Physics 105

Physics for the Life Sciences I

Mechanics
Oscillators
Fluids
Thermodynamics

Course Guide

PHYS 105
Sections: 01A
MTRF: 9:00

Text:
College Physics
with Enhanced WebAssign
By OpenStax

Spring 2021
Dr. Tom Kirkman

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. To contact me use direct email; the webassign messaging does not reach me directly. While the web promises global connections, it often promotes isolation. Consider 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 102; 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! You might also check out some data-based results of learning outcomes using online problem systems like WebAssign:

http://www.physics.csbsju.edu/lab/McKay:copy&fail.mp4

"in order to learn things in physics your homework must be done earnestly"

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:

9:00 Section 01A	csbsju 8607 5271

Topic 1 – Fundamentals

Day 1

<u>Reading</u>: Chapter 1 (particularly unit conversion)

<u>Objectives</u>:

1. Be able to give standard units of distance, mass, and time in the MKS (SI) system.
2. Be able to use the following prefixes: giga, mega, kilo, centi, milli, micro (μ), nano. Understand scientific notation and, in particular, the **E** notation used by computers and WebAssign.
3. Be able to perform **dimensional analysis**.
4. Be able to correctly apply uncertainties in measurements and significant figures (**sigfigs**) to calculations. **Rule:** on exams always report exactly 3 sigfigs regardless of the number of sigfigs in the problem's write-up.
5. Be able to **convert units** (e.g., miles per hour to meters per second).
6. Be able to make order of magnitude estimations.
7. Be able to use fundamental algebra and **trigonometry** (sine, cosine, tangent and Pythagorean theorem) and perform conversions between rectangular and polar coordinates. (Note: not needed until Chapter 3; many calculators have built in rectangular/polar conversion)

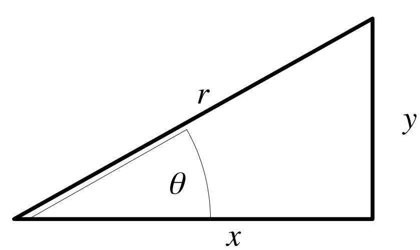
<u>Equations to Know from Memory</u>:

Pythagorean Theorem: $r^2 = x^2 + y^2$

Sine of angle: $\sin\theta = \frac{y}{r}$

Cosine of angle: $\cos\theta = \frac{x}{r}$

Tangent of angle: $\tan\theta = \frac{y}{x}$



Quadratic Equation: find *x* value that yields zero...

if $a x^2 + b x + c = 0$ then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

circle: circumference $2\pi r$ area πr^2 ; triangle area $\frac{1}{2} b h$

sphere: surface area $4\pi r^2$ volume $\frac{4}{3}\pi r^3$; prism volume $A h$

Topic 2 – One-Dimensional Kinematics
Days 1– 2

Reading: Chapter 2

Objectives:

1. Be able to define mathematically and in words and graphs: displacement, speed, average velocity, instantaneous velocity, average acceleration, and instantaneous acceleration. Note in particular the distinction between average and instantaneous; If this adjective is missing instantaneous is intended!
2. Be able to graph motion and **interpret motion graphs**, including that velocity is the slope of an (*x* vs. *t*) graph, acceleration is the slope of (*v* vs. *t*), the area under (*v* vs. *t*) between two times: t_i & t_f is $\Delta x = x_f - x_i$, the area under (*a* vs. *t*) between two times: t_i & t_f is $\Delta v = v_f - v_i$
3. Be able to solve problems involving **uniformly accelerated motion** using the equations of motion.

Equations to Know from Memory:

Displacement: $\Delta x \equiv x_f - x_0$

Average Velocity: $\bar{v} \equiv \frac{\Delta x}{\Delta t} \equiv \frac{x_f - x_0}{t_f - t_0}$; $\bar{v} = \frac{v_0 + v}{2}$ (for constant a)

Instantaneous Velocity: $v \equiv \lim_{\Delta t \to 0} \bar{v} \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$

Average Acceleration: $\bar{a} \equiv \frac{\Delta v}{\Delta t} \equiv \frac{v_f - v_0}{t_f - t_0}$

Instantaneous Acceleration: $a \equiv \lim_{\Delta t \to 0} \bar{a} \equiv \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$

Equations for Uniformly Accelerated Motion
(for Free Fall replace x with y and a with $-g$):

$$v = v_0 + at \qquad x = x_0 + v_0 t + \frac{1}{2} a t^2 \qquad v^2 = v_0^2 + 2a(x - x_0) \qquad \frac{x - x_0}{t} = \frac{v + v_0}{2}$$

Physical Constants to Know:

Acceleration due to gravity: $g = 9.80 \text{ m/s}^2 = 32 \text{ ft/s}^2$

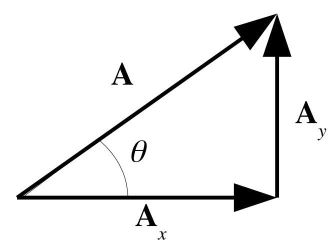
Topic 3 – Vectors and Two-Dimensional Kinematics
Day 2

Reading: Chapter 3

Objectives:

1. Be able to state the definitions of vector and scalar quantities (and give examples of each).
2. Be able to multiply and divide a vector by a scalar.
3. Apply **trigonometry** to find rectangular components of a vector. Note: many calculators have rectangular/polar conversion as buttons.
4. Be able to add and subtract vectors graphically and with the use of rectangular components.
5. Be able to define displacement, velocity, and acceleration vectors.
6. Be able to solve **projectile motion** problems.
7. Be able to calculate relative velocities.

Equations to Know from Memory:



Trigonometric Expressions for Vectors:

$$A^2 = A_x^2 + A_y^2 \qquad A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad \tan\theta = \frac{A_y}{A_x}$$

$$\vec{\mathbf{A}} = \vec{\mathbf{A}}_x + \vec{\mathbf{A}}_y \qquad \left|\vec{\mathbf{A}}\right| \equiv A = \sqrt{A_x^2 + A_y^2}$$

Displacement Vector: $\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}}_f - \vec{\mathbf{r}}_i$

Velocity Vector: $\vec{\mathbf{v}}_{av} \equiv \frac{\Delta\vec{\mathbf{r}}}{\Delta t} \qquad \vec{\mathbf{v}} \equiv \lim_{\Delta t \to 0} \frac{\Delta\vec{\mathbf{r}}}{\Delta t}$

Acceleration Vector: $\vec{\mathbf{a}}_{av} \equiv \frac{\Delta\vec{\mathbf{v}}}{\Delta t} \qquad \vec{\mathbf{a}} \equiv \lim_{\Delta t \to 0} \frac{\Delta\vec{\mathbf{v}}}{\Delta t}$

Equations of Motion:

$$v_x = v_{0x} + a_x t \qquad \Delta x = v_{0x} t + \tfrac{1}{2} a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2 a_x \Delta x \qquad v = \sqrt{v_x^2 + v_y^2}$$

$$v_y = v_{0y} + a_y t \qquad \Delta y = v_{0y} t + \tfrac{1}{2} a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2 a_y \Delta y \qquad \theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

For Projectile Motion: $a_x = 0 \qquad v_x = v_{0x} = v_0\cos\theta \qquad a_y = -g \qquad v_{0y} = v_0\sin\theta$

Relative Velocity: $\vec{\mathbf{v}}_{\mathrm{AB}} = \vec{\mathbf{v}}_{\mathrm{AE}} - \vec{\mathbf{v}}_{\mathrm{BE}}$

Equations to Know How to Use:

Range: $R = \frac{v_0^2 \sin(2\theta_0)}{g}$

Topic 4 – Newton's Laws
Day 3

Reading: Chapter 4

Objectives:

1. Be able to state the difference between mass and **weight**.
2. Be able to state Newton's three laws and explain their implications to physical phenomena. Be able to explain in words the meaning of notations like: $\sum \vec{\mathbf{F}}$ (aka $\boldsymbol{F}_{\mathbf{net}}$) and $\sum m_i x_i$.
3. Be able to define the unit newton.
4. Be able to distinguish between inertial and non-inertial reference frames.
5. Be able to work with **tension**, compression, and **normal** forces.
6. Be able to **apply Newton's laws** to problems in one and two dimensions.
7. Be able to make **free body diagrams**

Equations to Know from Memory:

Newton's First Law: $\vec{\mathbf{v}}=\text{constant}$ unless $\vec{\mathbf{F}}_{\text{net}}\neq 0$

Newton's Second Law: $\sum \vec{\mathbf{F}}=\vec{\mathbf{F}}_{\text{net}}=m\vec{\mathbf{a}}$

Newton's Third Law: $\vec{\mathbf{F}}_{12}=-\vec{\mathbf{F}}_{21}$

Weight: $w=mg$ $g=9.80\ \text{m/s}^2$

Conditions for Equilibrium: $\sum \vec{\mathbf{F}}=0$ if and only if: $\vec{\mathbf{v}}=\text{constant}$

Physical Constants to Understand:

Unit of Force, Newton: $1\ \text{N}\equiv 1\ \dfrac{\text{kg}\cdot\text{m}}{\text{s}^2}$

Topic 5 – More Forces
Day 3

Reading: Chapter 5

Objectives:

1. Be able to define and calculate **frictional forces**: static and kinetic
2. Be able to define and calculate **terminal velocity** for various **drag forces.**
3. Be able to explain the meaning of the often neglected minus sign in **Hooke's Law.** Understand that the linear relationship between deformation and force is an *approximation* with limits (e.g., tensile strength)
4. Be able to define and use **stress** and **strain.**
5. Be able to define and use: **Young's, shear and bulk modulus.**
6. Be able to apply the above forces to problems and free body diagrams

Equations to Know from Memory:

Frictional Forces: $f_s \leq \mu_s N \ (\text{static}) \qquad f_k = \mu_k N \ (\text{kinetic})$

Spring force: $F = -k \Delta x$

Equations to Know How to Use:

Drag forces: $F_D = \frac{1}{2} C \rho A v^2 \qquad F_S = 6 \pi \eta r v$

Elasticity: $Y \frac{\Delta L}{L_0} = \frac{F}{A} \qquad B \frac{\Delta V}{V_0} = \frac{F}{A} \qquad S \frac{\Delta x}{L_0} = \frac{F}{A}$

Topic 6 – Uniform Circular Motion and Gravitation
Day 4

Reading: Chapter 6

Objectives:

1. Be able to relate **angular displacement** to arc length and **angular velocity** to tangential velocity. Be able to appropriately use and convert angular units of degrees, revs and radians.
2. Understand that uniform circular motion is accelerated motion and therefore $\boldsymbol{F}_{\text{net}} = \boldsymbol{F}_c = m\boldsymbol{a}_c$
3. Be able to relate **centripetal acceleration** to angular velocity and identify **centripetal forces**.
4. Be able to make free body diagrams in cases of uniform circular motion and apply Newton's Laws to the resulting situation. Note that these problems often seem backward in that $\boldsymbol{F}_{\text{net}}$ is known (via $\boldsymbol{a}_c$) and the problem is to see how that $\boldsymbol{F}_{\text{net}}$ is composed of a sum of forces.
5. Be able to state Newton's law of universal gravitation and apply it to problems.
6. Be able to state and apply Kepler's Laws.

Equations to Know from Memory:

Instantaneous Angular Velocity: $\omega \equiv \lim_{\Delta t \to 0} \left(\frac{\Delta \theta}{\Delta t} \right)$

Tangential Length: $\Delta s = r \Delta \theta$, Velocity: $v_t = r \omega$

Centripetal Acceleration: $a_c = \frac{v^2}{r} = r \omega^2$

Newton's Universal Law of Gravitation: $F = G \frac{m_1 m_2}{r^2}$

Topic 7 – Work, Energy, and Power
Day 6

Reading: Chapter 7

Objectives:

1. Be able to define in words and mathematically **work**, **kinetic energy**, and **potential energy** and make calculations of each.
2. Be able to describe the difference between conservative and nonconservative forces.
3. Be able to mathematically apply the **Work-Energy Theorem**.
4. Be able to state and apply the principle of **conservation of energy**.
5. Be able to **graphically** find the work done by a varying force.
6. Be able to solve problems involving the potential energy of **springs** and **gravity** .
7. Be able to define power, define the unit of power, and calculate power.

Equations to Know from Memory:

Work: $W \equiv (F\cos\theta)\Delta x$ Hooke's Law: $F=-kx$

Kinetic Energy: $KE \equiv \frac{1}{2}mv^2$ Spring Potential Energy: $PE_s \equiv \frac{1}{2}kx^2$

Gravitational Potential Energy (near surface): $PE_g \equiv mgy$

Work-Energy Theorem: $W_{nc}+W_c=\Delta KE$ $W_{nc}=\Delta KE+\Delta PE_{\text{total}}=E_f-E_i$

Power: $\bar{P}=\frac{W}{\Delta t}$ Efficiency: $\frac{W_{\text{out}}}{E_{\text{in}}}$

Physical Constants to Understand:

Unit of Work, Joule: $1\ \text{J} \equiv 1\ \text{N}\cdot\text{m}$ Unit of Power, Watt: $1\ \text{W} \equiv 1\ \text{J/s}$

Topic 8 – Momentum and Collisions
Days 6 – 7

Reading: Chapter 8

Objectives:

1. Be able to define and calculate **momentum** and impulse.
2. Be able to apply Newton's laws to impulse and change of momentum problems.
3. Be able to state and apply the law of **conservation of linear momentum**.
4. Understand the meaning of elastic, inelastic and perfectly inelastic collisions.
5. Be able work out **elastic** and **perfectly inelastic collision problems**. (Note: the textbook uses primes to denote the final state.)
6. Be able to work out glancing collision problems (i.e., 2d).
7. Be able to describe how rocket propulsion works in terms of momentum.

Equations to Know from Memory:

Impulse: $\vec{\mathbf{I}} \equiv \vec{\mathbf{F}} \Delta t$ (more generally: area under force vs time curve)

Momentum: $\vec{\mathbf{p}} \equiv m \vec{\mathbf{v}}$

Impulse-Momentum Theorem: $\vec{\mathbf{I}} = \Delta \vec{\mathbf{p}} = m \vec{\mathbf{v}}_f - m \vec{\mathbf{v}}_i$

Conservation of Momentum: $\sum \vec{p}_i = \sum \vec{p}_f$

e.g., 2 objects $m_1 \vec{\mathbf{v}}_{1i} + m_2 \vec{\mathbf{v}}_{2i} = m_1 \vec{\mathbf{v}}_{1f} + m_2 \vec{\mathbf{v}}_{2f}$

Applied to 1-D Perfectly Inelastic Collisions:

$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$

Applied to 1-D Elastic Collisions:

$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$ $\quad \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$

$v_{1i} - v_{2i} = -(v_{1f} - v_{2f})$

Equations to Know How to Use:

rocket: $v = v_e \ln(m_0 / m_f)$

Topic 9 – Torque and Statics

Days 7 – 8

Reading: Chapter 9

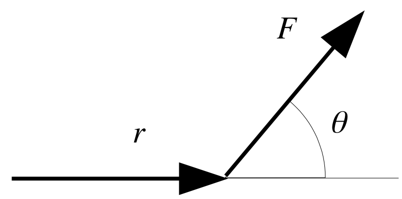
Objectives:

1. Be able to define **torque** (τ) and **lever arm** ($r_{\perp}$)
2. Be able to work problems involving **static equilibrium** using $\tau_{\text{net}}=0$ and $\vec{F}_{\text{net}}=0$
3. Be able to calculate the **center of mass** (gravity) of a distributed object.
4. Understand that for an extended object the force of gravity can be thought of as acting at the center of mass. In some sense the center of mass is the average position of an extended object.
5. Be able to solve **problems** and draw **free body diagrams** in situations involving torque.
6. Explain and calculate how simple machines provide a mechanical advantage.

Equations to Know from Memory:

Torque: $\tau=rF\sin\theta=rF_{\perp}=Fr_{\perp}$

Center of Mass: $X_{\text{CM}}=\frac{\sum m_i x_i}{\sum m_i}$ (aka CG)



Conditions for Equilibrium: $\sum\vec{\tau}=\vec{\tau}_{\text{net}}=0$

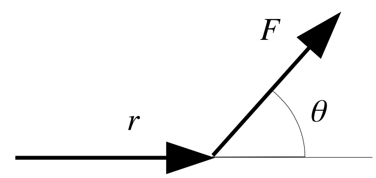
Topic 10 – Rotational Dynamics
Day 8

Reading: Chapter 10

Objectives:

1. Be able to define **angular acceleration** (α) and **moment of inertia**
2. Be able to state and use the relation between torque, angular acceleration and moment of inertia.
3. Be able to define **rotational kinetic energy** and **angular momentum**.
4. Solve problems using conservation of total mechanical energy
5. Be able to apply the **conservation of angular momentum** to problems.
6. See and use the relationship between 1d linear motion and rotation:
   $x \Leftrightarrow \theta \quad v \Leftrightarrow \omega \quad a \Leftrightarrow \alpha \quad M \Leftrightarrow I \quad F \Leftrightarrow \tau \quad p = Mv \Leftrightarrow L = I\omega \quad KE = \frac{1}{2}Mv^2 \Leftrightarrow KE = \frac{1}{2}I\omega^2$

Equations to Know from Memory:



Torque: $\tau = rF\sin\theta = rF_{\perp} = Fr_{\perp}$

Moment of Inertia: $I = \sum mr^2$

Newton's Second Law for Rotation: $\sum \tau = \tau_{\text{net}} = I\alpha$

Rotational Kinetic Energy: $KE_r = \frac{1}{2}I\omega^2$

Work-Energy Theorem: $W_{nc} = \Delta KE_{\text{total}} + \Delta PE_{\text{total}}$

Angular Momentum: $L \equiv I\omega \qquad L \equiv rp\sin\theta = r_{\perp}p = rp_{\perp} \qquad \sum \tau = \tau_{\text{net}} = \frac{\Delta L}{\Delta t}$

Conservation of Angular Momentum: $\sum \tau = 0 \;\Rightarrow\; I_i\omega_i = I_f\omega_f$

Equations for Uniform Angular Acceleration:

$\omega = \omega_0 + \alpha t \qquad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0) \qquad \frac{\theta - \theta_0}{t} = \frac{\omega + \omega_0}{2}$

Connections: if $s = R\theta$ then $v = R\omega$ and $a = R\alpha$

Topic 11 – Oscillations
Day 9

Reading: Chapter 16

Objectives:

1. Understand the concepts of **amplitude, frequency, period,** and **angular frequency**. Appropriately use radians in trigonometric functions.
2. Be able to apply **conservation of energy** to simple harmonic oscillator problems.
3. Be able to work simple harmonic oscillator problems using **displacement, velocity, and acceleration**.
4. Be able to calculate the angular frequency for a simple harmonic oscillator.
5. Define **damped** oscillatory motion, **forced** oscillations and the phenomena of **resonance**.
6. Be able to describe the difference between transverse and longitudinal waves.
7. Understand the concepts of **amplitude, frequency, wave speed** and **wavelength**.
8. Be able to describe **constructive and destructive interference** using the **superposition** principle.
9. Be able to describe **standing waves** as a superposition of waves traveling in opposite directions with a resulting pattern of **nodes** and **antinodes**.

Equations to Know from Memory:

Hooke's Law: $F_s = -kx$ Elastic Potential Energy: $PE_s \equiv \frac{1}{2}kx^2$

Simple Harmonic Motion:

Mass on a Spring: $v = \pm\sqrt{\frac{k}{m}(A^2 - x^2)}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $f = \frac{1}{T}$ $\omega = 2\pi f = \sqrt{\frac{k}{m}}$

Periodic Position: $x = A\cos(2\pi f t) = A\cos(\omega t)$ (radians!)

Periodic Velocity: $v = -A\omega\sin(2\pi f t) = -v_{max}\sin(\omega t)$

Periodic Acceleration: $a = -A\omega^2\cos(2\pi f t) = -a_{max}\cos(\omega t)$

Simple Pendulum: $T = 2\pi\sqrt{\frac{L}{g}}$

Wave Speed: Generally $v_w = f\lambda$

Beats: $f_B = |f_1 - f_2|$

Topic 12 – Static Fluids
Day 11

Reading: Chapter 11

Objectives:

1. Be able to describe the differences between solids, fluids, gases, and plasmas.
2. Be able to define **density** (ρ) and **pressure** and determine **pressure change with depth** in a fluid.
3. Be able to state and apply Pascal's principle.
4. Be able to define/distinguish: **gauge pressure** and **absolute pressure**.
5. Be able to state and apply **Archimedes' principle** (buoyant force)
6. Be able to explain how surface tension results in capillary action, contact angle, and meniscus.

Equations to Know from Memory:

Density: $\rho=\frac{m}{V}$ Pressure: $P=\frac{F_{\perp}}{A}$

Variation of pressure with depth: $P=P_0+\rho g \Delta h$

Archimedes' Principle: $F_B=\rho_{\text{fluid}} V_{\text{fluid}} g$

Surface Tension: γ= Force/Length or Energy/Area $P=\frac{4\gamma}{r}$

Physical Constants to Know:

Units of Pressure:

Pascal: $1\ \text{Pa}=1\ \text{N/m}^2$ $133\ \text{Pa}=1\ \text{mm Hg}=1\ \text{torr}$ $1\ \text{atm}=1.01\times10^5\ \text{Pa}$

density of water: 1000 kg/m^3 or 1 g/mL or 1 g/cm^3

Topic 13 – Moving Fluids

Days 11 – 12

Reading: Chapter 12

Objectives:

1. Be able to apply **flow rate** and the **equation of continuity** for problems involving incompressible fluids.
2. Be able to explain Bernoulli's equation in terms of conservation of energy.
3. Be able to apply **Bernoulli's equation** to problems.
4. Be able to define the viscosity (η) of a fluid in words.
5. Be able to distinguish between laminar and turbulent flow.
6. Be able to state the significance/use of the Reynolds number (N_R).
7. Be able to describe diffusion, osmosis, and Stoke's Law and how Stoke's Law relates to sedimentation rate.

Equations to Know from Memory:

Continuity Equation: $A_1 v_1 = A_2 v_2$

Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

Equations to Know How to Use:

viscosity: $\frac{F}{A} = \eta \frac{\Delta v}{\Delta y}$ Poiseuille: flow rate (m^3/s)= $\frac{\pi R^4 \Delta P}{8 \eta L}$

Reynolds number: $\frac{\rho v d}{\eta}$

Topic 14 – Thermal Physics
Days 12 – 13

Reading: Chapter 13

Objectives:

1. Be able to state and apply the Zeroth Law of Thermodynamics.
2. Be able to describe the **Celsius**, Fahrenheit, and **Kelvin** temperature scales and convert from one to another.
3. Be able to explain and calculate thermal expansion.
4. Be able to state and apply the **Ideal Gas Law**.
5. Be able to state the assumptions of the kinetic theory of gases and apply the results of the theory which relate the macroscopic characteristics of a gas to the microscopic characteristics of the particles in the gas.
6. Be able to state in words the meaning of notations like: $\sqrt{\left(\overline{v^2}\right)} = v_{\text{rms}}$ particularly with regard to the Maxwell-Boltzmann speed distribution
7. Be able to use *PV* diagrams and phase diagrams.

Equations to Know from Memory:

Kelvin to Celsius: $T_C = T_K - 273.15$

Celsius to Fahrenheit: $T_F = \frac{9}{5} T_C + 32$

Thermal Expansion: $\Delta L = \alpha L_0 \Delta T \quad \Delta A = 2\alpha A_0 \Delta T \quad \Delta V = \beta V_0 \Delta T$

Ideal Gas Law: $PV = nRT$

Kinetic Theory: $P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2} m \overline{v^2}\right) \quad \left(\frac{1}{2} m \overline{v^2}\right) = \frac{3}{2} k_B T \quad U = \frac{3}{2} nRT$

$$v_{\text{rms}} = \sqrt{\frac{3 k_B T}{m}} = \sqrt{\frac{3RT}{M}}$$

Physical Constants to Know:

Avogadro's Number: $N_A = 6.02 \times 10^{23}$ particles/mol

Boltzmann's Constant: $k_B = 1.38 \times 10^{-23}$ J/K

Universal Gas Constant: $R \equiv N_A k_B = 8.314$ J/(K·mole)

Topic 15 – Heat and Energy Transfer
Day 13

Reading: Chapter 14

Objectives:

1. Be able to state the difference between internal energy, temperature, and heat.
2. Be able to use and define **specific heats** and **latent heats**.
3. Be able to work simple heat transfer and **calorimetry problems**.
4. Be able to work heat transfer and calorimetry problems involving **phase changes**.
5. Be able to describe the differences between energy transfer by conduction, convection, and radiation.
6. Be able to state the significance of the emissivity, *e*, of a material and its range of values.
7. Be able to apply Stefan-Boltzmann Law to radiative heat transfer.
8. Be able to explain the greenhouse (atmospheric) effect.

Equations to Know from Memory:

Specific Heat: $c \equiv \frac{Q}{m \Delta T}$

Phase Changes: $Q = \pm m L$

Thermal Conduction: $\frac{Q}{t} = kA \frac{(T_2 - T_1)}{d}$ R-factor: $R = \frac{d}{k}$

Stefan-Boltzmann Law: $\frac{Q}{t} = \sigma A e T^4$

Physical Constants to Know:

$1\ \text{cal} \equiv 4.186\ \text{J}$

Note: 1 food calorie is equal to 1000 calories. $1\ \text{Cal} = 1\ \text{kcal}$

Topic 16 – Thermodynamics
Day 14

Reading: Chapter 15

Objectives:

1. Be able to calculate (numerically and graphically) the **work done by** or on a gas. Note signs!
2. Be able to state and apply the First Law of Thermodynamics.
3. Be able to describe and graph **isobaric, adiabatic, isovolumetric,** and **isothermal** processes and calculate changes in thermodynamic quantities for these processes.
4. Be able to define and graph a **Carnot cycle**.
5. Be able to state the Second Law of Thermodynamics in several ways.
6. Be able to distinguish between reversible and irreversible processes.
7. Be able to discuss the operation of **heat engines** and **heat pumps** and calculate work done, efficiencies, and coefficients of performance particularly in the case of a Carnot cycle.
8. Be able to define entropy and calculate changes in entropy for systems.

Equations to Know from Memory:

Work done by a gas (constant P): $W = P\,\Delta V$

First Law of Thermodynamics: $\Delta U = Q - W$

Isobaric Process: $Q = n C_p\,\Delta T$

Adiabatic Process: $Q = 0$ $\quad P V^{\gamma} = \text{constant}$ $\quad \gamma = \frac{C_p}{C_v}$

Isovolumetric Process: $W = 0$ $\quad Q = n C_v\,\Delta T$

Isothermal Process: $\Delta U = 0$ $\quad W = Q$ $\quad W = n R T \ln\left(\frac{V_f}{V_i}\right)$

Heat Engines: $W = |Q_h| - |Q_c|$ $\quad Eff \equiv \frac{W}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$

Heat Pumps: $\text{COP (cooling mode)} = \frac{|Q_c|}{W}$ $\quad \text{COP (heating mode)} = \frac{|Q_h|}{W}$

Carnot Engines: $Eff_C = 1 - \frac{T_c}{T_h}$ $\quad$ Entropy: $\Delta S \equiv \frac{Q_r}{T}$

Enthalpy: $H = U + PV$ $\quad$ Gibbs Free Energy: $G = H - TS$

Physical Constants to Know:

Molar specific heat of monatomic gas at constant volume: $C_v \equiv \frac{3}{2} R$

Molar specific heat of monatomic gas at constant pressure: $C_p \equiv \frac{5}{2} R$