Physics 105

Physics for the Life Sciences I

Mechanics, Thermodynamics, and Oscillators

Course Manual

PHYS 105
Section 04A
Even Days 1:00 – 2:10

Text:
College Physics, 9th Edition
with Enhanced WebAssign
By Raymond A. Serway and Chris Vuille

Fall 2011
Dr. Sarah A. Yost

Course Objectives

- Learn principles of mechanics and thermodynamics.
- Apply these principles to physical systems (biological examples when possible).
- Learn how to calculate results and solve problems related to mechanics and thermodynamics.

Contact Information: for Dr. Sarah A. Yost

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Email address	syost@csbsju.edu
Office Hours	Mornings, particularly 9:30-10:30 or just stop by, I'm almost always in, usually before 9 *Note: I teach on days 1-3-5: 11:20-12:30 all semester* *I supervise labs days 1&2: 5-9 PM and can be found in rooms 102, 106 PENGL* or by appointment

If you require any special accommodations, please contact me as soon as possible.

Methods of Assessment

Homework: Homework will be assigned to be completed online via the WebAssign website. You will have the opportunity to redo answers flagged as incorrect.

Special HW: Full questions which will be graded for correctness AND completeness. Partial credit will be assigned. As in a test situation, you will not have the answer to check before handing it in. Handed in IN CLASS on the indicated days.

Quizzes: Four short 15 minute quizzes given on the indicated days.

In-Class Exercises: You should expect a very short graded in-class exercise any time that there is no test or quiz, often at the start or end. **These exercises cannot be excused or made up if you miss class**.

Labs: Attendance and lab reports are required.

Tests: Four 70 minute tests will be given on the indicated days.

Exams: A two hour final exam.

Grading: Homework = 11% (WA questions: 1 pt per "part", Special: 10 pts per question),
4 Quizzes = 4%, In-class Exercises = 3%, Lab = 22%,
4 Tests = 40% (lowest score dropped), Final Exam = 20%

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:

1:00 – 2:10 Section 04A csbsju 4104 5467

Anticipated Grade Scale:

Grade	Percentage
A	93-100
AB	86-92
B	80-85
BC	73-79
C	67-72
CD	56-66
D	50-55
F	< 50

ASSESSMENT LOGISTICS

For quizzes, you must recall equations from memory. See the topical pages and their "equations to remember"

For tests, you will be given an equation sheet, based upon the "equations to remember".

Equation sheets for upcoming tests as well as solutions to quizzes, tests, and special homework will be sent as PDF files via classwide email. **If you do not get the "testing the list" email before the second class meeting, contact me.**

Scheduling:
Schedule problems related to tests and formal quizzes can be accommodated for documented school-related reasons, but ONLY if I know about it at least 2 class meetings prior to the test. Only medical / family emergencies can be accommodated on shorter notice.

Due Dates:
Online homework is due at the time posted with the WebAssign set. This will usually be before the corresponding quiz or test associated with the chapter. The due date can be overridden if there are problems. Inform me of any problems with the WebAssign access or site; I can also help contact the site administrators.

There will be zero-point "extra practice" questions set up through WebAssign. They will stay "open" through the semester.

Academic Honesty

CSBSJU's academic catalog defines plagiarism as *...the act of appropriating and using the ideas, writings, or works of original expressions of another person as one's own without giving credit to the person who created the work.* If suspected, the burden of proof rests with the faculty. If proven, the consequence for a first offense is failure of the course.

Again, please note that it is quite helpful to work in groups at times to solve homework problems, and this collective effort is **not** plagiarism. You may be asked to explain something in a "special homework" question, however, and you must find a way to say it *in your own words.*

Any unauthorized use of solution guides (particularly ``Instructor's Guides'') constitutes academic dishonesty. Presenting work assisted by such items is plagiarism.

THE STUDENT MANAGEMENT TEAM (SMT)

This class is working with a relatively new method for student feedback: a student management team, based upon Nuhfer's ideas for applying management concepts to education.

PHYS 105 is a challenging course with many concepts to learn and apply. There are many different ways to handle the material and sometimes we don't find out that some aspect isn't working well until well into the semester (or even on final course evaluations). *I want better feedback so that I can teach this course as much as possible in ways that will benefit you - this group of students.*

Therefore at the end of the first cycle I will solicit 3 volunteers for the SMT. This team will monitor the quality of the class and provide regular feedback including suggestions for improvement.

Student Commitment:
The SMT will meet weekly (if an evening time is agreeable) or each cycle (if a day time is agreeable). The goal of these meetings is to provide feedback about the course, instructor, methods, and best use of our class meeting time. The feedback includes not only what is and isn't working for this class but also suggested solutions for problems with the class.

This feedback can be based on any student's experience, not just those in the team. ALL students are welcome at these meetings, and the meeting time/place will be made public.

Faculty Commitment:
I will attend every second SMT meeting and participate in the process of critiquing the class. I will offer my own ideas for solutions to any problems that come up. I will work with the SMT on what suggestions can be implemented to improve the class.

I will use the SMT feedback to help determine how to best use our time in class meetings.

I will also be open to any student coming to talk about aspects of the class which aren't working well for them! The SMT doesn't replace that option; it is an attempt to consistently get deeper, more meaningful feedback than has been typical in physics courses.

Expected Operation:

The meetings will be public and near refreshments - the CSB library coffeeshop is one suggestion.
We'll keep a record of suggestions, plans for implementation, and results.

PROBLEM SOLVING STRATEGY

In a general physics course a student is asked to solve many problems. It is generally assumed that solving problems is the best way to clarify the concepts and principles of physics. This is true, provided that a student is able to make solving problems a real learning experience. It is possible that solving problems becomes only a routine: "How to discover the right equation." If a student approaches problem solving with the attitude that she/he only has to find the equation that will give the right answer, much time may be spent, but little learning of physics will take place. To make problem solving a more rewarding and profitable part of general physics, the following procedure should be kept in mind constantly.

1. Read the problem carefully enough so that you can state in your own words what physical situation is being described.

2. Draw a diagram or simple picture of the physical situation as you reread the problem. This is essential to the understanding of most problems. Trying to solve a problem mentally or intuitively usually consumes much time with no results.

3. Label all physical quantities in the diagram using appropriate letters and choose a coordinate system.

4. Identify the physical principle(s) or law(s) you think you ought to apply to the problem, as well as the knowns and unknown. List them all and circle the unknowns.

5. Equations are written down next which relate the physical quantities (knowns and unknowns) and which are consistent with the principle(s) or laws(s) from the previous step.

6. Solve the set of equations algebraically for the unknown quantities. Do not substitute in known values (unless they are zero) yet – some cancellation may take place that will simplify your calculator operations in the next step.

7. Substitute in the known values with their units to find numerical values with units for the unknowns.

8. Check your answer: Are the units correct? Is the number (including sign) reasonable?

The procedure outlined above will be applicable in many other situations outside of physics for solving problems in the other sciences. Most problems in business, medicine, and scholarly research of any kind will be solved more easily if a disciplined, orderly approach is developed.

Physics 105 Course Schedule

Cycle	*Day*	*Date*	*Text*	*Topics*	*Tests*	*Labs*
1	2	Thu 9/1	1.1 – 1.9	Fundamentals, Units, Estimation, Trigonometry		No Lab
	4	Mon 9/5	2.1 – 2.3	Displacement, Velocity, Acceleration		
	6	Wed 9/7	2.4 – 2.6	Equations of Motion, Free Fall **SPECIAL HW1 DUE**		
2	2	Fri 9/9	3.1 – 3.4	Vectors, 2D motion: **Δx, v, a** **HW1 BACK**		Uncertainties
	4	Tues 9/13	4.1-4.4	POST-QUIZ: Newton's Laws	QUIZ 1	
	6	Thu 9/15	4.1-4.5	2-D applications of Newton's Laws		
3	2	Mon 9/19	4.6	Newton's Laws with friction		Data Analysis
	4	Wed 9/21	CH 1-4	REVIEW		
	6	Fri 9/23	**1.1 – 4.6**	**TEST: Kinematics and Newton's Laws**	TEST 1	
4	2	Tues 9/27	5.1 – 5.3	Work, Kinetic Energy, Gravitational Potential Energy		Acceleration of Gravity
	4	Thu 9/29	5.4 – 5.6	Spring Potential Energy, Systems, Power		
	6	Mon 10/3	5.7, 6.1-6.2	Work by a Varying Force, Impulse and Momentum		
5	2	Wed 10/5	6.3-6.5	Collisions; Rocket Propulsion		Projectile Motion
	4	Fri 10/7	7.1 – 7.3	POST-QUIZ: introduction to circular motion	QUIZ 2	
	6	Tues 10/11	7.4 – 7.5	Centripetal acceleration, gravity **SPECIAL HW2 DUE**		
6		**Thu 10/13**	**Fri 10/14**	**FREE DAYS**		NO LAB Long Weekend
	2	Mon 10/17	8.1 – 8.4	Torque, Equilibrium, Center of Gravity **HW2 BACK**		
	4	Wed 10/19	8.5 – 8.7	Rotational Inertia, Energy, and Momentum		
	6	Fri 10/21	CH 7-8	REVIEW		
7	2	Tues 10/25	**5.1 – 8.7**	**TEST: W, E, p, collisions, rotation, equilibrium**	TEST 2	Kinetic Friction
	4	Thu 10/27	9.1-9.3	Solids and Fluids		
	6	Mon 10/31	9.4 – 9.6	Fluids at Rest, buoyancy		
8	2	Wed 11/2	9.7	POST-QUIZ: introduction to Bernouilli's equation	QUIZ 3	Ballistic Pendulum
	4	Fri 11/4	9.7 – 9.10	Fluids in motion, surface/viscosity/diffusion phenomena		
	6	Tues 11/8	10.1 – 10.3	Temperature, Thermal Expansion		
9	2	Thurs 11/10	10.4 – 10.5	Ideal Gases, Kinetic Theory of Gases, SHORT REVIEW		Rotational Motion
	4	Mon 11/14	**9.1 – 10.5**	**Solids, Fluids, and Thermal Physics**	TEST 3	
	6	Wed 11/16	11.1 – 11.4	Heat, Calorimetry, Phase Changes		
10	2	Fri 11/18	11.5	Energy Transfer, examples		Archimedes' Principle
	4	Tues 11/22	12.1 – 12.2	Work, 1st Law of Thermodynamics		
		Wed 10/23	**Fri 10/25**	**Thanksgiving Recess**		
	6	Tues 11/29	12.3 – 12.4	Thermal Processes, Second Law of Thermodynamics		
11	2	Thurs 12/1	12.4	POST-QUIZ: further examples, Carnot engine	QUIZ 4	Gas Behavior
	4	Mon 12/5	12.5	Entropy, SHORT REVIEW		
	6	Wed 12/7	**11.1 – 12.6**	**Thermal Energy and Thermodynamics**	TEST 4	
12	2	Fri 12/19	13.1 – 13.4	Hooke's Law,Energy,describing Simple Harmonic Motion		Lab assessment AND online Assessment Exam
	4	Tues 12/13	13.5 – 13.7	Damping, the pendulum, introduction to waves		
	6	Thurs 12/15	13.8 – 13.11	Wavelength, speed, interference		
Exam Week		Fri 12/15	Study Day			
		Mon 12/19	**1 – 3:00 PM**	**Section 04A (1:00 class period, 2-4-6)**	**Final Exam**	

Topic 1 – Fundamentals
Cycle 1, Day 2

Reading: Chapter 1 – Introduction, pp. 1-18

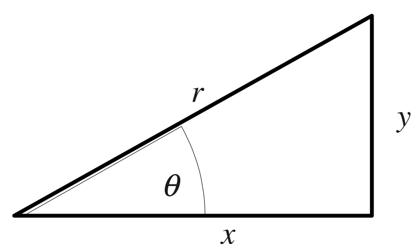
Objectives:

1. Be able to give standard units of distance, mass, and time in the MKS (SI) system.
2. Be able to state the meaning, in powers of ten, of the following prefixes: mega, kilo, centi, milli, micro (Table 1.4, p. 3 of text).
3. Be able to perform dimensional analyses.
4. Be able to correctly apply uncertainties in measurements and significant figures to calculations.
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.
8. Be able to list steps in a procedure for working problems. (See p. 3 of this handout, p. 16-17 of text.)

Equations to Know from Memory:

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: $\tan\theta = \frac{y}{x}$

Typical Problems:

Chapter 1 – Concepts: 5,9
Problems: 1,2,4,5,9,10-14,20,21-23,26,30,31,38,39,41-44,48,49

Physical Constants to Know:

Standard Units, MKS (SI) System

Topic 2 – One-Dimensional Kinematics

Cycle 1, Days 46

Reading: Chapter 2 – Motion in One Dimension, pp. 24-47

Objectives:

1. Be able to define mathematically and in words: displacement, speed, average velocity, instantaneous velocity, average acceleration, and instantaneous acceleration.
2. Be able to graph motion and interpret motion graphs.
3. Be able to describe uniformly accelerated motion in detail by solving problems using the equations of motion.

Equations to Know from Memory:

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

Average Velocity: $\bar{v} \equiv \frac{\Delta x}{\Delta t} \equiv \frac{x_f - x_i}{t_f - t_i}$; $\bar{v} = \frac{v_0 + v}{2}$ (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: $\bar{a} \equiv \frac{\Delta v}{\Delta t} \equiv \frac{v_f - v_i}{t_f - t_i}$

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

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

$$v = v_0 + at \qquad \Delta x = v_0 t + \frac{1}{2} a t^2 \qquad v^2 = v_0^2 + 2 a \Delta x$$

Typical Problems:

Chapter 2 – Concepts: 1-3,5,6,8
Problems: 1-3,7,8,10,11,15,17-19,22-25,28,30-35,45,47-50, 51,68

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

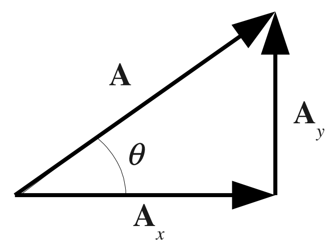
Cycle 2, Days 246

Reading: Chapter 3 – Vectors and Two-Dimensional Motion, pp. 54-78

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.
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:

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

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

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:

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

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

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

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

Typical Problems:

Chapter 3 – Concepts: 1,2,4,7
Problems: :3-5,9-11,17-20,22,23,25,27,29,30,32-35,39-41,52,63

Physical Constants to Know:

none

Topic 4 – Newton's Laws
Cycle 2, Day 6, Cycle 3, Days 24

Reading: Chapter 4 – The Laws of Motion, pp. 83-109

Objectives:

1. Be able to state the difference between inertia, mass, and weight.
2. Be able to state Newton's three laws and explain their implications to physical phenomena.
3. Be able to define the Newton.
4. Be able to define in words and mathematically Newton’s Law of Universal Gravitation.
5. Be able to distinguish between inertial and non-inertial reference frames.
6. Be able to describe the difference between static and translational equilibrium.
7. Be able to describe the difference between static and kinetic friction.
8. Be able to work with tension, compression, and normal forces.
9. Be able to apply Newton's laws to problems in one and two dimensions.

Equations to Know from Memory:

Newton’s First Law: $\vec{\mathbf{v}} = \text{constant}$ unless $\sum \vec{\mathbf{F}} \neq 0$

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

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

Newton’s Universal Law of Gravitation: $F_g = G\dfrac{m_1 m_2}{r^2}$

Weight: $w = mg$ $\quad g = \dfrac{F_g}{m} = G\dfrac{M_E}{R_E^2} = 9.80\ \text{m/s}^2$

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

Frictional Forces: $f_s \leq \mu_s n$ (static) $\quad f_k = \mu_k n$ (kinetic)

Typical Problems:

Chapter 4 – Concepts: 3,4,6
Problems: 2,3,5-7,9-12,14,18-21,23-26,27,28-31,36,38,40,41,44(a),45,47-51,53,54,70

Physical Constants to Know:

Definition of the Newton: $1\ \text{N} \equiv 1\ \text{kg}\cdot\text{m/s}^2$

Universal Gravitation Constant: $G = 6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

Topic 5 – Work, Energy, and Power

Cycle 4, Days 246

Reading: Chapter 5 – Energy, pp. 119-151

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 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: $KE \equiv \frac{1}{2}mv^2$ Gravitational Potential Energy: $PE_g \equiv mgy$

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

Work-Energy Theorem: $W_{nc} + W_c = \Delta KE$ $W_{nc} = \Delta KE + \Delta PE_g + \Delta PE_s = E_f - E_i$

Power: $\bar{P} = \frac{W}{\Delta t} = F\,\bar{v}$

Typical Problems:

Chapter 5 – Concepts: 3,6,13,15
Problems: 4-10,13,15,16-18,23,25-27,30-37,40,43-45,47,50-54,59-62,69,71

Physical Constants to Know:

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

Topic 6 – Momentum and Collisions
Cycle 4, Day 6, Cycle 5, Days 2

Reading: Chapter 6 – Momentum and Collisions, pp. 161-181

Objectives:

1. Be able to define and calculate momentum and impulse.
2. Be able to apply Newton's second law to impulse and change of momentum problems.
3. Be able to state and apply the law of conservation of linear momentum.
4. Be able work out elastic and inelastic collision problems.
5. Be able to work out glancing collision problems.
6. Be able to describe how rocket propulsion works in terms of momentum.

Equations to Know from Memory:

Impulse: $\vec{\mathbf{I}} \equiv \vec{\mathbf{F}} \Delta t$

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

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

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:

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

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

Typical Problems:

Chapter 6 – Concepts: 2,5,6,8 and the conceptual piece of problem 67(d)
Problems: 2-5,7-12,18,22,23,25,26,29-33,37-42,45,49-51

Physical Constants to Know:

none

Topic 7 – Circular Motion and Gravitation
Cycle 5, Days 46

Reading: Chapter 7 – Rotational Motion and the Law of Gravity, pp. 190-219

Objectives:

1. Be able to relate angular displacement to arc length, angular velocity to tangential velocity, and angular acceleration to tangential acceleration.
2. Be able to relate radial acceleration to angular velocity and identify centripetal forces.
3. Be able to state Newton's law of gravitation and apply it to problems.
4. Be able to describe the difference between bound and unbound systems in terms of their mechanical energy.
5. Be able to state and apply Kepler's Laws.

Equations to Know from Memory:

Arc Length: $s = r\theta$

Angular Velocity: $\omega \equiv \frac{\Delta\theta}{\Delta t} = 2\pi f$ Tangential Velocity: $v_t = r\omega$

Angular Acceleration: $\alpha \equiv \frac{\Delta\omega}{\Delta t}$ Tangential Acceleration: $a_t = r\alpha$

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

Equations of Rotational Motion for constant α :

$$\omega = \omega_i + \alpha t \qquad \Delta\theta = \omega_i t + \tfrac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_i^2 + 2\alpha\Delta\theta$$

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

Gravitational Potential Energy: $PE_g = -G\frac{m_1 m_2}{r}$

Kepler's Third Law: $T^2 = \left(\frac{4\pi^2}{G M_S}\right) r^3$

Typical Problems:
Chapter 7 – Concepts: 2,4,5,6,9
Problems: 2-8,10,11,13,16,18,19,20,21,23,27,31-34,36-38,41,42,43,44,53

Physical Constants to Know:

$$G = 6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2} \qquad g = G\frac{M_E}{R_E^2} = 9.80\ \mathrm{m/s^2}$$

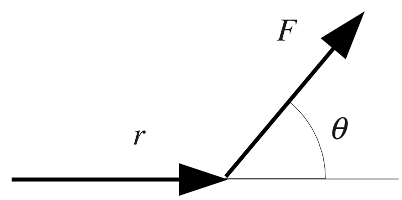
Topic 8 – Rotational Dynamics
Cycle 6, Days 24

Reading: Chapter 8 – Rotational Equilibrium and Rotational Dynamics, pp. 228-254

Objectives:

1. Be able to define torque.
2. Be able to work problems involving static equilibrium.
3. Be able to calculate the center of gravity of a distributed object.
4. Be able to state the relation between torque and angular acceleration and define moment of inertia for a particle.
5. Be able to solve problems involving torque.
6. Be able to define rotational kinetic energy and angular momentum.
7. Be able to apply the conservation of angular momentum to problems.

Equations to Know from Memory:



Torque: $\tau = rF\sin\theta$

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

Newton's Second Law for Rotation: $\sum \tau = I\alpha$

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

Work-Energy Theorem: $W_{nc} = \Delta KE_t + \Delta KE_r + \Delta PE$

Angular Momentum: $L \equiv I\omega$ $\qquad \sum \tau = \frac{\Delta L}{\Delta t}$

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

Typical Problems:

Chapter 8 – Concepts: 3,5,6
Problems: 1,2,4,5,7-10,17-19,22,27,29,35,39,40,43,46,47,52,56,61-63,65,72,82

Physical Constants to Know:

none

Topic 9 – Fluids

Cycle 7, Days 246; Cycle 8, Days 24

Reading: Chapter 9 – Solids and Fluids, pp. 268-312

Objectives:

1. Be able to describe the differences between solids, fluids, gases, and plasmas.
2. Be able to state the relationship between stress and strain and apply it to the elasticities of length, shape, and volume.
3. Be able to define density and pressure and determine pressure change with depth in a fluid.
4. Be able to state and apply Pascal's principle.
5. Be able to state and apply Archimedes' principle.
6. Be able to define the viscosity of a fluid in words.
7. Be able to distinguish between laminar and turbulent flow.
8. Be able to apply the equation of continuity for problems involving incompressible fluids.
9. Be able to explain Bernoulli's equation in terms of conservation of energy.
10. Be able to apply Bernoulli's equation to problems.
11. Be able to explain the contributions of surface tension and cohesive and adhesive forces to capillary action.
12. Be able to state the importance of the Reynolds number.
13. Be able to describe diffusion, osmosis, and Stoke's Law.

Equations to Know from Memory:

Deformation of solids: $\text{stress} = \text{elastic modulus} \times \text{strain}$

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: $B = \rho_{\text{fluid}} V_{\text{fluid}} g$

Continuity Equation: $A_1 v_1 = A_2 v_2$

Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

Typical Problems:

Chapter 9 – Concepts: 2,4,5,10,11

Problems: 3,5,6,7,11, 13-15, 16, 23-25,28,31,34,35,38,40-48,53,55,60-62,66,68,71,73-76,80

Physical Constants to Know:

Unit of Pressure, Pascal: $1 \text{ Pa} = 1 \text{ N/m}^2$ $1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$

Topic 10 – Thermal Physics

Cycle 8, Day 6, Cycle 9, Day 2

Reading: Chapter 10 – Thermal Physics, pp. 322-346

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.

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: $\Delta L = \alpha L_0 \Delta T$ $\quad \Delta A = \gamma A_0 \Delta T$ $\quad \Delta V = \beta V_0 \Delta T$

Ideal Gas Law: $PV = nRT$

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

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

Typical Problems:

Chapter 10 – Concepts: 1,2,4,6,8-13
Problems: 1-9,11-13,15,23,24,29-37,39,40,42,43,44,46

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 11 – Heat and Energy Transfer

Cycle 9, Day 6, Cycle 10, Day 2

Reading: Chapter 11 – Energy in Thermal Processes, pp. 352-378

Objectives:

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

Equations to Know from Memory:

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

Phase Changes: $Q = \pm m L$

Thermal Conduction: $\mathcal{P} = kA \frac{(T_h - T_c)}{L}$ R-factor: $R = \frac{L}{k}$

Stefan's Law: $\mathcal{P} = \sigma A e T^4$

Typical Problems:

Chapter 11 – Concepts: 2,3,4,9,10,12
Problems: 3-8,11-13,15-21,25-28,31-36,38-41,44,45,48-50

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 12 – Thermodynamics
Cycle 10, Days 46; Cycle 11, Days 24

Reading: Chapter 12 – The Laws of Thermodynamics, pp. 385-417

Objectives:

1. Be able to calculate the work done on or by a gas.
2. Be able to state and apply the First Law of Thermodynamics.
3. Be able to describe isobaric, adiabatic, isovolumetric, and isothermal processes.
4. Be able to state the Second Law of Thermodynamics in 2 ways.
5. Be able to distinguish between reversible and irreversible processes.
6. Be able to discuss the operation of heat engines and heat pumps and calculate work done, efficiencies, and coefficients of performance.
7. Be able to define entropy and calculate changes in entropy for systems.

Equations to Know from Memory:

Work done on a gas (constant P): $W = -P\Delta V$

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

Isobaric Process: $Q = nC_p \Delta T$

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

Isovolumetric Process: $W = 0$ $\quad Q = nC_v \Delta T$

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

Heat Engines: $W_{\text{eng}} = |Q_h| - |Q_c|$ $\quad e \equiv \frac{W_{\text{eng}}}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$

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

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

Typical Problems:

Chapter 12 – Concepts: 5,7,12
Problems: 1,3-10,13-15,21-23,27,28,29-31,33-35,38-41,45-49,51,52

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: $C_p \equiv \frac{5}{2}R$

Topic 13 – Oscillations

Cycle 12, Days 246

Reading: Chapter 13 – Vibrations and Waves, pp. 425-451

Objectives:

1. Understand the concepts of amplitude, frequency, period, and angular frequency.
2. Be able to work simple harmonic oscillator problems using energy considerations.
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. Be able to describe the difference between transverse and longitudinal waves.
6. Be able to describe constructive and destructive interference using the superposition principle.

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: $x = A\cos(2\pi f t)$

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

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

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

Wave Speed: Generally $v = f\lambda$ on a string $v = \sqrt{\frac{F}{\mu}}$

Typical Problems:

Chapter 13 – Concepts: 1,4,5,6,12

Problems: 1,2,5,6,8-13,15,17,20,22,24-29,31,32,34-37,39,40,43-47,49-51,53-57,61,62

Physical Constants to Know:

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