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Physics 3 CRAMSheet

PHYSICS 3

ELECTROMAGNETIC INDUCTION

MOTION IN MAGNETIC FIELDS AND INDUCTANCE

Equations you will need

Description	Equation	Description	Equation
Faraday's law of induction 1. The emf induced in a loop is directly proportional to the rate of change of magnetic flux through the loop	$\varepsilon = -N\frac{d\phi_B}{dt}$	2. Emf and current induced in a moving conductor	$\varepsilon = -Blv$
Lenz's law 1. The induced current in the loop is in such a direction so as to oppose the changing magnetic flux through the area of the loop.	$I = \frac{Blv}{R}$	2. A changing magnetic field can induce an electric field	$\oint \vec{E}.d\vec{s} = -\frac{d\phi_B}{dt}$
		3. Emf induced in a generator	$\varepsilon = NAB\omega \sin \omega t$
Max 1. Gauss' law of electricity relates net electricity flux to net enclosed electric charge.	$\oint \vec{E}.\overrightarrow{dA} = q_{enc} / \varepsilon o$	2. Gauss' law for magnetism relates net magnetic flux to net enclosed magnetic charge.	$\oint \vec{B}.\overrightarrow{dA} = 0$
3. Faraday's law relates induced electric field to changing magnetic flux.	$\oint \vec{E}.d\vec{s} = -\frac{d\phi_B}{dt}$	4. Ampere- Maxwell law relates induced magnetic field to changing electric flux and to current.	$\oint \vec{B}.d\vec{s} = \mu_0\varepsilon_0\frac{d\phi_E}{dt} + \mu_o i_{enc}$
5. Self inductance	$\varepsilon_L = -L\frac{dI}{dt}$	6. Inductance of a solenoid	$L = \frac{\mu_o N^2 A}{l}$
7. Energy stored in the magnetic field of an inductor	$u = \frac{1}{2}LI^2 = B^2 Al / 2\mu_o$	8. Magnetic energy density	$u_B = \frac{B^2}{2\mu_o}$
9. Mutual inductance	$M_{12} = \frac{N_2\phi_{12}}{I_1} = M_{21} = \frac{N_2\phi_{21}}{I_2}$	10. Relationship between induced emf and inducing current	$\varepsilon_1 = -M\frac{dI_2}{dt}$ And $\varepsilon_2 = -M\frac{dI_1}{dt}$

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ALTERNATING CURRENT CIRCUITS

Equations you will need

Description	Equation	Description	Equation
Instantaneous voltage of an AC source	$\Delta V_R = I_{max} R Sin wt$	RMS voltage and current	$V_{rms} = 0.707 V_{max}$ $I_{rms} = 0.707 I_{max}$
Current through the inductor in an LR AC circuit	$i_L = \frac{\Delta V_{max}}{\omega L} Sin(\omega t - \pi/2)$	Inductive reactance	$X_L = \omega L$
For an inductor voltage leads current by π/2 where X_L =inductive reactance.	$\Delta V_L = -\Delta V_{max} Sin\omega t$ $= -I_{max} X_L Sin\omega t$	Current through the capacitor in an RC AC circuit where Xc = capacitive reactance	$I_{max} = \frac{\Delta V_{max}}{Xc}$
Capacitive reactance	$Xc = \frac{1}{\omega C}$	For a capacitor voltage lags behind current by π/2	$\Delta V_c = \Delta V_{max} Sin\omega t$
Impedance of an LCR circuit	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	Maximum current in an LCR circuit	$I_{max} = \frac{\Delta V_{max}}{\sqrt{R^2 + (X_L - X_C)^2}}$
Phase angle between voltage and current	$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$	Power factor	$Cos\phi = R/Z$
Average power delivered by the source	$P_{av} = I_{RMS} \Delta V_{RMS} Cos\phi$	Resonance frequency in an LCR circuit	$f_o = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$
Average power delivered by the source at resonance	P_{av} at resonance $= (\Delta V_{rms})^2 / R$	Quality factor	$Q = \omega_o L / R$
Turns ratio in a transformer	$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$	Conservation of power in an ideal transformer	$Ip\Delta Vp = Is\Delta Vs$

ELECTROMAGNETIC WAVES

Good to know

Properties
1) E.M. are transverse waves because the electric and magnetic fields are perpendicular to the direction of travel.
2) E.M. waves travel with the speed of light.

Equations you will need

Description	Equation	Description	Equation
The speed of E.M. waves	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$	The rate of flow of energy is given by the pointing vectors S.	$S = \frac{1}{\mu_0} E \times B$
The wave intensity I	$I = \frac{C}{2\mu_0} B^2_{max}$	Polarization EM waves are polarized if there eclectic field vectors are all in a single plane called the plane of polarization.	
Radiation pressure exerted 1). By a perfectly absorbing surface 2). By a perfectly reflecting surface	$P = \frac{S}{C}$ $P = \frac{2S}{C}$	Intensity of transmitted light	$I = \frac{1}{2} I_0$
		Malu's law or cosine square law for polarized light	$I = I_0 \cos^2 \theta$
Energy density	$u = \frac{B^2}{\mu_0}$	Brewster's law	$n = \tan \theta_p$
Average energy density	$u_{av} = \frac{B^2_{max}}{2\mu_0}$		

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SPECIAL RELATIVITY

Good to know

Two basis postulates
1). Laws of physics are the same in all inertial frames of reference.
2). Speed of light is the same for all inertial frames and independent of their motion or the motion of the sources of light.

Equations you will need

Description	Equation	Description	Equation
Time dilation	$\Delta t = \gamma \Delta t$	Length contraction	$L = L_0 / \gamma$
Lorentz transformation equations	$x^1 = \gamma(x - vt)$ $y' = y$ $z' = z$ $t' = \gamma(t - vx/c^2)$	Relativistic momentum	$p = \gamma mV$ where $\gamma = 1 \big/ \sqrt{1 - v^2/c^2}$
Galilean transformation	$x' = x - vt$ $t' = t$	Relativistic velocity transformation	$u = \dfrac{u' + v}{1 + u'v/c^2}$ where u = velocity of particle in S frame. u' = velocity of particle in S' moving with velocity 'v' relative to S.
Relativistic mass variation	$m = \gamma m_0$		
Relativistic expression for kinetic energy	$K.E. = mc^2(\gamma - 1)$	Relativistic expression for total energy	$E = KE + mc^2$
Relativistic doppler effect	$f = f_0 \sqrt{\dfrac{1-\beta}{1+\beta}}$ where $\beta = v/c$	Transverse doppler effect	$f = f_0 \sqrt{1 + \beta^2}$

PARTICLES AND WAVES

Equations you will need

Description	Equation	Description	Equation
Black body radiation		Relations between cut off frequency and work function	$f_c = \dfrac{\phi}{h}$
Wein's law	$\lambda_p T = 2.90 \times 10^{-3}\, mK$ $\lambda_p =$ wavelength of peak of spectrum	Photon momentum	$p = \dfrac{h}{\lambda}$
Photo electric effect :- Photon energy	$E = hf$	**Compton effect**	
Plank's constant	$h = 6.63 \times 10^{-34}\, Js$ $= 4.14 \times 10^{-15}\, eVs$	Compton shift	$\Delta\lambda = \lambda' - \lambda = \lambda_c(1 - \cos\phi)$
hc	$1240\, eVnm$	Compton wavelength	$\lambda_c = \dfrac{h}{m_e c} = 2.43\, pm$
The photo electric equation	$hf = K.E_{max} + \phi$ $\phi =$ work function	**Matter waves**	
The maximum kinetic energy	$K.E_{max} = eV_o$ where $V_o =$ stopping potential	de Broglie wavelength	$\lambda = h/\rho$
		Frequency of matter waves	$f = E/h$

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PARTICLES AND WAVES

Equations you will need

Description	Equation
Schrödinger's equation **:** - The Schrödinger's equation plays the role of Newton's law and conservation of energy in quantum mechanics. It is a wave equation in terms of the wave function which predicts precisely the probability of events or outcome	
Time dependent Schrödinger equation	$\frac{-h}{2m}\frac{\partial^2\Psi(x,y)}{\partial x^2}+u(x)\Psi(x,t)=i\hbar\frac{\partial\Psi}{\partial t}(x,t)$
For free particle $u(x)=0$	$\Psi(x,y)=Ae^{icx-iwt}$
Time independent Schrödinger equation	$\frac{d^2\Psi}{dx^2}+\frac{8\pi^2k}{h^2}\left[E-u(x)\right]\Psi=0$
For a free particle where $u(x)=0$ the Schrödinger equation becomes	$\frac{d^2\Psi}{dx^2}+\frac{2mE}{h^2}\Psi=0$ Or $\Psi = A\sin kx + B\cos kx$ Where $k=\sqrt{\frac{2mE}{h^2}}$
Probability density	$\lvert\Psi\rvert^2$
Heisenberg's uncertainty principle	$\Delta x.\Delta p \geq h/4\pi$ $\Delta E.\Delta t \geq h/4\pi$
Barrier tunneling: - The probability that a particle of mass 'm' in and energy E will tunnel though a barrier of u_0 height and thickness L is given by the transmission co-efficient T	$T=e^{-2kL}$ Where $k=\sqrt{\frac{8\pi^2m(u_o-E)}{h^2}}$
Particle in a box	
The solution to S.E. becomes	$\Psi_n(x)=A\sin kx$ where $k=n\pi/L$
After normalization	$\Psi_n(x)=\sqrt{\frac{2}{L}}\sin\frac{n\pi}{L}x$ Where n = 1, 2, 3…

Description	Equation
Box with infinite (rigid) walls	
The normalized wave function	$\Psi_n(x)=\sqrt{\frac{2}{L}}\sin\frac{n\pi}{L}x$
Energy	n = 1, 2, 3 L = width of well $E_n=\left(\frac{h^2}{8mL^2}\right)n^2$
The probability density	$\Psi_n^2(n)=A^2\sin^2\left(\frac{n\pi}{L}\right)x$
Normalizing equation	$\int_{-\infty}^{\infty}\Psi_n^2(x)dx=1$
Finite potential well quantized energy for electron trapped in 2D infinite potential well	$E_{nx,ny}=\frac{h^2}{8m}\left(\frac{n_x^2}{L_x^2}+\frac{n_y^2}{L_y^2}\right)$
Electron trapped in 3D infinite potential well	$E_{n,ny,nz}=\frac{h^2}{8m}\left(\frac{n_x^2}{L_x^2}+\frac{n_y^2}{L_y^2}+\frac{n_z^2}{L_z^2}\right)$
In hydrogen atom, energy of electronic quantum states	$E_n=-\frac{13.6}{n^2}eV$ Where n = 1, 2…..
Potential energy function	$u=-\frac{1}{4\pi\epsilon_0}\frac{e^2}{r}$ e = electron charge
Radical probability density	$P(r)=\frac{4}{a^3}r^2e^{-2r/a}$ a = Bohr radius = 52.9 pm

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NATURE OF ATOM

Equations you will need

Description	Equation
The Rydberg-Ritz formula The reciprocal wavelength	$\frac{1}{\lambda} = R\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$ n_1 and n_2 are integers and R = Rydberg constant
<u>Bohr's model of hydrogen atom</u>	
The potential energy	$u = -\frac{1}{4\pi \in_o}\frac{e^2}{r}$ r = radial distance from proton
Bohr's postulates 1. The electron in the hydrogen atom moves only in non-radiating circular orbits 2. The frequency of emitted radiation during a transition = difference between the initial & final energies 3. The angular momentum of an electron in a stable orbit is quantized	
Photon frequency from energy conservation	$f = \frac{E_i - E_f}{\lambda}$
Quantized angular momentum	$mvr = n\hbar \quad n = 1, 2, \ldots$
First Bohr radius	$a_0 = \frac{\hbar^2}{mke^2} = 0.0529nm$
Radius of Bohr orbits	$r = \frac{n^2 a_0}{Z}$
Energy levels in hydrogen atom	$E_n = -\frac{mk^2e^4}{2\hbar^2}.\frac{Z^2}{n^2} = -Z^2\frac{E_o}{n^2}$
The energies with Z = 1, are he quantized allowed energies for H_2 atom E_o	$-\frac{mk^2e^4}{2\hbar^2}$ □ $13.6eV$
Wavelength emitted by hydrogen atom	$\lambda = \frac{1240eVnm}{E_i - E_f}$

Description	Equation
<u>Quantum numbers</u>	
Principle quantum number	n = 1, 2, 3 …
Orbital quantum number	$l = 0, 1, 2, 3 \ldots\ldots(N-1)$
Magnetic quantum number	$m_l = -l, (-l+1), \ldots. -2, -1, 0, 1, 2, \ldots(l+1), l$
Orbital angular momentum	$L = \sqrt{l(l+1)}\hbar$
Z component of angular momentum	$L_Z = m_l \hbar$
Wave functions for hydrogen atom Ground state	$\Psi_{1,0,0} = C_{1,0,0}e^{-Zr/a_o}$ $= \frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_o}\right)^{3/2} e^{-Zr/a_o}$
Magnetic dipole moment	$\vec{\mu}_{orb} = -\frac{e}{2m}\vec{L}$
Orbital magnetic dipole moment	$\mu_{orb.Z} = -m_i \mu_b$
Spin angular momentum	$\vec{S} = \sqrt{S(S+1)}\hbar$
Spin magnetic dipole moment	$\vec{\mu}_S = -\frac{e}{m}\vec{S}$ $= -\frac{e}{m}\sqrt{S(S+1)}\hbar$
Pauli's exclusion principle No two electrons in an atom can have the same set of values for the quantum nos. n, l, m_e and m_S	

Description	Equation
<u>X – Rays</u> Minimum possible X – rays wave length Moseley's law –empirical law concerning the characteristic electromagnetic spectrum that is emitted or absorbed by atom.	$\lambda_{min} = \frac{hc}{k_o}$ (cut off wave) Where k_o = initial kinetic energy $\sqrt{f} = k_1(z + k_2)$ f=frequency of main x- ray emission line. k_1 and k_2 are constants and same for all kα lines
<u>Lasers</u> The natural population of atoms in thermal equilibrium at gives by the Boltzmann distribution The ratio of the number of atoms in two states N' and N	$N_n = C_e^{-E_n/kT}$ $\frac{N_n}{N_n'} = e^{-\left(\frac{E_N - E_N'}{kT}\right)}$

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NUCLEAR PHYSICS AND RADIOACTIVITY

Equations you will need

Description	Equation	Description	Equation
Radius of nucleus	$R = R_o A^{1/3}$ where $R_o = 1.2\, f_m$	Radioactive decay law	$N = N_o e^{-\lambda t}$
Total nuclear binding energy	$E_b = (ZM_H - Nm_N - M_n)c^2$ Where M_H = mass of 1 hydrogen atom; M_n = mass of neutron; M_A = atomic mass of atom	Half life	$T_{1/2} = \frac{0.693}{\lambda}$
		Mean life	$\tau = \frac{T_{1/2}}{0.693}$
		Alpha decay	${}_Z^A N \rightarrow {}_{Z-2}^{A-4} N + {}_2^4 He$
Radioactivity The decay rate R (no. of decays / sec)	$R = -\frac{dN}{dt} = \lambda N = \lambda N_o e^{-\lambda t}$	Beta decay	${}_Z^A N \rightarrow {}_{-1}^0 e + {}_{z+1}^A N'$
		Gamma decay	${}_Z^A \underset{\downarrow}{N^*}_{\text{exuted state}} \rightarrow {}_Z^A N + \gamma$

IONIZING RADIATION, NUCLEAR ENERGY, AND ELEMENTARY PARTICLES

NUCLEAR RADIATION

Equations you will need

Description	Equation	Description	Equation
Effective cross-section σ (particular reaction occurring/ target nucleus)	$\sigma = \frac{R}{R_0 nt}$ R = rate at which collision occurs; R_o = rate of which projectile strikes the target/ unit	Reaction energy or Q value	If $a + X = Y + b$; $Q = (M_a + M_x - M_b - M_y)c^2$
		Reaction is exothermic	If Q > 0
		reaction is endothermic	If Q < 0
Nuclear fusion		**Absorbed dose**	
Fusion reactions in the sun (proton – proton cycle)	${}_1^1 H + {}_1^1 H \rightarrow {}_1^2 H + e^+ + \delta\,(0.42\, Mev)$; ${}_1^1 H + {}_1^2 H \rightarrow {}_2^3 He + \gamma\,(5.49\, Mev)$; ${}_2^3 He + {}_2^3 He \rightarrow {}_2^4 He + {}_1^1 H + {}_1^1 H\,(12.86\, Mev)$	Absorbed dose	$= \frac{\text{Energy absorbed}}{\text{mass of absorbing material}}$
Lawson criterion		1rad	$1\text{rad} = 1.00\times10^{-2}\ J/kg$
The Lawson criterion has to reached to produce ignition	$n\tau \gtrsim 2\times10^{20} S/M^3$; $n = ion\ density$; $\tau = confinement\ time$	Gray	$1Gy = 1\ J/kg = 100 rad$
Dosimetry		The relative biological effectiveness (RBE) or quality factor (QF)	
1 Curie	$1Ci = 3.70\times10^{10}$ disintegration per sec	* Effective dose (rem)	$= dose(in\ \ rad)\times QF$
1 Becquerel	$1Bq$ = 1 disintegration/ sec	* Elective dose (sievert)	$= dose(Gy)\times QF$
		* Biological equivalent dose (in rems)	= Absorbed dose $\times = RBE$ (in rads)

NUCLEAR ENERGY

Equations you will need

Description	Equation
Diatomic molecule moment of inertia	$I = \mu r_0^2$
Reduced mass	$\mu = \frac{m_1 m_2}{m_1 + m_2}$
Rotational energy levels	$E_l = \frac{l(l+1)\hbar^2}{2I} = l(l+1)E_{or}, \quad l = 0,1,2$ Where $E_{or} = \frac{\hbar^2}{2I}$
Vibration energy level	$E_v = \left(\frac{v+1}{2}\right)hf \qquad v = 0,1,2$
The frequency of oscillation of a diatomic molecule connected by a spring	$f = \frac{1}{2\pi}\sqrt{\frac{kf}{\mu}}$
Net attractive potential of an ion in crystal	$u = -\frac{\alpha k e^2}{r}$ r = separation between ions α = Madelung constant
Dissociation energy of crystal	$u(r_0) = -\frac{\alpha k e^2}{r_0}\left(1 - \frac{1}{n}\right)$ r_0 = equilibrium separation
Resistivity in terms of Vav and λ	$\rho = \frac{m_e v_{av}}{n_e e^2 \lambda}$

Description	Equation
The Fermi Energy	
Fermi energy at T = 0 in one dimension	$E_F = \frac{h^2}{32 m_e}(N/L)^2$ where N = number of electrons
In three dimensions	$E_F = \frac{h^2}{8m_e}\left(\frac{3N}{\pi V}\right)^{2/3}$ $E_F = (0.365eVnm^2)\left(\frac{N}{V}\right)^{2/3}$
Average energy of electrons in a Fermi gas at T = 0	$E_{av} = \frac{3}{5}E_F$
The probability of an energy state being occupied is called the Fermi factor f/E	$f/E) = 1, \; E<E_F$ $f/E) = 0, \; E>E_F$
Fermi factor	$f/E) = 1\Big/\left[e^{(E-E_f)/(kT)} + 1\right]$
The Fermi temperature T_F	$kT_F = E_F$
The Fermi speed U_F	$U_F = \sqrt{\frac{2E_F}{m_e}}$

NUCLEAR ENERGY

Equations you will need

Description	Equation	Description	Equation
The Fermi energy			
When two metals are placed in contact, the contact potential	$V_{contact} = \frac{\phi_1 - \phi_2}{e}$ where ϕ_1 and ϕ_2 are the work functions of the metal	Specific heat due to conduction electrons The Fermi-Dirac distribution	$C_v^1 = \frac{\pi^2}{2}R\frac{T}{T_F}$
The number of electrons with energies E and E + dE	$n(E)dE = g(E)dE + f(E)$	The density of states	$g(E) = \frac{8\sqrt{2}\pi m_e^{3/2}V}{h^3}E^{1/2} = \frac{3}{2}NE_F^{-3/2}E^{1/2}$ $f(E) = fermi\ factor$