A.P. Physics 1 Second Semester Review Sheet

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Chapter 13: Oscillations About Equilibrium

A. Simple Harmonic Motion (SHM)

- Periodic motion repeats after a definite length of time. The period is the time required for a motion to repeat (one "cycle"), and the frequency is the number of oscillations (cycles) per unit time.
- The period, T, frequency, f, and angular frequency, ω, are related to each other by: $f = \frac{1}{T}$ and $\omega = 2\pi f = \frac{2\pi}{T}$. Rapid motion has a ***short*** period and a ***large*** frequency.
- Classic examples of simple harmonic motion (SHM) include the oscillation of a mass attached to a spring and the periodic motion of a pendulum. See Tables 1 and 2 for additional information like the period for each type of system.
- The position, x, of an object undergoing simple harmonic motion varies with time, t, as $x = A\cos(\omega t) = A\cos\left(\frac{2\pi}{T}t\right)$ where the amplitude, A, is the maximum displacement from equilibrium.
- Simple harmonic motion is the projection of uniform circular motion onto the $x-$axis.
- The maximum speed of an object in simple harmonic motion is $v_{\max} = A\omega$ and the maximum acceleration is $a_{\max} = A\omega^2$.
- From $v_{\max} = A\omega$ and $a_{\max} = A\omega^2$, it can be shown that the amplitude, A, is $A = \frac{v_{\max}^2}{a_{\max}}$ and the period, T, is $T = \frac{2\pi v_{\max}}{a_{\max}}$.

Table 1: Relative Velocity, Acceleration, and Restoring Force at Various Positions for a Spring-Mass System or Pendulum in SHM

Quantity	***Maximum Displacement Left***	***Equilibrium Position***	***Maximum Displacement Right***
Velocity, v	$v = 0$	$v = v_{\max}$	$v = 0$
Acceleration, a	$a = a_{\max}$	$a = 0$	$a = a_{\max}$
Restoring Force, F_x	$F = kx = F_{\max}$	$F = kx = 0$ since $x =$ change in distance from the equilibrium position.	$F = kx = F_{\max}$

Table 2: Periods for Oscillating Objects

Period Type	***Equation***	***Comments***
Period of a Mass on a Spring:	$T = 2\pi\sqrt{\frac{m}{k}}$	When a spring obeys Hooke's Law, the period is independent of the amplitude. For a vertical spring, Hooke's Law gives $F_y = ky = mg = W$ so $k = \frac{mg}{y}$.
Period of a Simple Pendulum with a Small Amplitude: ***($<15^o$, Serway & Faughn)*** ***($<10^o$, Knight)***	$T = 2\pi\sqrt{\frac{L}{g}}$	***For a pendulum with an amplitude less than 10^o, the period is independent of the amplitude and the mass.*** The pendulum's mass is assumed to be a point mass.
Period of a Physical Pendulum:	$T = 2\pi\sqrt{\frac{L}{g}}\left(\sqrt{\frac{I}{mL^2}}\right)$	A physical pendulum has its mass distributed over a finite volume like a hollow, glass Christmas ornament. The quantity $\sqrt{I/mL^2}$ is a correction factor that accounts for the size and shape of the physical pendulum.

- Vibrations at the natural frequency produce resonance. Structural resonance caused the Tacoma Narrows suspension bridge to collapse in 1940 only four months after it had opened.

Chapter 14: Waves and Sound

A. Wave Types

- Be able to distinguish between wavelength, frequency, and amplitude and use $v = f\lambda$ to perform related calculations.
  - Wavelength is the distance a wave travels during one cycle.
  - Frequency is the number of cycles per second; it has units of $1/s = s^{-1}$ = Hz.
  - Amplitude is the wave height (maximum displacement from the equilibrium position).
- Be able to explain the difference between transverse and longitudinal waves, sketch them, and give examples of each.
  - Transverse waves—particle movement is perpendicular to the direction of wave motion. Ex. Electromagnetic radiation, which includes gamma rays, X-rays, ultraviolet light, visible light, infrared, microwaves, and radio waves.
  - Longitudinal waves—particle movement is parallel to the direction of wave motion. Ex. Sound, earthquake tremors.
- Be able to distinguish between a pulse wave and a periodic wave.

B. Waves on a String

- Transverse waves can propagate on a string held taut with a tension force, F, in N.
- The mass per length of a string is $\mu = m / L$ where m is the mass in kg and L is the length in m.
- The speed of a wave on a string with a tension force F and a mass per length μ is $v = \sqrt{\frac{F}{\mu}}$.

C. Sound Waves

- Sound waves are longitudinal waves.
- Be able to distinguish between compression and rarefaction. Suppose the prong of a tuning fork moves to the right. On the right side, the higher air pressure results in compression. On the left side, the lower air pressure results in rarefaction.
- Frequency determines pitch.
- Ultrasonic waves can produce images.
- The speed of sound depends on the medium. For example, sound travels faster through water (1450 m/s at 20^{o}C) than through air (343 m/s at 20^{o}C).

D. Sound Intensity

- Be able to calculate the intensity of a spherical wave using $Intensity = \frac{P}{4\pi r^2}$ where P is the power in Watts, r is the distance from the source to the receiver in meters, and the intensity has units of W/m^2.
- Relative intensity is measured in decibels, dB. Note that the decibel scale is logarithmic.
- There is a 2^n increase in loudness and a 10^n increase in sound intensity where n = a 10 dB increase in sound.

E. Doppler Effect

- Be able to explain how the Doppler Effect changes the pitch when a car passes you on the road. Relative motion creates a change in frequency, which results in a change in pitch.

F. Wave Interference and Reflection

- Be able to explain the difference between constructive and destructive interference.
  - Constructive interference results in larger wave amplitudes.
  - Destructive interference results in smaller wave amplitudes.
- Be able to explain the difference between reflection from fixed and free boundaries.
  - Wave inversion occurs when waves are reflected from a fixed boundary.
  - No wave inversion occurs when waves are reflected from a free boundary.

G. Standing Waves and Beats

- Be able to determine the number of nodes and antinodes for a standing wave.
- Table 3 shows how to calculate the fundamental frequency (f_1), harmonics (f_n), and corresponding wavelengths (λ_n) for standing waves on a string or standing waves in vibrating columns of air (pipes). In these expressions, v is the speed of sound and L is the length of the string or column of air (pipe).
- The frequency difference between two sounds can be found by the number of beats heard per second. In other words, if waves of frequencies f_1 and f_2 interfere, the beat frequency is $f_{beat} = |f_1 - f_2|$.

Table 3: Frequencies and Wavelengths for Standing Waves on a String and Standing Waves in Vibrating Columns of Air

Quantity	*Frequency, f*	*Wavelength, λ*	*Harmonic Number, n*
String	$f_n = n\left(\frac{v}{2L}\right) = nf_1$	$\lambda_n = \frac{\lambda_1}{n} = \frac{2L}{n}$	$n = 1,2,3...$
Column of Air Open at Both Ends	$f_n = n\left(\frac{v}{2L}\right) = nf_1$	$\lambda_n = \frac{\lambda_1}{n} = \frac{2L}{n}$	$n = 1,2,3...$
Column of Air Closed at One End	$f_n = n\left(\frac{v}{4L}\right) = nf_1$	$\lambda_n = \frac{\lambda_1}{n} = \frac{4L}{n}$	$n = 1,3,5...$

Chapter 19: Electric Charges, Forces, and Fields

A. Electric Charge

- Charge is quantized with e = 1.60 x 10^{-19} C. Recall that you can use this as a conversion factor with units 1.60 x 10^{-19} C/electron, for example.
- Electrons have a negative charge, *–e*, protons have a positive charge, +*e*, and neutrons are electrically neutral.
- The SI unit of charge is the coulomb, C.
- Charge is conserved: The total charge in the universe is constant.
- Charge transfer occurs in two ways:
  1. Charging through contact (ex. walking across a carpet, rubbing a balloon on your hair)
  2. Charging by induction (recall electroscope demonstrations)
- Conductors, insulators, and semiconductors are compared in Table 4.
- A spherical distribution of charge, when viewed from the outside, behaves the same as an equivalent point charge at the center of the sphere.
- A van de Graaff generator collects electric charge (recall demonstrations)

Table 4: Conductors, Insulators, and Semiconductors

Material Type	*Description*
Conductor:	Each atom gives up one or more electrons that are then free to move throughout the material.
Insulator:	Does not allow electrons within it to move from atom to atom.
Semiconductor:	Has properties that are intermediate between those of insulators and conductors.

B. Electric Force

- Electric charge, force, and field are compared in Table 5.
- Electric charges exert forces on one another along the line connecting them: Like charges repel, opposite charges attract.
- Compare and contrast electric force to gravitational force (Law of Universal Gravitation):
  1. Both forces are field forces
  2. Both are inverse square laws; recall that $F = G\frac{m_1 m_2}{r^2}$ where G = 6.67 x 10^{-11} Nm^2/kg^2
  3. Electric force is significantly stronger than gravitational force
  4. Electric force can be attractive or repulsive whereas gravitational force is only attractive.

Table 5: Electric Charge, Force, and Field

Quantity	***Value or Equation***	***Comments***
Electric Charge:	e = 1.60 x 10^{-19} C Charge on an electron is –e. Charge on a proton is +e.	Charge comes in quantized amounts that are always ***integer multiples*** of e.
Electric Force: ***(The lower equation is called Coulombs's Law):***	$\vec{F} = q_o\vec{E}$ and $\vec{F} = k\frac{\lvert q_o\rvert\lvert q\rvert}{r^2}$ where k = 8.99 x 10^9 Nm^2/C^2	***Electric force is a conservative force.*** ***Superposition principle is followed:*** the electric force on one charge due to two or more other charges is the vector sum of each individual force.
Electric Field:	$\vec{E} = \frac{\vec{F}}{q_o}$ and $\vec{E} = k\frac{\lvert q\rvert}{r^2}$ $E = -\frac{\Delta V}{\Delta s}$ (or $\Delta V = -E\Delta s$)	1 N/C = 1 V/m ***Superposition principle is followed:*** the total electric field due to two or more charges is given by the vector sum of the fields due to each charge individually.

C. Electric Field

- The electric field is the force per charge at a given location in space.
- The electric field vector, $\vec{E}$, points in the direction experienced by a positive test charge.
- Electric field strength depends on charge and distance
- Electric fields can be represented by electric field lines. Rules for drawing electric field lines are given in Table 6.

Table 6: Rules for Drawing Electric Field Lines

Number	*Rule*
Rule 1:	Electric field lines point in the direction of the electric field vector, $\vec{E}$, at all times.
Rule 2:	Electric field lines start at positive charges or at infinity.
Rule 3:	Electric field lines end at negative charges or at infinity.
Rule 4:	Electric field lines are more dense the greater the magnitude of $\vec{E}$. In other words, for a set of point charges, the number of electric field lines connected to each charge is proportional to the magnitude of the charge.
Rule 5:	The electric field is always perpendicular to the equipotential surfaces, and it points in the direction of decreasing (more negative) electric potential (voltage).
Rule 6:	The electric field is perpendicular to the surface of a conductor.

D. Shielding and Charging by Induction

- Excess charge on a conductor, zero field within a conductor, shielding, and charging by induction are compared in Table 7.
- Connecting a conductor to the ground is referred to as grounding. The ground itself is a good conductor, and it can give up or receive an unlimited number of electrons.
- Charge tends to accumulate at sharp points on a conductor's surface.

Table 7: Shielding and Charging by Induction

Concept	*Description*
Excess Charge on a Conductor:	Excess charge placed on a conductor, whether positive or negative, moves to the exterior surface of the conductor.
Zero Field within a Conductor (Shielding):	The electric field within a conductor in equilibrium is zero. Thus, a conductor ***shields*** a cavity within it from external electrical fields.
Charging by Induction:	A conductor can be charged without direct physical contact with another charged object. This is charging by induction.

Chapter 20: Electric Potential and Electric Potential Energy

A. Electric Potential = Potential Difference = Voltage

- The change in electric potential is defined by $\Delta V = \Delta U / q_o$.
- The electric field is related to the rate of change of the electric potential. In particular, if the electric potential changes by the amount ΔV with a displacement Δs, the electric field in the direction of the displacement is $E = -\dfrac{\Delta V}{\Delta s}$.

Chapter 21: Electric Current and Direct-Current Circuits

A. Electric Current

- Current is the rate of charge movement $I = \frac{\Delta Q}{\Delta t}$ where I is current in Amps (A), ΔQ is charge passing through a given area in Coulombs (C), and Δt is change in time in seconds (s). By definition, 1 Amp is one Coulomb per second (1 A = 1 C/s).
- By definition, the direction of the current I in a circuit is the direction in which ***positive*** charges would move. The actual charge carriers, however, are generally electrons, which move opposite in direction to I.
- Drift velocity—net velocity of charge carriers (drift speed is relatively small; 68 min. on average for an electron to travel 1.0 m)
- Current sources
  1. Batteries—change chemical energy into electrical energy
  2. Generators—change mechanical energy into electrical energy
- There are two types of current: Direct current (DC) and alternating current (AC).

B. Resistance

- When electrons move through a wire, they encounter resistance to their motion. In order to move electrons against this resistance, it is necessary to apply a potential difference (voltage) between the ends of the wire.
- Ohm's Law is $V = IR$ where V is potential difference (voltage) in Volts (V), I is current in Amps (A), and R is resistance in Ohms (Ω).
- See Table 8 for a comparison of the electrical quantities in Ohm's Law and their water analogies.
- Ohmic versus nonohmic materials:
  1. Ohmic materials have a constant resistance over a wide range of potential differences (ex. most metals)
  2. Nonohmic materials do not have a constant resistance over a wide range of potential differences. (ex. diodes, which are analogous to check valves in plumbing)
- For an ohmic material, Ohm's Law can be experimentally determined by plotting the current (x-axis) against the voltage (y-axis). The equation for the resulting line is $V = RI + 0$ where the slope is the resistance, R, and the y-intercept is 0 since the line passes through the origin.

Table 8: Electrical Quantities in Ohm's Law and Their Water Analogies

Electrical Quantity	***Description***	***Unit***	***Water Analogy***
Electric Potential (Voltage)	Energy difference per unit charge between two points in a circuit.	Volt (V)	Water Pressure
Current	Amount of charge flowing per unit time.	Ampere (A)	Amount of water flowing per unit time.
Resistance	A measure of how difficult it is for electrical current to flow in a circuit.	Ohm (Ω)	A measure of how difficult it is for water to flow through a pipe.

- Factors affecting resistance include length of conductor, cross-sectional area of a conductor, conductor material, and temperature.
- $R = \frac{V}{I} = \frac{\rho L}{A}$ where R is resistance in Ohms, V is potential difference (voltage) in Volts, I is current in Amps, ρ is resistivity in Ohm-meters (See Table 21-1 on p.700), L is the length of the conductor in meters, and A is the conductor's cross-sectional area in m^2.
- Resistors can be used to control the amount of current in a conductor. As resistance increases, current decreases at constant voltage.
- Superconductors have no resistance below a critical temperature.
- Salt water and perspiration lower the body's resistance.

C. Electric Power

- Electric power, P, is the rate at which electrical energy is converted to other forms of energy. It can be calculated using $P = IV$ where P is power in Watts (W), I is current in Amps (A), and V is potential difference (voltage) in Volts (V).
- $P = I^2R$ and $P = \frac{V^2}{R}$ are both combinations of the power formula, $P = IV$, and Ohm's Law, $V = IR$.
- Most light bulbs are labeled with their electric power rating in Watts; the amount of heat and light given off by the bulb is related to the power rating.
- Electric companies measure energy consumed in kilowatt hours (1 kWh = 3.6×10^6 J)
- Electrical energy is transferred at high potential differences (voltages) to minimize energy loss.

D. Schematic Diagrams

- Make sure you can read, understand, and draw schematic diagrams.
- Know the symbols for wire, resistor, battery, open and closed switch, capacitor, bulb, and plug.
- Be able to identify open circuits, closed circuits, and short circuits
- Short circuits occur when there is little or no resistance to the movement of charges; the increase in current may cause the wire to overheat and start a fire.
- When a light bulb is screwed in, charges can enter through the base, move along the wire to the filament, and exit the bulb through the threads.
- Light bulbs emit light because the filament is a resistor which converts some electrical energy to light energy and heat energy.
- The electromotive force (emf) is the source of a circuit's potential difference (voltage) and electrical energy.

E. Resistors in Series and Parallel Circuits

- Be able to use Ohm's Law, $V = IR$, and the information in Table 9 to determine the equivalent resistance, R_{eq}, current, I, and voltage V, for complex circuits containing both series and parallel parts.
- For complex circuits containing batteries, Ohm's Law, $V = IR$, is expressed as $\varepsilon = I_{Battery}R_{eq}$ where ε is the battery's emf (voltage), $I_{Battery}$ is the current passing through the battery, and R_{eq} is the circuit's equivalent resistance.
- In real life, batteries have a small internal resistance that must be included in calculations when current is ***flowing***. However, when current is ***not flowing*** like when a circuit switch is open, this internal resistance is ignored.
- Kirchoff's rules in Table 10 are statements of charge conservation and energy conservation as applied to closed electrical circuits. Kirchoff's rules give an alternate way to find current and voltage in complex circuits.

Table 9: Series and Parallel Circuits

Quantity	***Series Circuit***	***Parallel Circuit***
Equivalent Resistance, R_{eq}:	$R_{eq} = R_1 + R_2 + R_3 + \ldots = \Sigma R$	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots = \Sigma \frac{1}{R}$
Current, I :	$I = I_1 = I_2 = I_3 = \ldots$	$I_{total} = I_1 + I_2 + I_3 + \ldots = \Sigma I$
Voltage, V : ***(emf, ε, when batteries are involved)***	$V_{total} = V_1 + V_2 + V_3 + \ldots = \varepsilon$	$V = V_1 = V_2 = V_3 = \ldots = \varepsilon$

Table 10: Kirchhoff's Rules

Rule	***Description***
Junction Rule: ***(Charge Conservation)***	***The algebraic sum of all currents meeting at a junction must equal zero.*** Currents entering the junction are taken to be positive; currents leaving the junction are taken to be negative.
Loop Rule: ***(Energy Conservation)***	***The algebraic sum of all potential differences around a closed loop is zero.*** The potential increases in going from the negative to the positive terminal of a battery and decreases when crossing a resistor in the direction of the current.

F. Ammeters, Voltmeters, and Multimeters

- Ammeters and voltmeters are devices for measuring currents and voltages, respectively, in electrical circuits.
- Ammeters, voltmeters, and multimeters are compared in Table 11.

Table 11: Ammeters, Voltmeters, and Multimeters

Meter Type	***Connected in:***	***Ideal Case***	***Comments***
Ammeter:	Series	Resistance is zero	Measures electric current in Amps
Voltmeter:	Parallel	Resistance is infinite	Measures electric potential in Volts
Multimeter:	Measures electric current in Amps, electric potential in Volts, and resistance in Ohms depending on the instrument settings.		