PHYSICS 106

Physics for the Life Sciences II

Sound
Electricity and Magnetism
Optics
Modern Physics

PHYS 106
Sections 01A
MWF 11:30
PEngel 173

Text:
College Physics
with Enhanced WebAssign
By Open Stax

Fall 2019
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Homework will be assigned via WebAssign.net. Note that these homework problems are selected from the chapter-end problems in our textbook, but different students will get different numerical values and hence have different answers. Generally homework is due before midnight on the following lecture day. Late homework will be assessed a 15% penalty; you must request a WebAssign “extension” within one day of the original due date in order to turn in late homework. While the web promises global connections, it often promotes isolation. Consider avoiding web-induced isolation by forming a problem solving group. (Again, everybody's numbers will be slightly different, but the algebra and thought required to solve the problems will be the same.) Or just work the homework with classmates in our “Physics Library” PEngel 104; I'll then be near by when you have questions. Note that assigned homework should just be the start to developing your problem solving skills: work extra odd problems and check the answer in the back of the textbook!

To use WebAssign for homework you will need the access code you purchased with your textbook to self-register for your course section.

1. Go to http://www.webassign.net/login.html
2. Click on the “I have a class key” button below the “Login” button
3. Enter the class key corresponding to your class section listed below:

11:30 Section 01A   csbsju 0970 0865

Topic 1 – Sound
Class 1-3

Reading: Chapter 17

Objectives:

1. Be able to describe characteristics of sound waves including speed, intensity, pitch, timbre, wavelength, frequency, amplitude, reflection.
2. Know that the speed of sound varies with temperature and material.
3. Be able to calculate decibel levels.
4. Be able to describe the **Doppler effect** and apply the Doppler equation.
5. Be able to define **superposition, standing wave, node, antinode, resonance, and beat frequency**.
6. Be able to calculate **resonant frequencies** (fundamental and harmonics) for columns of air (pipes).

Equations to Know from Memory:

sound speed in air: $v=(331\ \mathrm{m/s})\sqrt{\dfrac{T}{273\,\mathrm{K}}}$ frequency/wavelength: $v=f\lambda$

Intensity: $I\equiv\dfrac{\text{power}}{\text{area}}=\dfrac{\mathcal{P}}{A}=\dfrac{(\Delta p)^2}{2\rho v}$

Decibel Level: $\beta\equiv 10\log\left(\dfrac{I}{I_0}\right)$ $I_0=10^{-12}\,\mathrm{W/m^2}$

Doppler Effect: $f_O=f_S\left(\dfrac{v+v_O}{v-v_S}\right)$

Standing Waves:

Both Ends Same ($n = 1, 2, 3, ...$)

$\lambda_n=\dfrac{2L}{n}$ $f_n=\dfrac{v}{\lambda_n}=\dfrac{nv}{2L}=nf_1$

Different Ends ($n = 1, 3, 5, ...$)

$\lambda_n=\dfrac{4L}{n}$ $f_n=\dfrac{v}{\lambda_n}=\dfrac{nv}{4L}=nf_1$

Beat Frequency: $f_b=|f_2-f_1|$

surface area of sphere: $4\pi R^2$

Topic 2 – Electric Forces and Fields
Class 4-5

Reading: Chapter 18

Objectives:

1. Be able to describe the difference between **conductors** and **insulators**.
2. Be able to describe the conservation and quantization of electric charge.
3. Be able to describe how to charge by friction, conduction, and induction.
4. Be able to describe polarization.
5. Be able to calculate electric forces using **Coulomb's Law**.
6. Be able to calculate **electric fields** due to point charges.
7. Be able to use superposition (vector addition) to find the electric field when multiple sources are present
8. Be able to draw and interpret electric field lines.

Equations to Know from Memory:

Coulomb's Law: $F = k_e \frac{|q_1||q_2|}{r^2}$ Electric Field: $\vec{E} \equiv \frac{\vec{F}}{q_0} = k_e \frac{|Q|}{r^2}$

Physical Constants to Understand:

Fundamental Charge: $e = 1.6 \times 10^{-19}$ C

Coulomb Constant: $k_e = 8.9875 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2 \approx 9 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$

Permittivity of Free Space: $\epsilon_0 = \frac{1}{4\pi k_e} = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

Topic 3 – Electrical Potential and Capacitance
Class 6-8

Reading: Chapter 19

Objectives:

1. Be able to describe **electric potential** (in volts) and **electrical potential energy** (in J).
2. Be able to calculate electric potential differences. Note the textbook will often abbreviate: $\Delta V \rightarrow V$ nevertheless voltages are always voltage **differences,** e.g., the voltage difference between capacitor plates
3. Be able to use superposition to calculate electric potential and electrical potential energy if multiple sources are present.
4. Be able to calculate electrical potential energy.
5. Be able to describe the operation of a **capacitor** – calculate capacitance based on electrical measurements and physical attributes.
6. Be able to calculate the equivalent capacitance for **series, parallel**, and complex combinations of capacitors.
7. Be able to calculate the **energy stored** in a capacitor.
8. Be able to describe how dielectrics modify electric fields. Be able to define dielectric constant κ .

Equations to Know from Memory:

Change in potential energy in uniform electric field: $\Delta PE = -qE_x \Delta x$

Potential Difference: $\Delta V = \frac{\Delta PE}{q}$ in uniform E-field: $\Delta V = -E_x \Delta x$

Point charges: Electric Potential: $V = k_e \frac{Q}{r}$ Potential Energy: $PE = k_e \frac{q_1 q_2}{r}$

Capacitance: $C \equiv \frac{Q}{\Delta V}$ Parallel-Plate Capacitor: $C = \kappa \epsilon_0 \frac{A}{d}$ $\kappa \equiv \frac{\epsilon}{\epsilon_0}$

Energy Stored in Capacitor: $W = \frac{1}{2} Q (\Delta V) = \frac{1}{2} C (\Delta V)^2 = \frac{Q^2}{2C}$

Capacitors in Parallel: $C_{\mathrm{eq}} = C_1 + C_2 + C_3 + \cdots$

Capacitors in Series: $\frac{1}{C_{\mathrm{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

Physical Constants and Units to Understand:

Volt: $1\ \mathrm{V} = 1\ \mathrm{J/C}$
Electron Volt: $1\ \mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$
Electric Field: $1\ \mathrm{N/C} = 1\ \mathrm{V/m}$
Capacitance (farads): $1\ \mathrm{F} = 1\ \mathrm{C/V}$

Topic 4 – Current and Resistance
Class 9-10

Reading: Chapter 20

Objectives:

1. Be able to define and calculate **current** and drift velocity.
2. Be able to describe the operation of a resistor – calculate **resistance** based on electrical measurements and physical attributes.
3. Be able to apply **Ohm's Law**.
4. Be able to calculate **power** supplied to devices and power dissipated by resistors.
5. Be able to calculate using equivalent **alternating current** quantities ($I_{rms}, V_{rms}, P_{avg}$) and to relate them to corresponding amplitudes (I_0, V_0)

Equations to Know from Memory:

Current: $I_{\text{av}} \equiv \frac{\Delta Q}{\Delta t}$ $\quad I = \lim_{\Delta t \to 0} I_{\text{av}} = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t}$ $\quad I = nqv_d A$

Resistance: $R \equiv \frac{\Delta V}{I}$ $\quad R = \rho \frac{L}{A}$ $\quad$ Ohm's Law: $\Delta V = IR$

Power Supplied: $\mathcal{P} = \Delta V\, I$ $\quad$ Power Dissipated by Resistor: $\mathcal{P} = I^2 R = \frac{\Delta V^2}{R}$

AC: $I_{rms} = \frac{I_0}{\sqrt{2}}$ $\quad V_{rms} = \frac{V_0}{\sqrt{2}}$ $\quad I_{rms} = \frac{V_{rms}}{R}$ $\quad P_{ave} = I_{rms} V_{rms}$

Physical Constants and Units to Understand:

Current (amps): $1\text{ A} = 1\text{ C/s}$
Resistance (ohms): $1\ \Omega = 1\text{ V/A}$
Energy (kilowatt-hour): $1\text{ kWh} = 3.60 \times 10^6\text{ J}$

Topic 5 – DC Circuits

Class 11-12

Reading: Chapter 21

Objectives:

1. Be able to describe sources of **emf** and calculate their terminal voltage and power output.
2. Be able to describe how to use voltmeters and ammeters in circuits
3. Be able to calculate the equivalent resistance for **series, parallel**, and complex combinations of resistors.
4. Be able to apply **Kirchhoff's Rules** to complex circuits.
5. Be able to describe transient currents in **RC circuits** and calculate time constants.
6. Be able to describe household circuits.

Equations to Know from Memory:

emf Sources – Terminal Voltage: $\Delta V = \mathcal{E} - Ir$ Power Output: $\mathcal{P} = I\mathcal{E}$

Resistors in Series: $R_{eq} = R_1 + R_2 + R_3 + \cdots$

Resistors in Parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

Kirchhoff's Rules: $\sum I_{in} = \sum I_{out}$ (junction rule) $\sum \Delta V = 0$ (loop rule)

Capacitor Charging: $\Delta V = \mathcal{E}\left(1 - e^{-t/RC}\right)$ $I = (\mathcal{E}/R) e^{-t/RC}$

Capacitor Discharging: $\Delta V = \mathcal{E} e^{-t/RC}$

Time Constant: $\tau = RC$

Topic 6 – Magnetism and Magnetic Fields
Class 15-16

Reading: Chapter 22

Objectives:

1. Be able to describe sources of **magnetic fields**.
2. Be able to draw **magnetic field lines** in simple cases.
3. Be able to calculate the **magnetic force** on moving charges and current-carrying wires.
4. Be able to calculate the **torque** on a current loop.
5. Be able to describe the motion of a charged particle in a magnetic field and explain quantitatively how a mass spectrometer works.
6. Be able to **calculate the magnetic fields** due to straight wires, loops, and solenoids.
7. Be able to calculate the magnetic force between parallel conductors.

Equations to Know from Memory:

Magnetic Forces: $F = qvB\sin\theta$ (moving charge) $F = BIl\sin\theta$ (current carrying wire)

Torque on current loop: $\tau = BIAN\sin\theta = \mu B\sin\theta$ Magnetic Moment: $\mu = IAN$

Magnetic Fields: $B_{\text{wire}} = \dfrac{\mu_0 I}{2\pi r}$ $B_{\text{loop}} = N\dfrac{\mu_0 I}{2R}$ $B_{\text{solenoid}} = \mu_0 n I$ $n = \dfrac{N}{l}$

Motion of Charged Particle in Magnetic Field: $r = \dfrac{mv}{qB}$

Force between 2 Parallel Conductors: $\dfrac{F}{l} = \dfrac{\mu_0 I_1 I_2}{2\pi d}$

Physical Constants and Units to Understand:

Tesla (T): $1\ \text{T} = 1\ \text{Wb/m}^2 = 1\ \dfrac{\text{N}}{\text{C}\cdot\text{m/s}} = 1\ \dfrac{\text{N}}{\text{A}\cdot\text{m}}$ Gauss (G): $1\ \text{G} = 10^{-4}\ \text{T}$

Permeability of Free Space: $\mu_0 = 4\pi\times10^{-7}\ \dfrac{\text{T}\cdot\text{m}}{\text{A}}$

Topic 7a – Electromagnetic Induction
Class 17-19

Reading: Chapter 23

Objectives:

1. Be able to define and calculate **magnetic flux**.
2. Be able to apply **Faraday's Law** of electromagnetic induction.
3. Be able to explain and apply **Lenz's Law**.
4. Be able to calculate motional emf.
5. Be able to explain the operation of electric generators and calculate their emf.
6. Be able to explain the operation of transformers.
7. Be able to explain and calculate self-inductance.
8. Be able to calculate emf and current for **series RL circuits**.
9. Be able to calculate the **energy stored** in the magnetic field of an inductor.

Equations to Know from Memory:

Magnetic Flux: $\Phi_B \equiv BA\cos\theta$ Faraday's Law of Induction: $\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$

Motional emf: $|\varepsilon| = Blv$

Electric Generators: $\varepsilon = NBA\omega\sin(\omega t)$

Transformers: $V_2 = \frac{N_2}{N_1}V_1$

RL Circuits: $\varepsilon \equiv -L\frac{\Delta I}{\Delta t}$ $I = \frac{\varepsilon}{R}\left(1 - e^{-t/\tau}\right)$ $\tau = L/R$

Inductors: $L = \frac{N\Delta\Phi_B}{\Delta I}$ $L = \frac{\mu_0 N^2 A}{l}$

Energy Stored in a Magnetic Field of an Inductor: $PE_L = \frac{1}{2}LI^2$

Units to Understand:

Henry (H): $1\ \text{H} = 1\ \text{V}\cdot\text{s/A}$

Topic 7b – AC Circuits
Class 20

Reading: Chapter 23 (continued)

Objectives:

1. Understand the relationship between **rms values** and maximum values.
2. Be able to calculate capacitive and inductive **reactance**.
3. Be able to describe phase relationships for **RLC series** circuits.
4. Be able to calculate the **impedance** and **phase angle** for RLC circuits.
5. Be able to calculate the power dissipated in RLC circuits.
6. Be able to calculate the **resonant frequency** for an RLC circuit.
7. Know the basic characteristics of US household electrical service

Equations to Know from Memory:

RMS values: $A_{\text{rms}}=\frac{A_{\text{max}}}{\sqrt{2}}$ Ohm's Law: $\Delta V_{\text{rms}}=I_{\text{rms}}R$

Capacitors: $X_C\equiv\frac{1}{2\pi fC}$ $\Delta V_{C,\text{rms}}=I_{\text{rms}}X_C$

Inductors: $X_L\equiv 2\pi fL$ $\Delta V_{L,\text{rms}}=I_{\text{rms}}X_L$

AC Circuits: $Z\equiv\sqrt{R^2+(X_L-X_C)^2}$ $\Delta V_{\text{max}}=I_{\text{max}}Z$ Phase Angle: $\tan\phi=\frac{X_L-X_C}{R}$

Power: $\mathcal{P}_{\text{av}}=I_{\text{rms}}\Delta V_{\text{rms}}\cos\phi$ $\cos\phi=R/Z$

Resonance: $f_0=\frac{1}{2\pi\sqrt{LC}}$

Properties of Electromagnetic Waves: $\frac{E}{B}=c$ $c=f\lambda$ $\frac{U}{c}\leq p\leq\frac{2U}{c}$

Intensity: $I=\frac{E_{\text{max}}B_{\text{max}}}{2\mu_0}=\frac{E_{\text{max}}^2}{2\mu_0 c}=\frac{c}{2\mu_0}B_{\text{max}}^2$ Doppler Shift: $f_O\approx f_S\left(1\pm\frac{u}{c}\right)$

Physical Constants to Know:

Speed of Light in vacuum: $c=3.00\times 10^8\ \text{m}/s$

Topic 8 – Electromagnetic Waves

Class 21

Reading: Chapter 24

Objectives:

1. Be able to describe Maxwell's Equations
2. Be able to describe light as a transverse electromagnetic wave.
3. Be able to describe various types of EM waves and sort them by frequency and/or wavelength.

Equations to Know from Memory:

speed of light $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

Properties of Electromagnetic Waves: $\frac{E}{B} = c$ $c = f\lambda$

Intensity: $I = \frac{E_{\max} B_{\max}}{2\mu_0} = \frac{E_{\max}^2}{2\mu_0 c} = \frac{c}{2\mu_0} B_{\max}^2$ Doppler Shift: $f_O \approx f_S \left(1 \pm \frac{u}{c}\right)$

Physical Constants to Know:

Speed of Light in vacuum: $c = 3.00 \times 10^8 \text{ m}/s$

Topic 9a – Geometric Optics: Reflection and Refraction
Class 22

Reading: Chapter 25

Objectives:

1. Be able to apply the law of **reflection** to plane surfaces
2. Be able to define the **index of refraction**.
3. Be able to apply **Snell's law** for refraction.
4. Be able to describe dispersion as it applies to prisms and rainbows.
5. Be able to describe **total internal reflection** and find the critical angle.

Equations to Know from Memory:

Reflection: $\theta_1' = \theta_1$

Index of Refraction: $n \equiv \frac{c}{v}$ $\quad n = \frac{\lambda_0}{\lambda_n}$

Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$ Critical Angle: $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Physical Constants to Understand:

Topic 9b – Geometric Optics: Mirrors and Lenses
Class 23-24

Reading: Chapter 25

Objectives:

1. Be able to draw **ray diagrams** for mirrors and lenses.
2. Be able to distinguish **real** and **virtual** images.
3. Be able to use the sign conventions for lenses and mirrors.
4. Be able to calculate **image distances and heights** for lenses and mirrors
5. Be able to work problems with multiple lenses/mirrors.

Equations to Know from Memory:

Lenses/Mirrors: $m=\frac{h_i}{h_o}=-\frac{d_i}{d_o}$ $\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$ Mirror: $f=R/2$

Units to Understand:

diopter (D): $1\ \mathrm{D}=1\ \mathrm{m}^{-1}$

Topic 10 – Optical Instruments
Class 25-26

Reading: Chapter 26

Objectives:

1. Be able to describe the operation of a **camera**.
2. Be able to describe how the human eye functions.
3. Be able to calculate power of a lens needed to **correct hyperopia** and **myopia**.
4. Be able to describe (e.g., using ray diagrams) how magnifying lenses, microscopes, and telescopes work. Be able to calculate their theoretical **magnification** and the practical limits to that magnification.
5. Be able to describe f-number and numerical aperture.
6. Be able to describe optical aberrations.

Equations to Know from Memory:

Cameras: $f\text{-number} \equiv f/D$

Magnifying Lens: $m \equiv \frac{\theta}{\theta_0}$ $\quad m_{\max} = 1 + \frac{25\ \text{cm}}{f}$ $\quad m = \frac{25\ \text{cm}}{f}$

Microscope: $m = -\frac{L}{f_o}\left(\frac{25\ \text{cm}}{f_e}\right)$ Telescope: $m = -\frac{f_o}{f_e}$

Resolved size using microscope: $R = \frac{\lambda}{2\,NA} = \frac{\lambda}{2\,n\sin\theta}$ (future)

Numerical Aperture: $NA = n\sin(\alpha)$

Constants to Understand:

Typical Human Near Point: 25 cm

Topic 11 – Wave Optics
Class 29-31

<u>Reading</u>: Chapter 27

<u>Objectives</u>:

1. Be able to define **destructive and constructive interference** both in words and mathematically.
2. Be able to mathematically describe a two-source interference pattern.
3. Be able to mathematically apply the principle of thin film interference.
4. Be able to recognize and apply 180° phase changes.
5. Be able to mathematically apply the principles of diffraction to single slits and gratings.
6. Be able to describe polarization, optical activity and apply Brewster's Law.

<u>Equations to Know from Memory</u>:

Young's <u>Interference</u> $(m=0,\pm1,\pm2,\pm3,...)$: geometry: $L\tan\theta=y$

Constructive: $d\sin\theta_{\text{bright}}=m\lambda$ Destructive: $d\sin\theta_{\text{dark}}=\left(m+\frac{1}{2}\right)\lambda$

Wavelength in Medium: $\lambda_n=\dfrac{\lambda}{n}$ $n\equiv\dfrac{c}{v}$

Thin Film Interference: $2nt=\begin{Bmatrix}\left(m+\frac{1}{2}\right)\lambda\\ m\lambda\end{Bmatrix}$ where $m=0,1,2,3,...$

Single-Slit Diffraction: $\sin\theta_{\text{dark}}=m\dfrac{\lambda}{a}$ where $m=\pm1,\pm2,\pm3,...$

circular aperture: $\theta_{dark}=1.44\dfrac{\lambda}{D}$

Diffraction Grating: $d\sin\theta_{\text{bright}}=m\lambda$ where $m=0,\pm1,\pm2,\pm3,...$

Polarization – Malus's Law: $I=I_0\cos^2\theta$ Brewster's Law: $n=\tan\theta_p$

Topic 12 – Special Relativity
Class 32

Reading: Chapter 28

Objectives:

1. Be able to explain the difference between inertial and accelerated frames of reference.
2. Be able to explain how the Michelson-Morley experiment showed that the speed of light in vacuum is a constant.
3. Be able to state the **two postulates of special relativity**.
4. Be able to explain the relativity of simultaneity
5. Be able to distinguish proper time intervals from time intervals when applying the **time dilation** formula.
6. Be able to distinguish proper lengths from lengths when applying the **length contraction** formula.
7. Be able to state the two postulates of general relativity.

Equations to Know from Memory:

Time Dilation: $\Delta t = \gamma \Delta t_0$ Length Contraction: $L = L_0 / \gamma$

Relativistic Factor: $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$

KE = $\gamma mc^2 - E_0$ where $E_0 = mc^2$ is the rest energy

momentum: $p = \gamma mv$ $E^2 - (pc)^2 = (mc^2)^2$

Topic 13 – Quantum Physics
Class 33-34

Reading: Chapter 29

Objectives:

1. Be able to explain how Planck's concept of quantized energy contributed to our understanding of **blackbody radiation**.
2. Be able to explain the **photoelectric effect** in terms of **photons**.
3. Be able to explain why some sorts of light endanger life whereas other types of light are largely harmless.
4. Be able to explain bremsstrahlung and characteristic X-rays in the context of how an X-ray tube works.
5. Be able to describe **matter waves** qualitatively and quantitatively.
6. Be able to explain how X-rays can be used to map crystal structure (Bragg reflection)
7. Be able to describe the **wave function** in terms of a probability distribution.
8. Be able to apply the **Heisenberg uncertainty principle**.

Equations to Know from Memory:

Wien's Displacement Law: $\lambda_{max} T = 0.2898 \times 10^{-2}\ \mathrm{m \cdot K}$
Stefan's law: $P = \sigma A T^4$

Photoelectric Effect: $KE_{max} = e\Delta V_s = hf - BE$

Photon Energy: $E = hf = hc/\lambda$ Photon Momentum: $p = \frac{E}{c} = \frac{h}{\lambda}$

X-ray Production: $\lambda_{min} = \frac{hc}{e\Delta V}$

deBroglie Wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$

Heisenberg Uncertainty Principle: $\Delta x \Delta p_x \geq \frac{h}{4\pi}$ and $\Delta E \Delta t \geq \frac{h}{4\pi}$

Physical Constants to Understand:

Planck's Constant: $h = 6.63 \times 10^{-34}\ \mathrm{J \cdot s}$
eV conversion: $1\,e\mathrm{V} = 1.6 \times 10^{-19}\ \mathrm{J}$

Topic 14 – Atomic Physics
Class 35-37

Reading: Chapter 30

Objectives:

1. Be able to explain Thomson's and Rutherford's models of the atom.
2. Be able to explain line spectra in terms of the Rydberg formula and **calculate wavelengths of emission and absorption**.
3. Be able to describe the **Bohr model** of the atom in terms of quantization.
4. Be able to describe how transitions between stable electron 'orbits' results in emission or absorption of photons.
5. Be able to calculate radii and energies of electron orbits using the Bohr model.
6. Be able to describe how the $n, l, m_l, s=½, m_s$ **quantum numbers** correspond to physical quantities; be able to describe states with these quantum numbers and to encode the l value as a letter.
7. Be able to use conventional notation for electronic structure and apply same to simple cases of atomic paramagnetism and diamagnetism.
8. Be able to explain how the periodic table is the result of Pauli exclusion and H-atom energy levels slightly modified by nuclear charge shielding.
9. Be able to explain the origin of characteristic x-rays and bremsstrahlung.
10. Be able to explain how *K, L, M*, ... encode the principal quantum number of characteristic X-rays and how to calculate the energies of those X-rays.
11. Be able to describe the operation of a laser.

Equations to Know from Memory:

Rydberg Formula: $\frac{1}{\lambda}=R_H\left(\frac{1}{m^2}-\frac{1}{n^2}\right)$

Bohr Model: $m_e v r = n\hbar$ $\quad r_n = n^2\frac{\hbar^2}{m_e Z k_e e^2}=n^2\frac{a_B}{Z}$ $\quad E_n=-\frac{m_e Z^2 k_e^2 e^4}{2\hbar^2}\left(\frac{1}{n^2}\right)=\frac{Z^2}{n^2}E_1$

Characteristic X-rays: $E_n=\frac{E_1 Z_{eff}^2}{n^2}$ $\quad \frac{1}{\lambda}=R_H Z_{eff}^2\left(\frac{1}{m^2}-\frac{1}{n^2}\right)$

Emitted Photon Frequency: $f=\frac{E_i-E_f}{h}$

Physical Constants to Understand:

Rydberg Constant for Hydrogen: $R_H=1.097\times10^7\ \text{m}^{-1}$
Planck's Constant: $\hbar=h/2\pi$
Bohr Radius (hydrogen): $a_B=0.0529\ \text{nm}$
Ground State Energy (hydrogen): $E_1=-13.6\ \text{eV}$
angular momentum: *s, p, d, f*

Topic 15 – Nuclear Physics
Class 38-39

Reading: Chapter 31

Objectives:

1. Be able to describe nuclei in terms of constituents and stability.
2. Be able to list **types of radiation** and their sources.
3. Be able to calculate decay constants and **half-lives**.
4. Be able to balance **nuclear reaction equations** using baryon conservation, charge conservation, and energy conservation.
5. Be able to properly account for electron mass in beta decay since tabulated atomic masses include *Z* electrons

Equations to Know from Memory:

Binding Energy: $\Delta m c^2 = \left[\left(\sum_{\text{nucleons}} m \right) - m_{\text{nucleus}} \right] c^2$

Nuclear Radius: $r = r_0 A^{1/3} \quad r_0 = 1.2 \times 10^{-15}\ \text{m}$

Radioactive Decay: $N = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}} \qquad T_{1/2} = \frac{0.693}{\lambda}$

$$R = \left| \frac{\Delta N}{\Delta t} \right| = \lambda N \qquad R = R_0 e^{-\lambda t} = R_0 2^{-t/T_{1/2}}$$

α decay: ${}^{A}_{Z}\text{X} \rightarrow {}^{A-4}_{Z-2}\text{Y} + {}^{4}_{2}\text{He} + \Delta E$

β^- decay: ${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + \text{e}^- + \bar{\nu}$

β^+ decay: ${}^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + \text{e}^+ + \nu$

γ decay: ${}^{A}_{Z}\text{X}^* \rightarrow {}^{A}_{Z}\text{X} + \gamma$

Physical Constants and Units to Understand:

Activity: $1\ \text{Ci} = 3.70 \times 10^{10}\ \text{Bq} \qquad 1\ \text{Bq} \equiv 1\ \text{decay/s}$

atomic mass unit $u = 1.6605 \times 10^{-27}\ \text{kg}$ or $931.5\ \text{MeV}/c^2$

Topic 16 – Nuclear Physics Applications
Class 42

Reading: Chapter 32.5-6

Objectives:

1. Be able to describe nuclear fission
2. Be able to describe how a nuclear reactor works
3. Be able to describe nuclear fusion
4. Be able to describe the fundamental forces of nature