(a) Law of Intrinsic Mass $\rightarrow$ P&B pg 212, 213

Q3(b) Classification of Molecules based on $I_A, I_B, I_C \rightarrow$ PDF print in DIAS (5)

Q5(c) conservation of Baryon Number & stability of proton $\rightarrow$ P&B Hyperphysics website (Also refer Hyperphysics same page for cons. of leptons & interesting thing like muon μ^- decay, etc) (and $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$ implies no mass number, etc)

Q1(d) spin-orbit coupling (single e^-) selection rules: $\Delta l = \pm 1, \Delta j = 0, \pm 1, \Delta s = 0$
 compound doublet between $2p$ & $2p \rightarrow$ direct answer on jagad college website PDF pg 2, 3 PDF pg 2, 223

2012 - Paper 2 (v. Fast 1st Iteration)

17

Q1(b) proof of $\sin(\sigma_2 \phi) = \sigma_2 \sin \phi$ and $\cos(\sigma_2 \phi) = \cos \phi$
 Use $e^{i\alpha(\vec{\sigma} \cdot \hat{n})} = I \cos \alpha + i(\hat{n} \cdot \vec{\sigma}) \sin \alpha = \cos(\alpha(\vec{\sigma} \cdot \hat{n})) + i \sin(\alpha(\vec{\sigma} \cdot \hat{n}))$ $\angle \sin \alpha e^{i\theta} = \cos \theta + i \sin \theta$
 now put $\alpha = \phi$ and $\hat{n} = \hat{z}$

Q2(b) degeneracy = $\sum_{l=0}^{n-1} (2l+1) = n^2$ ~ becomes $2n^2$ with spin; $\psi = \psi(r, \theta, \phi) \chi_{\text{spin}}$ and $\hat{n} = \hat{z}$

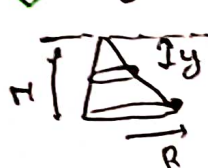
Q3(c) chemical shift NMR ~ SBP pg 301 ~ due to shielding of outer e^-
 $B_{\text{eff}} = B_0(1 - \sigma)$ ~ &

Q5(b) Recoil of ^{57}Fe ~ (simple) pg 304 SBP

Q7(b) PB pg 252, 254 and printout of γ vs T (254 PB has $1/2$ vs T)

procession of e^-
 create new opposing field $\vec{B}_d$. Then
 $B_{\text{net}} = B - B_d$
 shifts resonance frequency from value corresponding to free proton due to e^- shielding & precession
 (verified from internet & YT)

Q1(c) 2012 paper 1



now $r = \frac{y}{H} R$
 $\rho = \frac{M}{\frac{1}{3} \pi R^2 H}$
 $dm = \pi r^2 \rho$

$dI = \frac{r^2}{4} dm + y^2 dm$ (11 Marks Hedeem)
 put $r = \frac{y}{H} R$
 on solving ~ $I = \frac{3M}{5} (H^2 + \frac{R^2}{4})$ ✓

2013 - Paper 1 (V. Fout 1st Iteration)

①

Q3(b) First 2 Maxima at $\alpha = 1.43\pi$ and $\lambda = 2.46\pi$

Q5(d) $\left(\frac{dn}{d\lambda}\right)_{\lambda} = \frac{n_2 B_{21}(\nu(\omega))}{n_2 A_{21}} = \frac{8\pi h \nu^3 / c^3}{e^{h\nu/kT} - 1} \times \frac{1}{8\pi h \nu^3 / c^3} = \frac{1}{e^{h\nu/kT} - 1}$

Q1(e) - do it
I think I skipped it by mistake

Q7(c)(i) $\vec{D} = \epsilon \vec{E} = \epsilon_0 n^2(\lambda, y, z) \vec{E}$

$\nabla \cdot \vec{D} = 0 \rightarrow \nabla \cdot (n^2 \vec{E}) = 0$
scalar vector

$\nabla \cdot (n^2 \vec{E}) = (\vec{\nabla} n^2) \cdot \vec{E} + n^2 (\nabla \cdot \vec{E}) = 0$

Thus $\nabla \cdot \vec{E} = -\frac{1}{n^2} (\vec{\nabla} n^2) \cdot \vec{E}$

Now $\nabla \times (\nabla \times \vec{E}) = \nabla \times \left(-\frac{\partial \vec{B}}{\partial t}\right) = -\frac{\partial^2 \vec{D}}{\partial t^2} = \mu_0$

Thus $-\nabla^2 \vec{E} + \nabla (\nabla \cdot \vec{E}) = -\frac{\partial^2 \vec{D}}{\partial t^2} = \mu_0$

$\nabla^2 \vec{E} + \nabla \left(\frac{1}{n^2} \nabla (n^2) \cdot \vec{E}\right) - \mu_0 \epsilon_0 n^2 \frac{\partial^2 \vec{E}}{\partial t^2} = 0$

- 1(e) → reduce pulse dispersion to make it
↳ reduce v. no (single-mode fiber)
- reduce diameter of core
- use low refractive index for cladding
- use monochromatic source like LASER
- use graded index rather than step-index

5(b), 6(b) → LCA AC double

7(a) (cc), (iv) (?)

7(b) Doubt → wire Poynting Vector.

GBG pg 9.32

Q8(a) *

given are vapour equations
use $\frac{L}{RT}$ for solid state eqn
Solid → Vapour → L → L Sublimation
Liq → Vapour → L → L evaporation

also $L_{\text{sublimation}} = L_f + L_{\text{evap}}$

and 760 mm of Hg = 1 Atm
= 1.013 x 10⁵ Pascal

2014 - Paper 1 (V. Fout 1st Iteration)

Q1(c) Chess

Q1(e) Fractional Index difference: $\Delta = \frac{n_1 - n_2}{n_1} \approx \frac{n_1 - n_2}{n_2}$

Q2(b) $\vec{\omega} \cdot \vec{J} = 2T \rightarrow +ve$ → then acute (cos θ > +ve)

Q2(a) KE converts to Heat (Temp rises)

Q3(a) Simple Doppler for light twice (in light → only relative velocity v, no v_s or v_o)

$f'' = f' \sqrt{\frac{1-v/c}{1+v/c}} = \left(f' \sqrt{\frac{1-v/c}{1+v/c}}\right) \sqrt{\frac{1-v/c}{1+v/c}} = f' \left(\frac{1-v}{1+v}\right)$

Q3(b) Difficult ~ Intensity of reflected light (electromagnetic physics, etc.)

Q5(c) Requirements for holography → ASG 21.6

Q8(d) If -ve Temp → then high energy states are more occupied than low energy states without any upper limit. This not allowed for finite energies

GBT also mentioned Heat, seismic / tectonic activity, friction b/w Earth & atmosphere, and oceanic effects, etc. → KE into sound & thermal energy (heat)

2015 - Paper 1 (V. Fault 1st Iteration)

Q1(c) & Q3(d)

(2)

Q6(b) Average Intensity $= \frac{1}{2} \epsilon_0 c E_0^2$ (HCV pg 335)

Q1(c) use $\omega = \frac{2\pi}{T}$ ~ sidereal day (23 hrs 56 min ⁴ seconds) ~ method of measurement

Q4(e) optical Resonator: ASG 27.14 onwards (put 2π in Radian s)

wt fixed star (?)

Q4(a) Viscosity $\rightarrow \eta$. Poise $= 1 \text{ cm}^2 \text{gs}^{-1} = 1 \text{ dyne} \cdot \text{sec} / \text{cm}^2 = 0.1 \text{ Pa} \cdot \text{Sec}$ (Pa is SI)

kinematic viscosity $= \frac{\eta}{\rho} \rightarrow \frac{\text{dynamic viscosity}}{\text{density}}$. stoke $= 1 \text{ cm}^2 / \text{sec} = 10^{-4} \text{ m}^2 / \text{sec}$ (m^2/s is SI unit)

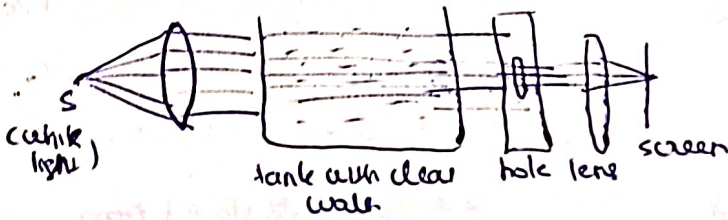
Q5(b) recall $\nabla \cdot D = \rho_{\text{free}} \rightarrow (D_1)_n = (D_2)_n$ only if $q_{\text{free}} = 0$. here $(D_2)_n = \sigma_{\text{free}}$ on surface ($D_1)_n = 0$ inside conductor)

Q7(b) $\frac{dE}{dt} = 2cE$ ~ Energy loss per cycle $= 2cE \times \text{Time (T)} = \frac{1}{100} E$ (period)

~ DIAS (2) pg 26, 27 < exact same procedure >. ~ except use $E = \frac{Q^2}{2C} + \frac{1}{2} LI^2$ instead of $\frac{1}{2} bx^2 + \frac{1}{2} mv^2$

we could also do $E = E_0 e^{-2cT} = 0.99 E_0 \rightarrow 2cT = \ln(1/0.99) = 0.01005$ (same as $1/100$)

Q8(b) Experimental demonstration of Rayleigh scattering (draw X NCERT experiment)



Add Sodium Thiosulphate in water (for sulphur particles)
we observe blue light on three sides due to scattering of shorter wavelengths by colloidal sulphur. The transmitted light on 4th side on screen is first orange and then changes red. This helps explain blue color of sky & red sun at sunrise (sunset).
precipitate in soln

2016 - Paper 1 (V. Fault 1st Iteration)

Q1(d) $V = \frac{2\pi a}{\lambda} \cdot NA = \frac{\pi d}{\lambda} \cdot NA = \frac{\pi d}{\lambda} \sqrt{n_1^2 - n_2^2}$ (similar to $\frac{2\pi}{\lambda} a \sin \theta = z \sim \text{here } \sin \theta = NA$)

also called (normalized frequency). No. of modes $= \frac{V^2}{2} \frac{g}{g+2}$. for step index $\rightarrow g \rightarrow \infty$ parabolic $\sim g=2$

Q7(c) Displacement current = conduction current in AC circuit.

Q8(b) Phase Transition $\rightarrow$ Abrupt change in one or more physical properties with an infinitesimal change in Temperature.

Q5(c) GBG pg 11.34. The 2 diff. Temp correspond to Noon & light reflected from Sun.

$S = \sigma T^4 = \frac{1}{4} c u$ ~ energy density and $p = \frac{u}{3}$ or u ? (I think we like to use $p = \frac{u}{3}$?)

Q3(c) $z = 1 + e^{-\epsilon_i / k_B T}$. $n_1 = \frac{N e^{-\epsilon_1 / k_B T}}{z}$. $n_2 = \frac{N e^{-\epsilon_2 / k_B T}}{z} = \frac{N e^{-\epsilon_2 / k_B T}}{1 + e^{-\epsilon_1 / k_B T}}$

(GBG pg 13.4 example 13.2)

$z = \sum g_i e^{-\epsilon_i / k_B T}$ ($g_i = 1$)

$u = n_1 \epsilon_1 + n_2 \epsilon_2$
 $= \frac{N \epsilon_1 e^{-\epsilon_1 / k_B T} + N \epsilon_2 e^{-\epsilon_2 / k_B T}}{1 + e^{-\epsilon_1 / k_B T}}$

2017 - paper 1 CV. Fault 1st Iteration)

(3)

Q6(d) use $i = dq/dt$ simple

Q7(b)(i) use capacitor in parallel: $C = C_1 + C_2 + \dots$

$$dC = \frac{\epsilon_0 l dx}{a + dx}$$

$$C = \frac{\epsilon_0 l}{x} \ln\left(\frac{a+dx}{a}\right) \approx 1 + \frac{dx}{a}$$



$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

log(1+x) = x - x^2/2 + x^3/3 - x^4/4 + ...

$$\log(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots$$

Q6(b)(ii) $e^{\sigma(T^4 - 300^4)} = e^{\sigma(300^4 - T^4)} \rightarrow T$ can't be found. Rate of energy transfer

rel. emissivity $\epsilon = (\epsilon - a)$

suppose Energy emitted = $\epsilon A \sigma T_1^4$

Energy absorbed = $a A \sigma T_2^4$

Then Net = $(\epsilon - a) \sigma (T_1^4 - T_2^4)$

rel. emissivity

Q4(c) Cr is Active medium in Ruby laser. Energy level of chromium taken place in lasing action

Q5(b) Note: 120V, 240V are RMS. For Bulb we need same current.

$$Power = 60 = VI \rightarrow I = 0.5A \text{ and } R = 240\Omega$$

$$Now we need |Z| = V/I = 240/0.5 = 480\Omega \rightarrow L = 240\sqrt{3} \rightarrow L = \frac{2\sqrt{3}}{\pi} H$$

Q5(c) $F = \frac{kq^2}{4\pi r^2} \rightarrow W = \int F dx = \frac{kq^2}{4} \left(\frac{1}{a}\right) \sim$ Then u same as 1/2 K.E as in DIAS notes.

Q3(a) ~ More research reqd } check
Q4(c) ~ Cr in Ruby laser } BSS

since $\omega = 2\pi f$

2018 - paper 1 CV. Fault 1st Iteration)

Q3(a) Narrow Tube $\rightarrow$ so that He atoms in level E_2 can get de-excited by collision with walls of tube (27-14 ASG)

$$Now v = \frac{mc}{2d} \sim dv = \frac{c}{2d} \sim dv = -\frac{c}{\lambda^2} d\lambda \rightarrow |d\lambda| = \frac{\lambda^2}{2d} = \frac{(6328 \times 10^{-10})^2}{2 \times 0.3} = 0.66 \times 10^{-3} \text{ nm}$$

(It is actually $\frac{mc}{2\mu d}$ here $\mu=1$)

$$Number \text{ of modes} = \frac{\text{Half-width of gain profile}}{\Delta \lambda} = 3$$

$$Q5(a) U = \frac{1}{2} LI^2 \sim \frac{dU}{dt} = LI \frac{dI}{dt}$$

$$Q5(b) \phi = LI \propto NI \text{ (}\phi \text{ is total Flux). HCV B 2915 } \sim \phi = LI = \mu_0 n_1 I_1 n_2 \pi r_1^2 \times (n_1 l)$$

$$Q7(a) S = S(T, V) \sim dS = \left(\frac{\partial S}{\partial T}\right)_V dT + \left(\frac{\partial S}{\partial V}\right)_T dV$$

$$\begin{aligned} L &= \mu_0 n_1^2 \pi r^2 l \\ \phi &= MI = \mu_0 n_1 I_1 \times \pi r_2^2 \times n_2 l \\ L &= \mu_0 n_1 n_2 \pi r_2^2 l \end{aligned}$$

$$isochoric: C_V dT + V ad dV = 0 \rightarrow dS = C_V dT$$

r_1, r_2 depending on which is smaller (M remove same in both cases)

$$Q8(a) use $\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0} \rightarrow V = -\frac{\rho}{2\epsilon_0} + a_3 + b$ (2 eqns 2 unknown)$$

$$Q8(b) \text{ Fay use } \vec{B} = -\nabla \phi_m \text{ (Refer SPFM pg 244)}$$

$$Q7(b) dW = -PdV = -P \left[\left(\frac{\partial V}{\partial T}\right)_P dT + \left(\frac{\partial V}{\partial P}\right)_T dP \right] = -PV\beta dT + PV\kappa dP \text{ (we have } dT=0)$$

$$Then dW = PV\kappa dP \sim W = \frac{1}{2} V\kappa (P_2^2 - P_1^2) \text{ where } V = m/\rho \text{ (soln on chgg) } \rightarrow \text{cause } V \text{ is const \& doesn't change much}$$

2019 - paper 1 CV. Fast 1st Iteration

This is not asked in Question. I have just mentioned for extra knowledge.

(4)

Q1(d) Axial & longitudinal Aberration. (Lateral aberration 'a variation' in magnification of different colours.)

Q1(c) Use proper critically damped, ~ it will make one swing and return slowly to zero posn
Ballistic Galvanometer → deflects needle in dirn and proportional to current for a short duration
External critical damp. R → proper amount of R when motion just doesn't become oscillatory.

Q3(c) Laser Spiking in Ruby → ASG 27-12

Q7(b)(ii) $C_V = \frac{12}{5} \pi^4 R \left(\frac{T}{\Theta_0} \right)^3 \sim \text{GBG 12-35}$ (easy derivation from Debye C_V at low temp approximation)

Q8(a) GBG pg 13-8. use $U = k_B T^2 \frac{\partial \ln Z}{\partial T}$ and refer GBG pg 13-2 for derivation.

Q4(c) Gyroscope → OIAS (1) pg 88

2020 - paper 1 CV. Fast 1st Iteration

Q5(a) Use Force on Dipole in Non-uniform field: $(\vec{p} \cdot \nabla) \vec{E}$, where $E = \frac{2kp}{r^3}$

Force b/w 2 dipoles: $\frac{p_1}{r} \frac{p_2}{r} \rightarrow F = p_2 \frac{dE}{dr} = p_2 \frac{d}{dr} \left(\frac{2kp_1}{r^3} \right) = -\frac{6kp_1 p_2}{r^4}$ (Then attractive)

Q4(b) Fermat Principle → BJS pg 20

Q4(c) Electromagnetic Theory of Double Refraction → BJS pg 508

Q8(a)(i) $\frac{8\pi}{15} d\lambda \propto kT \left(\frac{1}{2} m v^2 + \frac{1}{2} k x^2 \right)$ classical, → Rayleigh Jeans Law

Q8(b) couldn't find derivation from integral form from anywhere. Probably not possible because integral average over full closed surface. Poen't give value at point.

Q5(d) $dU = dQ - PdV + \mu dN \sim$ cons. of Energy. (GBG 5.7)

Q7(a) $1 \text{ Erg} = 10^{-7} \text{ Joule}$
(cgs) (SI)

$1 \text{ oe} = 1 \text{ dyne} / \text{maxwell} = \frac{1}{4\pi} \times 10^3 \text{ A/m}$
(cgs) (SI)

Q5(b) $J = \sigma E$
 $J_{\alpha} = \sigma \partial \phi / \partial t$

Q6(b) use $V = V_0 e^{i\omega t} \sim I = I_0 e^{i(\omega t + \phi)} \sim \bar{I} = \bar{V} / \bar{I}$

Q5(c)(i) $Z = \sum_{n=0}^{\infty} e^{-\beta E_n} = e^{-\frac{1}{2} \beta \hbar \omega} \sum_{n=0}^{\infty} e^{-n \beta \hbar \omega} = \frac{e^{-\frac{1}{2} \beta \hbar \omega}}{1 - e^{-\beta \hbar \omega}}$
(assume $g_1 = g_2 = g_3 = 1$) $\sim \sum_{n=0}^{\infty} e^{-n \beta \hbar \omega}$

For power, we need $\cos \phi = \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| |\vec{b}|}$

Q6(a) Good example → HCV pg 137 part 2 Q4



Shell A inner → 0
outer → +q

Shell B inner → -q
outer → 0

(using Gauss law)

Now $V_1 = k \frac{(q_1 - q_2)}{r_2} + \frac{kq_2}{r_1}$

$V_2 = \frac{kq_1}{r_2}$

(V in shell = kQ / Radius)

we get $V = \frac{kq}{r} + \frac{k(q_1 - q_2)}{r_2}$

Solving: $V = V_2 + (V_1 - V_2) \left(\frac{1}{r} - \frac{1}{r_2} \right)$

2013 - Paper 2 (v. Fast 1st Iteration)

(1)

Q3(b) Mutual Exclusion Rule → RSK pg 342

Q5(d) solved in PTA book next to question.

Q6(b) Experimental Detection of Neutrino → C. Rowan & Review exp. SBP 160-164

Role of Neutrino → Lepton participate in weak interaction: Neutrino helps conserve leptonic numbers

Q6(a) Experimental procedure of Wu experiment - SBP pg 165-167

Parity is conserved in strong & EM. Parity not conserved in weak interaction

Other decay where parity violation is demonstrated → Θ^+ meson decays into two π -mesons
 Z^+ neutron " " " " " "

$$\left[\begin{array}{l} \Theta^+ \rightarrow \pi^+ + \pi^0 \\ Z^+ \rightarrow \pi^+ + \pi^+ + \pi^- \\ Z^+ \rightarrow \pi^+ + \pi^0 + \pi^0 \end{array} \right]$$

Basically weak interactions

This was Tau-Theta puzzle which was explained by Parity Violation. Today Tau & Theta Mesons are kaons (Kappa Meson)

Muon-decay also parity violation → $\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$

$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$

electron neutrino
muon anti-neutrino

Q7(c) London $e^- \rightarrow$ Meissner Effect → DIAS(6) pg 30

Q7(b) PSB pg 283, 284 → Perfect conductor vs Superconductor.

Q7(a) $n = p = n_i = (N_c N_v)^{1/2} e^{(-\frac{E_g}{2kT})}$ simple derivation from D.O.S equation

proof: $dn = 2 \int (E) g(E) dE \rightarrow$ PSB pg 208, 209 simple proof: $n = N_c e^{-\frac{(E_c - E_F)}{kT}}$

Now $np = n_i^2 \rightarrow n_i = (N_c N_v)^{1/2} e^{-\frac{E_g}{2kT}} \sim$ pg 213 PSB

2014 - Paper 2 (v. Fast 1st Iteration)

Q2(b) TDSE: $H\psi = i\hbar \frac{\partial \psi}{\partial t} \rightarrow$ derive by starting with wave eqn $\psi(x,t) = A e^{i(kx - \omega t)}$ and work backwards. Reduce to TISE by putting $\psi = \psi_0 e^{-iEt/\hbar}$

Q6(a) SEM vs TEM → DIAS(6) pg 35-37

Q5(d) pg 290 PSB → Energy gap in superconductor vs Insulator, and it's variation with Temp

Q5(c) ex 4.3, pg 143, PSB

Q5(b) Use deuteron approach method $\frac{1}{2} m_\alpha v^2 = \frac{k Q_1 Q_2}{r_0}$ (KE = PE) $\rightarrow$ $\frac{Z_1 Z_2}{r_0} \sim \frac{Z_1 Z_2}{r_0} \left(\frac{\alpha \text{ particle}}{\text{has } +2e \text{ charge}} \right)$ Assume α -particle stops at Radius of Nucleus

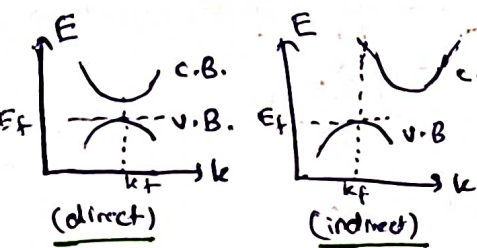
Q4(b) Nuclear spin I depends on Mass no. A and atomic no. Z

Mass A	At. Z	Nuclear spin I
odd	odd or even	$1/2, 3/2, 5/2, \dots$
Even	even	0
Even	odd	$1, 2, 3, \dots$

2015 - Paper 2 (V. Fast 1st Iteration)

- Q1(e) $k_\alpha : L \rightarrow k$, $k_\beta : M \rightarrow k$, $L_\alpha : M \rightarrow L$
- Q2(b) $-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial z^2} + mgz \psi(z) = E \psi(z)$ where ground is $z=0$. For perfectly elastic collision $\psi(0) = 0$. Also $\psi(z) \rightarrow 0$ as $z \rightarrow \infty$ it will be very high since ball is compressed (we assume ∞)
- Q3(c) Use $\vec{u}_J = -\frac{e}{2m} g_J \vec{J}$
 we don't use $\vec{u} = \vec{u}_p + \vec{u}_s$ because component of $\vec{u}$ not along $\vec{J}$ precesses and averages out to zero
- Q4(c) Perfect conductor $\rightarrow$ ideal concept whereas superconductors do exist in real life.
 * Perfect " will keep its magnetic flux condition, A. s.c. always expels magnetic field (Meissner effect)
 * S.C. has Band gap $= 2\Delta$. conductor has overlapping Bands.
- Q4(c) probability blew $p \rightarrow p+dp$ is $|a(p)|^2 dp$ (from HCV) where $a(p) = \frac{1}{\sqrt{2\pi\hbar}} \int_0^\infty \psi(x) e^{-ikx} dx$
 we have $\psi = \sqrt{\frac{2}{a}} \sin(\frac{\pi x}{a})$ and limit is from 0 to a only.
 Doing $a(p) = \frac{1}{\sqrt{2\pi\hbar}} \int_0^a \sqrt{\frac{2}{a}} \sin \frac{\pi x}{a} e^{-ikx} dx \rightarrow$ Do Integration by parts twice (use ILATE)
 $a(p) = \sqrt{\frac{\pi a}{\hbar}} (e^{ika} + 1)(\pi^2 - k^2 a^2)^{-1}$
 then $|a(p)|^2 = \frac{\pi a}{\hbar} (e^{ika} + 1)(e^{-ika} + 1)(\pi^2 - k^2 a^2)^{-2} = \frac{4\pi a}{\hbar} \cos^2(\frac{ka}{2})(\pi^2 - k^2 a^2)^{-2}$

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- Q3(a) small Rotational Raman Displacement $= 4B$
- Q7(b) $\Delta \rightarrow$ Delta Baryon $\Delta^{++}, \Delta^+, \Delta^0, \Delta^-$ (Isospin $= \frac{3}{2}$)
 uuu uud udd ddd
- Q8(a) 
 solar cells use Direct since easy to form e^- -hole pair in direct since e^- need not to gain much momentum. For indirect, large momentum must also be given to e^- to produce e^- -hole pair. Then apart from photon, a phonon (lattice vibration) interaction is reqd for e^- to lose/gain momentum.
 The only flip side is that direct Band gap material suffers from carrier recombination loss.
- Q8(b) Lame eqn for X-ray diffraction $\rightarrow$ P3B pg 37 onwards.
- Q6(b) $\hbar\omega = 4/A^{-1/3}$ MeV $\rightarrow$ DCT pg 366
- Q6(a) DCT $\rightarrow$ pg 362-365
- Q5(c) P3B $\rightarrow$ pg 288 & 289

Q6(b)(c) constancy of $BE/A \rightarrow$ due to saturation property of Nuclear Force & short range nature

$\frac{BE}{A}$ vs A curve
 small nuclei $\rightarrow$ low BE/A - since (most nucleons on surface)
 large nuclei low BE/A - since (coulomb effect $\propto Z^2$)

A vs Z curve skewed towards neutron since Nuclear force is short-ranged but coulomb force throughout nucleus. Thus more neutron to hold nucleus & they don't interact in coulomb force

Q7(c) use $V_d = a + \tau = -\frac{eE\tau}{m}$ and $\mu = \frac{V_d}{E}$

Q7(a) Langevin (classical) Theory of Paramagnetism - pg 238-240 p38

here we have 2 energy level $\rightarrow$ Thus let $J = 1/2$ and $g = 2$ (assume $S = 1/2$ & $L = 0$)

$M = N \frac{g^2 \mu_B^2 B}{3kT} S(S+1)$ and $\chi_{para} = \frac{\mu_0 M}{B}$ (Also see pg 257 Eq 8-2)
 ★ p28

Q6(a)(ii) Refer DCT pg 324 & 325 (Hard)

- Q6(a)(i) • torque present for angular momentum change ($\ell = 0$ & $\ell = 2$)
 • presence of quadrupole moment proves non-central force
 • dependence on orientation of spin is characteristic of non-central force.

Q5(a) use $KE = PE$ and at $v=0$, $r=R$

Q5(b) charge independence: $F_{pp} = F_{nn} = F_{pn}$ (eg: mass, BE & excitation spectra of mirror nuclei)

charge symmetry: $F_{pp} \neq F_{nn}$ ~~depend~~ Force depends if spin is parallel or anti-parallel (spin-dependence), (eg: higher distance in nature of even-even nuclei is proof of charge symmetry (spin dependence) among stable nuclei.)

charge independence & a bigger symmetry.

concept of charge independence & charge symmetry lead to concept of Isospin. Isospin is abstract way of describing symmetry b/w neutron & proton.

MCV: Nuclear Force independent of charge (n & p same). But since Nuclear Force not a central force, Force is not solely determined by distance. Nuclear Force also depends on dirn of spin. (Force is stronger for 11^{th} spin) (Both $m_s = +1/2$ or Both $m_s = -1/2$) than for anti-parallel spin (one is $+1/2$ & other is $-1/2$)

Q5(c) Experimental observation of μ_N expt $\rightarrow$ SBP pg 166

Q4(c) $\mu_N \approx 0.5 \mu_B = 4BBg_s$ (proton $g_s \approx 5.58$)

Q4(b) NMR Active Nuclei $\rightarrow$ proton, deuterium, Tritium, 3He , 7Li , ^{10}B , ^{11}B , ^{13}C (Most common: 1H , ^{13}C)
 not all are active, eg: ^{12}C and ^{16}O are inactive (since nuclei no spin) (Both have $1/2$ spin)

major inferences $\rightarrow$ measurement of g , μ , chemical shift, & physical (chemical properties of molecules (eg: structure, dynamics, reaction state, chemical envt)). Also used in NMR.

most NMR use $\rightarrow$ chemical shift & coupling constant (BNW pg 214)

Q4(a) since $[L_x, L_y]$ don't commute. Also Griffith OM pg 179 (spin $\rightarrow$ simultaneous is violation of HUP)

$\vec{L}^2 \rightarrow L_z$ fixed in precision so L_x, L_y can take many possible values.

Q3(b) Polarisation in Raman: BNW pg 117, 118

Q1(d) Intensity & population. $\frac{N_{J+1}}{N_J} = (2J+1)e^{-\Delta E/kT}$ take $B = 2cm^{-1}$, $T = 300K$ and $J = 0$ we get $\frac{N_1}{N_0} \approx 0.98$ (BNW pg 38)

Q1(e) Transition lines in vib. spectra of HCl at room temp $\rightarrow$ ASk pg 305

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(4)

Q1(b) zero point energy = $\frac{1}{2} \hbar \omega$, $\omega = \sqrt{k/m}$

Q3(b) DIAS (4) pg 155

Q1(c) $\psi_n(x) = c_n u_n(y) e^{-y^2/2}$ where $u_n(y) \rightarrow$ Hermite polynomial = $(-1)^n e^{y^2} \frac{d^n}{dy^n} (e^{-y^2})$

Discuss parity using ψ -diagram $\rightarrow$ EM Griffiths pg 59.

if $V = \infty$ for $x \leq 0$. Then eigenstates will be all odd eigenstates of harmonic oscillator

since $\psi(0) = 0$. Then take $n = 1, 3, 5, \dots$ (note $n = 0, 2, 4, \dots$ are even)

Q5(c) characteristic times - PCT pg 698.

Refer pg 76 SDCT for examples

quas. weak EM strong (O.E. at $\sim \hbar$)
 $10^{-16}s$ $10^{-8}s$ 10^{-15} 10^{-24}

Q2(a)(i) Wikipedia Pauli Matrices (Perfect) $\rightarrow (\hat{n} \cdot \vec{\sigma}) = (a_1 \sigma_x + a_2 \sigma_y + a_3 \sigma_z)$ where $a_1^2 + a_2^2 + a_3^2 = 1$
 Now $(\hat{n} \cdot \vec{\sigma})^2 = a_1^2 \sigma_x^2 + \dots + a_1 a_3 (\sigma_x \sigma_z + \sigma_z \sigma_x) = I$ (since $\sigma_x^2 = \sigma_y^2 = \sigma_z^2 = I$) and Anti-commutation: $\sigma_x \sigma_y + \sigma_y \sigma_x = 0$
 since $\hat{n}$ is unit vector.

Thus we generalize $(\hat{n} \cdot \vec{\sigma})^{2p} = I$

and $(\hat{n} \cdot \vec{\sigma})^{2p+1} = (\hat{n} \cdot \vec{\sigma})$

Now $e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots = \sum_{k=0}^{\infty} \frac{x^k}{k!}$

Then $e^{i(\hat{n} \cdot \vec{\sigma})\theta} = \sum_{k=0}^{\infty} \frac{(i(\hat{n} \cdot \vec{\sigma})\theta)^k}{k!} = \sum_{p=0}^{\infty} \frac{(-1)^p (\hat{n} \cdot \vec{\sigma})^{2p} \theta^{2p}}{(2p)!} + \sum_{q=0}^{\infty} \frac{(-1)^q i (\hat{n} \cdot \vec{\sigma})^{2q+1} \theta^{2q+1}}{(2q+1)!}$

using Taylor series for sine & cosine

$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)!}$

and $\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2n)!}$

Q5(e) Lame Method & Debye Scherrer Method: P3B pg 41 (exponential schps)

Q6(b) P107008-2 Q3(a) $T = \frac{(\pi - \alpha)^2 c^2}{2\pi} = 4.12 \text{ MeV}$ (putting $m_{\mu} c^2 = 105.7 \text{ MeV}$)
 $m_{\pi} c^2 = 139.6 \text{ MeV}$

deuteron (d) $\rightarrow 0.511 \text{ MeV}/c^2$ $\pi \equiv m_{\pi}$

Muon (μ^-) $\rightarrow 105.7 \text{ MeV}$ (207 m_e)

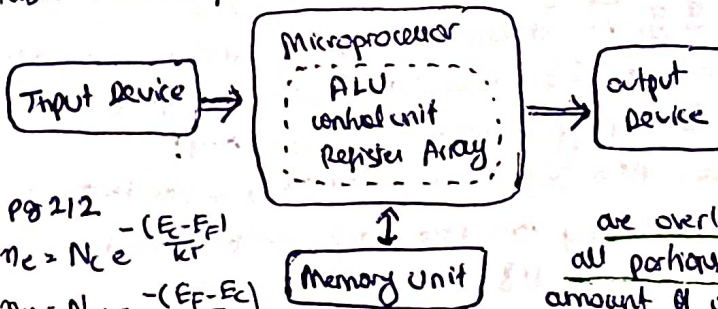
$\pi^\pm \rightarrow 139.6 \text{ MeV}/c^2$

$\pi^0 \rightarrow 135.0 \text{ MeV}/c^2$

Tauon (τ^-) $\rightarrow 1777 \text{ MeV}/c^2$ (3490 m_e)

Q6(c) Stable Isobar for odd & Even Isobar - SBP pg 190 & 193-195

Q8(c)



$\rightarrow$ P3B pg 212

Q7(c) use $n_e = N_e e^{-\frac{(E-E_F)}{kT}}$
 and $n_v = N_v e^{-\frac{(E_F-E_v)}{kT}}$

intrinsic: $n_e = n_v$

also take approximation that $N_c \approx N_v$

Then we can easily solve: $E_F = \frac{E_c + E_v}{2}$

Pipelining is the process of accumulating instruction from the processor through a pipeline. It allows storing and executing instructions in an orderly process.

It is a technique where multiple instructions are overlapped during execution. Pipelining keeps all portions of the processor occupied and increases amount of useful work processor can do in given time. Pipelining eliminates waiting time and speeds up processing. This is because CPU doesn't have to wait for one instruction to complete the machine cycle.

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(5)

- Q1(a) De Broglie used plank eqn ($E = h\nu$) and Einstein eqn ($E = mc^2$). We can also show for wave packet $v_g = v$ for rel. and non-rel. case.
- (or also $\vec{p} = -i\hbar \frac{\partial}{\partial x}$, take $\psi = Ae^{i(kx - \omega t)}$ $\rightarrow \vec{p}\psi = \hbar k\psi = \frac{h}{2\pi} \times \frac{2\pi}{\lambda} = \frac{h}{\lambda}$ $\hookrightarrow$ De Broglie - Gabor conjecture for electrons)
- Q2(b) Bohr Radius $\rightarrow$ Most Probable distance b/w Nucleus & e^- in H atom in ground state.
- Q4(a) L^2 in spherical polar coordinates - RSK pg 62
- Q4(b) use QM Griffiths technique to get $E_n = (n + \frac{1}{2})\hbar\omega$ using a_+ , a_- operators.
- Q2(a) like in P3B: D.O.S = $4\pi k^2 dk$ $\left(\frac{2\pi}{L}\right)^3 \sim 2$ from denom. gives $1/8 \rightarrow D(\omega)d\omega = \frac{V}{2\pi^2} k^2 dk \rightarrow D(\omega) = \frac{V}{2\pi^2} k^2 \frac{dk}{d\omega}$ (Don't do $\times 2$, Not given Fermions)
- Q8(c)(i) Magnetic Moment $\rightarrow$ Schmidt (DCT pg 375, 376)
- Q7(b) $f(E) = \frac{1}{e^{E - E_F/kT} + 1} \approx e^{-\frac{(E - E_F)}{kT}} \sim \langle E \rangle = \frac{\sum E_i f_i}{\sum f_i} \sim \frac{\sum E_i e^{-\frac{(E_i - E_F)}{kT}}}{\sum e^{-\frac{(E_i - E_F)}{kT}}}$ $\rightarrow$ the $e^{-E_F/kT}$ comes out and cancels
- Q5(b) Magnetic moment of nucleon using Gouda (DCT pg 752) & we get similar derivation as MB
- Q6(a) method to find size of Nuclei: Rutherford's closest approach method of α -decay $\rightarrow$ Find maxima of e^- diffraction pattern using Nucleus as diffracting object & e^- as particle. $2R \sin\theta = 1.22\lambda$
- Q5(c) close-packed planes & close-packed dirn $\rightarrow$ refer P3B pg 22 $R = \frac{1.22 \times 0.61h}{\sin\theta \cdot mv}$

2020 - Paper 2 (V. Fault 1st Iteration)

Better $\leftarrow$ Arthur Beiser pg 138 (or) M.C Jain pg 50 QM

- Q1(c) Diamond occupies $1/2$ of tetra voids $\rightarrow$ Total 4 in cell & 4 in voids $\Rightarrow 8$ total (pg 24 & 33 P3B $\rightarrow$ diamond)
- Q1(a) $E \propto \frac{1}{n^2} \rightarrow$ at large n , All closely spaced & Freely diff like a continuum. $\rightarrow$ (Bohr correspondence principle: Quantum theory agrees with classical theory in limit of large quantum numbers)
- Q4(a) Reunion: 96% $3s$, and 4% $3p$. $\rightarrow$ Ms. state = $4p + 4n$ $\leftarrow$ refer DCT 324, 325
- Q5(c) $\tau_{av} = 1/\lambda \sim$ derivation $\tau_{av} = \frac{\int_0^\infty t e^{-\lambda t} dt}{\int_0^\infty e^{-\lambda t} dt}$ where $N = N_0 e^{-\lambda t}$ so $dN = -N_0 \lambda e^{-\lambda t} dt$ (SBP 62 & 63)
- Q5(e) Hall coefficient = $1/ne$
- Q7(c) Harder version of Question $\rightarrow$ P3B pg 96
- Q6(b) P3B pg 201 $\rightarrow$ Intrinsic Semiconductor P3B pg 212 $\rightarrow$ Fermi-level of intrinsic Diff. coefficient
- Q5(a) Fick's Law: Diffusion flux $J = -D \frac{\partial C}{\partial x}$ $\rightarrow$ concentration $\rightarrow$ units will match since given: $D = (-) m^2 s^{-1}$
- Now $n = \frac{4}{a^3}$ in FCC $\rightarrow \frac{C_1}{C_2} = \frac{0.19 \times 10^{-2} \times n}{0.18 \times 10^{-2} \times n} \rightarrow J = -D \times \frac{\partial C}{\partial x}$
- Q8(b) Zeeman Effect on Basis of classical electron theory RSK $\rightarrow$ pg 202 $(m r \omega^2 r \sin\theta \cos\theta = m r (\omega + d\omega)^2)$ $\rightarrow$ FC (centrifugal) $\rightarrow$ FB (magnetic) $\rightarrow$ number density $\rightarrow$ C same unit as n $\rightarrow$ number density $\rightarrow$ Final result in Transp. plane $(D = \frac{1}{2} \bar{v} \lambda)$

2021 - Paper 1 (V. Fast 1st Iteration)

⑥

- Q1(c) use $(\Delta x)^2 - c^2(\Delta t)^2 = (\Delta x')^2 - c^2(\Delta t')^2$ → Faster than solving individual Lorentz eqn to find value of v , d , etc...
- Q3(a) Material Dispersion coefficient D_m (ASG pg 28.16). $\Delta T_m = D_m \times L \Delta \lambda_0$ (check unit of D_m to recall)
- Q5(d) Given unit is gm-mol at NTP → 22.4 L. I will show how:

$$b = 4 \times \frac{4}{3} \pi r^3 \times N_A, \text{ let } r = 1.5 \times 10^{-10} \text{ m} \sim \text{then } b = 4 \times 10^{-5} \text{ m}^3 \sim \text{put } 1 \text{ m}^3 = 10^3 \frac{\text{L} \times 22.4}{22.4}$$

$$\text{let unit } d = 22.4 \text{ L then } 1 \text{ m}^3 = \frac{10^3}{22.4} d \rightarrow b = 4 \times 10^{-5} \times \frac{10^3}{22.4} d = 0.002 d \text{ (as given)}$$

$$T_{\text{Boyle}} = \frac{a}{Rb}$$

$$Q8(c) E_{\text{cond}} = \sigma \epsilon_0 \quad E_{\text{charge sheet}} = \sigma / 2 \epsilon_0 \quad \text{Just use superposn principle.}$$

Q5(e) DIAS(3) pg 61 exact Question

Q6(b) Now $i_p = \frac{V}{R} = 3 \text{ A}$ and $i_{p0} = \frac{V}{R_0} = 1.5 \text{ A}$. When switch is disconnected, current through inductor cannot change suddenly, and (then current through R_0 becomes 3 A to right from previous 1.5 A to right)
 Now easy: $i = 3e^{-\frac{t}{L(R+R_0)}}$; $Q = \int i^2 R dt = R \times 3^2 \times L = 3 \mu\text{J}$

(or we can solve as $E_{\text{inductor}} = \frac{1}{2} L I^2 = 9 \mu\text{J}$ → dissipation in Ratio $\frac{R}{R_0} = \frac{1}{5}$ → then $3 \mu\text{J}$ in R and $6 \mu\text{J}$ in R_0 .)

Q8(b)(i) 2 defn of: (i) Highest Energy level an e^- can occupy at 0 kelvin
 Fermi level (ii) level at which we can expect e^- to be present 50% of the time

Q7(a) $(P_1 \ln - P_2 \ln) = \sigma_{\text{free}} = 0$. use $(F)_E = (E)_E$ & $(P_1 \ln - P_2 \ln)$

Q4(c) logarithmic decrement = $\delta = \ln \frac{x_{n+1}}{x_n}$ and $\delta = \frac{2\pi}{\sqrt{\omega_0^2 - \omega^2}}$
 Refer DIAS(2) pg 26
 and $\delta = \frac{1}{B} = \sqrt{\frac{2}{\mu_0 \omega}}$
 vs Ballistic Galvanometer DIAS(2) pg 27

Q7(b) Skin depth of EM wave → SPEN pg 328
 in a good conductor
 ($k \rightarrow \infty$)
 $\delta = \frac{1}{B} = \sqrt{\frac{2}{\mu_0 \omega}}$

2021 - Paper 2 (V. Fast 1st Iteration)

Q1(b) use $\langle \frac{1}{r} \rangle = \int_0^\infty \frac{1}{r} |\psi|^2 4\pi r^2 dr$
 Q1(c) $2B = 21.18 \text{ cm}^{-1}$ (pg 403 PTO 2016 → $4B = 41.6 \text{ cm}^{-1}$)

Q5(e) Critical size of core → SBP pg 223

Q6(b) $\hbar \omega = 41 \text{ A}^{-1/3}$ → PCT pg 366

Q6(c) Newton's Law → Bookmark: newlines.fnl.gov (read both tabs → Basics & Max Info)

Q4(b) $P(1x17a) \approx 0.16$ → DIAS(4) pg 123

Q3(c) Take all combination possibilities → The 5 values and no. of times S is repeated will come out same → Risk pg 163 example 5.

Q2(b) even for e^- → $\Delta V \approx 10^5$ → so we don't need to use relativistic anywhere. use normal HUP for all the subparts of this question.

Q7(b) Note → here there is an external field. we only put $1/2$ of Thomson precession for spin-orbit coupling due to internal field. Use 0.5 T to external.

Secondly: don't use $\mu_B g_s m$, because question not saying Zeeman split. Just about a dipole in field → so $-\vec{\mu} \cdot \vec{B} \rightarrow \text{min when } \parallel$.

Now $L = 2, S = 1/2 \rightarrow S = L - S = 3/2$ (since d orbital is less than half full, so take $S = L - S$)

Now $g \approx 0.8, S = \sqrt{S(S+1)} \hbar$ and $\vec{\mu} = -\frac{e}{2m} g_s \vec{S}$. Lowest $E = -\mu_B = -\frac{e}{2m} g_s \sqrt{S(S+1)} \hbar B$

Q8(b) Hund Rule → 3 e^- parallel → $S = 1/2 + 1/2 + 1/2 = 3/2$. (for L & S → use only unpaired e^-)
 Now Max $L = 3 + 2 + 1 = 6$ (since $m_l = 3, 2, 1$ → Pauli exclusion principle)
 $S = L - S = 9/2$ (L & S both less than half full) and $g = 0.73$ (putting L, S, S)
 Now $N = 10^{25} \text{ m}^{-3}$
 $T = 1 \text{ K}$
 $\chi = \frac{\mu_0 N g^2 \mu_B^2 S(S+1)}{3k_B T}$ [Do example 8-3 P28 pg 259 for more than half-filled]
 [Q7(b) & 8(b) from student test soln internet]