PHYS 1511 Review Session: Final Review

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Review

Chapter 1: Introduction and Mathematical Concepts

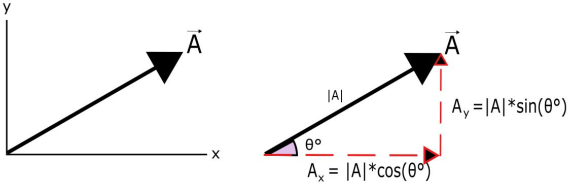
-Units/dimensional analysis

-Scalars vs Vectors

-Trig using vectors $\vec{\boldsymbol{A}}$

-Vector addition and subtraction (Tail to Head method)

-Vector Components (in 2D)



Chapter 1

$$|A| = \sqrt{(A_x)^2 + (A_y)^2} \qquad \text{(For a 2D Vector } \vec{A}\text{)} \tag{1}$$

$$cos(\theta) = \frac{\text{Adjacent}}{Hypotenuse} \tag{2}$$

$$sin(\theta) = \frac{Opposite}{Hypotenuse} \tag{3}$$

$$tan(\theta) = \frac{sin(\theta)}{cos(\theta)} = \frac{Opposite}{Adjacent} \tag{4}$$

Review

Chapter 2: Kinematics in One Dimension

-Speed vs Velocity & Distance vs Displacement

-$\Delta x = x_f - x_o$ notation & Kinematic Charts

-Acceleration due to gravity

Chapter 2

$$v = \frac{\Delta x}{\Delta t} \qquad \text{(Average Velocity)} \tag{5}$$

The Kinematic Equations:

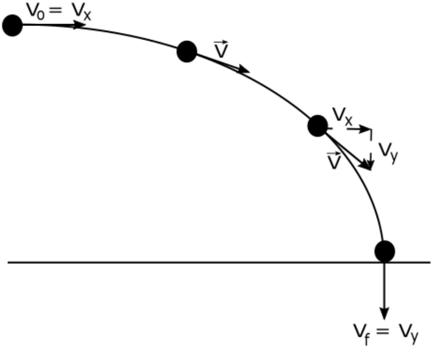
$$v_f = v_o + at \tag{6}$$

$$\Delta x = x_f - x_o = v_o t + \frac{1}{2}at^2 \tag{7}$$

$$v_f^2 = v_o^2 + 2a\Delta x \tag{8}$$

Review

Chapter 3: Kinematics in Two Dimensions



Kinematic Chart

x	y
$V_0 = V_x$	$V_0 = 0$
$V_f = V_x$	$V_f = ?$
$a = 0$	$a = g$
$t = ?$	$t = ?$
$\triangle x = 0$	$\triangle y = ?$

(*There's a typo above: $\Delta x = ?$ not 0)

-Kinematics in 2D

-Relative Velocity

-All object accelerate the same on earth (without air resistance)

Chapter 3

$$\mathbf{F}_{\text{net}} = \Sigma \vec{F} = m\vec{a} \quad \text{(Newton's 2nd Law)} \tag{9}$$

$$\vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC} \quad \text{(Relative Velocity)} \tag{10}$$

The Kinematic Equations:

$$v_f = v_o + at \tag{11}$$

$$\Delta x = x_f - x_o = v_o t + \frac{1}{2}at^2 \tag{12}$$

$$v_f^2 = v_o^2 + 2a\Delta x \tag{13}$$

Review

Chapter 4: Forces and Newton's Law of Motion

-Force and Mass

-Newton's First Law of Motion

-Gravitational Force

-The Normal Force

-Static and Kinetic Frictional Force

-The Tension Force

-Equilibrium of Forces

-Non-Equilibrium of Forces

Chapter 4

Newton's Laws:

1) An object stays at rest (or constant velocity) unless acted upon by exterior net force.

2) When a net force ($\Sigma \vec{F}$) is exerted, an acceleration $\vec{a}$ results and is given by: $\vec{a} = \frac{\Sigma \vec{F}}{m}$

3) Whenever one object exerts a force on another, the 2nd object exerts an equal and opposite force on the first object.

Chapter 4

$$\vec{F}_{net} = \Sigma\vec{F} = m\vec{a}_{net} \qquad \text{(Newton's 2nd Law)} \tag{14}$$

$$F = \frac{Gm_1 m_2}{r^2} \qquad \text{(Newton's Law of Gravity)} \tag{15}$$

$$\vec{F}_{\text{(s or k)}} = \mu_{\text{(s or k)}}\vec{N} \qquad \text{(Static or Kinetic Friction)} \tag{16}$$

$$\Sigma\vec{F} = \vec{F}_{net} = 0 \qquad \text{(Equilibrium)} \tag{17}$$

$$\Sigma\vec{F} = \vec{F}_{net} = m\vec{a} \qquad \text{(Non-Equilibrium)} \tag{18}$$

Review

Chapter 5: Uniform Circular Motion

-Uniform Circular Motion

-Centripetal Acceleration

-Centripetal Force

-Banked Curves

-Satellites in Circular Orbits

-Apparent Weightlessness

-Vertical Circular Motion

Chapter 5

$$a_c = \frac{v^2}{r} \qquad \text{(Centripetal Acceleration)} \tag{19}$$

$$\vec{F}_c = m\vec{a_c} = m\frac{\vec{v}^2}{r} \qquad \text{(Centripetal Force)} \tag{20}$$

$$v = \frac{2\pi r}{T} \qquad \text{(Velocity/period relation)} \tag{21}$$

$$\tan\theta = \frac{v^2}{rg} \qquad \text{(Banked Curved)} \tag{22}$$

$$v = \sqrt{\frac{GM_E}{r}} \qquad \text{(Speed of Satellite in Circular Earth Orbit)} \tag{23}$$

$$T = \frac{2\pi r^{3/2}}{\sqrt{GM_E}} \qquad \text{(Period of Satellite in Circular Earth Orbit)} \tag{24}$$

Chapter 6: Work and Energy

-Work done by a constant force

-Work-Energy Theorem and Kinetic Energy

-Conservative vs Non-Conservative forces

-Conservation of Mechanical Energy

-Power

Chapter 6

$$W = F\Delta x \cos(\theta) \qquad \text{(Work)} \tag{25}$$

$$KE = \frac{1}{2}mv^2 \qquad \text{(Kinetic Energy)} \tag{26}$$

$$PE = mgh \qquad \text{(Gravitational Potential Energy)} \tag{27}$$

$$KE_i + PE_i = KE_f + PE_f \qquad \text{(Conservation of Energy)} \tag{28}$$

$$W = \Delta KE = -\Delta PE \qquad \text{(Work-Energy Theorem)} \tag{29}$$

$$P = \frac{W}{\Delta t} \qquad \text{(Power)} \tag{30}$$

$$\bar{P} = F\bar{v} \qquad \text{(Average power delivered by a force)} \tag{31}$$

Review

Chapter 7: Impulse and Momentum

-Momentum

-Conservation of momentum (both x and y direction)

-Collisions in 1D and 2D

-Elastic and Inelastic Collisions

-Center of Mass

Chapter 7 (1 of 2)

$$\vec{p} = m\vec{v} \qquad \text{(Momentum)} \tag{32}$$

$$\vec{J} = \vec{F}\Delta t = \Delta\vec{p} \qquad \text{(Impulse)} \tag{33}$$

$$\vec{P}_{total_i} = \vec{P}_{total_f} \qquad \text{(Conservation of Momentum)} \tag{34}$$

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i} \implies = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} \qquad \text{(Center of Mass 2 objects)} \tag{35}$$

$(x_1, x_2, \dots)$ are the distance **to the center of mass** of (m_1, m_2)

Chapter 7 (2 of 2)

Elastic collision ($\Delta KE = 0$)
(2nd object start at rest):

$$v_{f_1} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{o_1} \tag{36}$$

Inelastic collision ($\Delta KE \neq 0$)
(2nd object start at rest):

$$v_{f_2} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{o_1} \tag{37}$$

Chapter 8: Rotational Kinematics

-Angular Displacement

-Angular Velocity

-Angular Variables

-Rotational Kinematics

-Rolling without slipping

Chapter 8

*(Every angle is in **radians**)

$$S = r\theta \qquad \text{(Arc Length)} \tag{38}$$

$$\omega = \frac{\Delta\theta}{\Delta t} \qquad \text{(\textbf{Angular} Velocity)} \tag{39}$$

$$\alpha = \frac{\Delta\omega}{\Delta t} \qquad \text{(\textbf{Angular} Acceleration)} \tag{40}$$

$$s = r\theta \qquad \text{(linear length - angular length connection)} \tag{41}$$

$$v = r\omega \qquad \text{(linear velocity - angular velocity connection)} \tag{42}$$

$$a = r\alpha \qquad \text{(linear accel. - angular accel. connection)} \tag{43}$$

Rotational Kinematics

$$\begin{aligned} v_f &= v_o + at^2 & & \omega_f = \omega_o + \alpha t^2 \\ \Delta x &= v_o t + \frac{1}{2}at^2 & \leftrightarrow \quad & \Delta\theta = \omega_o t + \frac{1}{2}\alpha t^2 \\ v_f^2 &= v_o^2 + 2a\Delta x & & \omega_f^2 = \omega_o^2 + 2\alpha\Delta\theta \end{aligned} \tag{44}$$

Review

Chapter 9: Rotational Dynamics

-Force and Torque's on Rigid Objects

-Rotational Statics (torques and force)

-Center of Gravity

-Newton's 2nd law of Rotational Motion

-Rotational Work and Energy

-Angular Momentum

Chapter 9

$$\vec{\tau} = |r||F|\sin(\theta) \qquad \text{(Torque)} \tag{45}$$

$$\Sigma\vec{\tau} = 0 \qquad \text{(Rotational Statics)} \tag{46}$$

$$\Sigma\vec{\tau} = \mathrm{I}\vec{\alpha}_{net} \qquad \text{(Rotational "Newton's 2nd law")} \tag{47}$$

$$x_{cg} = \frac{W_1 x_1 + W_2 x_2 + \ldots}{W_1 + W_2 + \ldots} \qquad \text{(Center of Gravity)} \tag{48}$$

$$\mathrm{KE_R} = \frac{1}{2}\mathrm{I}\omega^2 \qquad \text{(Rotational Kinetic Energy)} \tag{49}$$

$$\vec{L} = \mathrm{I}\vec{\omega} \qquad \text{(Angular Momentum)} \tag{50}$$

Review

Chapter 10: Simple Harmonic Motion and Elasticity

-Ideal Spring and Simple Harmonic Motion (SHM)

-SHM Frequency and period

-v_{max}, a_{max} in SHM

-Angular Frequency in SMH

-Energy in SHM

-The Pendulum

-Elastic Deformation

Chapter 10 (1 of 2)

SHM:

$$\vec{F} = -kx \qquad \text{(Spring Resorting Force)} \tag{51}$$

$$\omega = 2\pi f = \frac{2\pi}{T} \qquad \text{(General expression of angular frequency)} \tag{52}$$

$$\omega = \sqrt{\frac{k}{m}} \qquad \text{(angular frequency in SHM)} \tag{53}$$

$$x = A\cos(\theta) = A\cos(\omega t) \qquad \text{(x-position in SHM)} \tag{54}$$

$$2\pi f = \sqrt{\frac{g}{L}} = \sqrt{\frac{mgL}{\mathrm{I}}} \qquad \text{(Pendulum frequency for small angles)} \tag{55}$$

$$W = \Delta\mathrm{PE} = \frac{1}{2}kx^2 \qquad \text{(Work/Potential Energy done in SHM)} \tag{56}$$

Chapter 10 (2 of 2)

Elastic Deformation:

$$F = Y\left(\frac{\Delta L}{L_o}\right)A \qquad \text{(Stretch)} \tag{57}$$

$$F = S\left(\frac{\Delta X}{L_o}\right)A \qquad \text{(Sheer Force)} \tag{58}$$

$$\vec{P} = \frac{\vec{F}}{A} \qquad \text{(Pressure Definition)} \tag{59}$$

$$\Delta P = -B\left(\frac{\Delta V}{V_0}\right) \qquad \text{(Volume change by a pressure)} \tag{60}$$

*** Y,S & B are all constants that depend on the material

Review

Chapter 11: Fluids

-Mass Density

-Pressure/Pressure and Depth

-Archimedes Principle

-Equation of Continuity

-Bernoulli's Equation

-Viscous Flow

Chapter 11

$$\rho = \frac{m}{V} \qquad \text{(Density)} \tag{61}$$

$$\vec{P} = \frac{\vec{F}}{A} \qquad \text{(Pressure Definition)} \tag{62}$$

$$\vec{F_b} = \rho g V \qquad \text{(Buoyant Force)} \tag{63}$$

$$A_1 v_1 \rho_1 = A_2 v_2 \rho_2 \qquad \text{(Continuity Equation in General)} \tag{64}$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 \qquad \text{(Bernoulli's Eqn)} \tag{65}$$

$$F = \frac{\eta A v}{y} \qquad \text{(Vicous Flow)} \tag{66}$$

Review

Chapter 12: Temperature and Heat

-Temperature Scales (Kelvin, Celsius, Fahrenheit)

-Linear and Volume Thermal Expansion

-Heat flow and Temperature Change

-Phase Change: Latent Heat

-Sign convention for heat transfer ((+Q) flow in, (-Q) flow out)

-Equilibrium and Heat Flow

Chapter 12

$$T_k = T_c + 273.15 \qquad \text{(Kelvin} \rightleftarrows \text{Celsius)} \tag{67}$$

$$T_F = \frac{9}{5}T_c + 32 \qquad \text{(Fahrenheit} \rightleftarrows \text{Celsius)} \tag{68}$$

$$\Delta L = \alpha L_0 \Delta T \qquad \text{(Linear Thermal Expansion)} \tag{69}$$

$$\Delta V = \beta V_0 \Delta T \qquad \text{(Volume Thermal Expansion)} \tag{70}$$

$$Q = mc\Delta T \qquad \text{(Temperature Change w/ specific heat capacity)} \tag{71}$$

$$Q = mL \qquad \text{(Latent Heat)} \tag{72}$$

Chapter 13: The Transfer of Heat

-Conduction of heat through a material

-Radiative Diffusion

-Net Radiative Power

Chapter 13

$$Q = \frac{kA\Delta T}{L} \qquad \text{(Conduction Equation)} \qquad (73)$$

$$Q = e\sigma T^4 At \qquad \text{(Radiation Heat Energy)} \qquad (74)$$

$$P_{net} = e\sigma A(T^4 - T_o^4) \qquad \text{(Net Radiation Power)} \qquad (75)$$

where

e - emissivity ($0 \leq e \leq 1$) where e =1 is blackbody (absorbs all light)

A - surface area

σ - Stefan-Boltzmann constant. (just a number to look up)

T_o - temperature of environment

Review

Chapter 14: The Ideal Gas Law and Kinetic Theory

-Molecular Mass

-Mole

-Avogadro's Number

-The Ideal Gas Laws (Physics version, not chemistry)

-Charles & Boyles Laws

-Kinetic Theory of Gases

-Diffusion

Chapter 14

$$n = \frac{N}{N_A} \qquad \text{(molecular mass)} \tag{76}$$

$$PV = nRT = NkT \qquad \text{(Ideal Gas Law)} \tag{77}$$

$$P_1 V_1 = P_2 V_2 \qquad \text{(Boyles Law)} \tag{78}$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f} \qquad \text{(Charles Law)} \tag{79}$$

$$U = \frac{3}{2} nRT \qquad \text{(Internal Potential Energy of Ideal Gas)} \tag{80}$$

$$\bar{KE} = \frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT \qquad \text{(Avg. Kinetic Energy \textbf{per particle})} \tag{81}$$

$$m = \frac{DA(\Delta Concentration)t}{L} \qquad \text{(Diffusion)} \tag{82}$$

Review

Chapter 15: Thermodynamics

-Laws of Thermodynamics (0th - 3rd)

-Thermal Processes and work done on a thermal system

-Thermal processes using an Ideal gas

-Thermal Processes type (Isobaric, Isothermal, Isochoric, adiabatic)

-Specific heat capacities

-Heat Engines

-Carnot Engine

-Refrigerators, Air Conditioners and Heat Pumps

-Entropy

Chapter 15 (1 of 5)

Specific Heat Capacities:

$$Q = nC\Delta T \qquad \text{(Heat Transfer)} \tag{83}$$

$$\gamma = \frac{C_P}{C_V} \qquad \text{(Gamma Constant)} \tag{84}$$

$$P_i V_i^{\gamma} = P_f V_f^{\gamma} \qquad \text{(Generalized Boyle)} \tag{85}$$

$$C_P = \frac{5}{2}R \qquad \text{(Specific Heat: Constant Pressure)} \tag{86}$$

$$C_V = \frac{3}{2}R \qquad \text{(Specific Heat: Constant Volume)} \tag{87}$$

Chapter 15 (2 of 5)

$$W = P\Delta V \qquad \text{(Work done in static process)} \tag{88}$$

$$W = nRT \ln\left(\frac{V_f}{V_i}\right) \qquad \text{(Work done by Ideal Gas - isothermal)} \tag{89}$$

$$W = \frac{3}{2} nR(T_i - T_f) \qquad \text{(Work done by idea gas - adiabatic)} \tag{90}$$

$|Q_C| \implies$ Rejected heat from system

$|Q_H| \implies$ Input heat into system

$|W| \implies$ Work done by the system

$T_C \implies$ Colder temperature source

$T_H \implies$ Hotter temperature source

Engine:

$$e = \frac{\text{Work Input}}{\text{Input Heat}} = \frac{|W|}{|Q_H|} \qquad \text{(engine efficiency)} \tag{91}$$

$$e = 1 - \frac{|Q_C|}{|Q_H|} \qquad \text{(e - in terms of rejected heat, } |Q_C|) \tag{92}$$

$$\frac{|Q_C|}{|Q_H|} = \frac{T_C}{T_H} \qquad \text{(Carnot Engine)} \tag{93}$$

Chapter 15 (4 of 5)

$$\frac{|Q_C|}{|W|} = \text{refrigerator coefficient} \qquad \text{(refrigerator performance)} \qquad (94)$$

$$\frac{|Q_H|}{|W|} = \text{heatpump coefficient} \qquad \text{(heatpump performance)} \qquad (95)$$

$$\Delta S = \left(\frac{Q}{T}\right)_R \qquad \text{(Change in entropy for reversible process)} \qquad (96)$$

$$W_{\text{Unavailable}} = T_0 \Delta S_{\text{universe}} \qquad \text{(irreversible process)} \qquad (97)$$

Chapter 15 (5 of 5)

0th - Two systems are in thermal equilibrium if there is no net heat exchange between them when brought into thermal contact.

1st - When work, W, is done on a thermal system by added heat Q, a change in internal potential energy occurs (ΔU) where:

$$\Delta U = Q - W$$

2nd - Heat flows spontaneously from systems of higher temperature to lower temperature and never spontaneously the other way around.

3rd - It is fundamentally impossible to lower a substance to absolute zero ($T_K = 0K$) in a finite number of steps.

Review

Chapter 16: Waves and Sound

-The Nature of Waves

-Periodic Waves

-Speed of a wave on a string

-The mathematical description of a wave

-Sound/Speed of sound

-Sound intensity

-Decibels

-The Doppler Effect

Chapter 16 (1 of 3)

$$f = \frac{1}{T} \qquad \text{(Definition of frequency)} \tag{98}$$

$$v = f\lambda \qquad (\textbf{General} \text{ equation for wave velocity}) \tag{99}$$

$$y = A\sin\left(2\pi tf \pm \frac{2\pi x}{\lambda}\right) \qquad \text{(Wave equation with } \pm \text{ phase)} \tag{100}$$

Chapter 16 (2 of 3)

Speed of Sound in a medium:

$$v = \sqrt{\frac{F}{m/L}} \qquad \text{(Speed of wave on a string)} \tag{101}$$

$$v = \sqrt{\frac{\gamma k T}{m}} \qquad \text{(In ideal gas for } \gamma = C_p/C_V\text{)} \tag{102}$$

$$v = \sqrt{\frac{B_{ad}}{\rho}} \qquad \text{(In liquid for adiabatic bulk modulus } B_{ad}\text{)} \tag{103}$$

$$v = \sqrt{\frac{Y}{\rho}} \qquad \text{(In solid for Young's Modulus Y)} \tag{104}$$

Chapter 16 (3 of 3)

$$\mathrm{I} = \frac{P}{A} = \frac{P}{4\pi r^2} \qquad \text{(Sound Intensity for spherical radiation)} \qquad (105)$$

$$\beta = (10dB)\log_{10}\left(\frac{\mathrm{I}}{\mathrm{I_o}}\right) \qquad \text{(Sound Intensity)} \qquad (106)$$

(Generally use threshold for hearing, $\mathrm{I}_o = 10^{-12} W/m^2$, for reference.)

$$f_o = f_s\left(\frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}\right) \qquad \text{(Doppler Effect)} \qquad (107)$$

Note on Doppler shift:
Numerator: (+) if observer moving towards source (-) if observer moving away from source
Denominator: (-) if source moving towards observer (+) if source moving away from observer

Review

Chapter 17: The principle of linear superposition and interference phenomena

-Principle of Linear Superposition in Waves

-Constructive and Destructive interference of sound waves

-Beats

-Transverse standing waves

-Longitudinal standing waves

-Complex Sound Waves

Chapter 17

$$\sin\theta = \frac{\lambda}{D} \qquad \text{(General Diffraction)} \tag{108}$$

*θ corresponds to the first minimum Intensity

$$\sin\theta = 1.22\frac{\lambda}{D} \qquad \text{(Diffraction Circular Opening)} \tag{109}$$

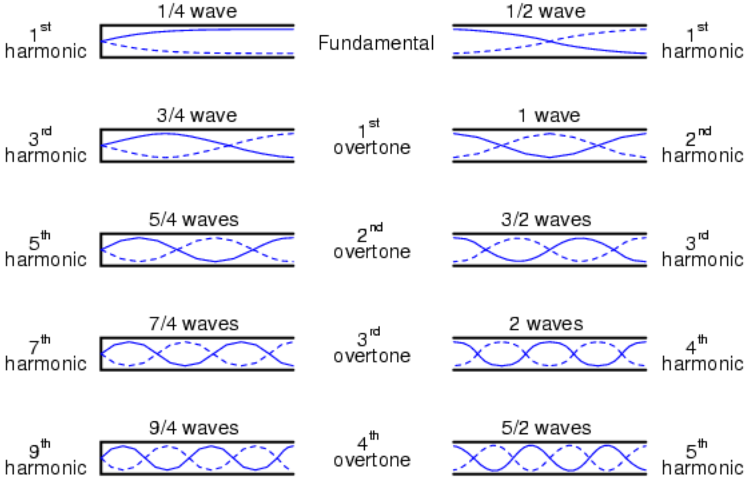
$$f_b = |f_1 - f_2| \qquad \text{(Beat Frequency)} \tag{110}$$

$$f_n = n\left(\frac{v}{2L}\right), n = 1, 2, 3\ldots \quad \text{(Standing Waves [Transverse])} \tag{111}$$

$$f_n = n\left(\frac{v}{2L}\right), n = 1, 2, 3\ldots \quad \text{(Longitudinal Standing Waves (Open))} \tag{112}$$

$$f_n = n\left(\frac{v}{4L}\right), n = 1, 3, 5\ldots \quad \text{(Longitudinal Standing Waves (1/2 closed))} \tag{113}$$

Review


1st harmonic
1/4 wave
Fundamental
1/2 wave
1st harmonic
3rd harmonic
3/4 wave
1st overtone
1 wave
2nd harmonic
5th harmonic
5/4 waves
2nd overtone
3/2 waves
3rd harmonic
7th harmonic
7/4 waves
3rd overtone
2 waves
4th harmonic
9th harmonic
9/4 waves
4th overtone
5/2 waves
5th harmonic