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The (Epic) AP Physics I Study Guide

I. Kinematics
   A. **velocity** is displacement over time, symbol—v, units—m/s
   B. **position** is a location in space, symbol—x
   C. **acceleration** is the change in velocity over time, units—m/s^2
   D. **displacement** is change in position, symbol—∂x, units—m
   E. all objects fall toward the center of the earth at constant acceleration 9.8 m/s^2, **gravity**
   F. vel, acc, & dis are **vectors** that include magnitude and direction, negative is usually down/left
   G. equations
      1. $a = \partial v/\partial t$
      2. $v = \partial x/\partial t$
      3. $v = v_0 + at$
      4. $x = x_0 + v_0 t + at^2/2$
      5. $v^2 = v_0^2 + 2a\partial x$

II. Dynamics
   A. **Law 1**; an object at rest stays at rest, an object in motion remains in constant velocity straight-line motion unless acted on by a net force
      1. **inertia** is the tendency of an object to remain at rest or in constant straight-line motion
      2. **mass** is the measure of an object's inertia, units—kg
   B. **Law 2**; the acceleration of an object is proportional to the net force acting on itself and its mass
      1. **force** is a vector, units—N
   C. Friction is the force between an object and a surface that acts parallel, symbol—f
      1. static friction applies when an object at rest is opposed by some maximum value with a coefficient of friction μ_s
      2. kinetic friction opposes the sliding motion of a moving object with a coefficient of friction μ_k that is always less than that of static friction
   D. an object is in **equilibrium** when it has a zero acceleration, or $\Sigma F = 0$
   E. Inclined planes; rotating standard axes can make force calculations simpler
   F. in systems, connected objects usually have the same acceleration but directions could vary
   G. equations
      1. $f_s \leq \mu_s N$
      2. $f_k = \mu_k N$
      3. $\mu_s > \mu_k$
      4. $a = \Sigma F/m$

III. Work & Energy
   A. when an object moves because of a force, **work** occurs; unit—J or Ns, a scalar
      1. depends on force parallel to displacement (s) (see equation 1)
      2. can be negative when force and displacement function in opposite directions
      3. zero when displacement/force is zero, or force is perpendicular to force
      4. **kinetic energy** is the energy of an object due to its velocity (see equation 2)
   B. potential energy
      1. **gravitational potential energy**, aka work done by gravity; relative to chosen origin, stored potential energy (to do work)
      2. the force exerted on an object by a **spring** is proportional to a spring constant k; there is an elastic **potential energy** associated with work done by said force
   C. forces
      1. **conservative forces** do work that is easily reversed and doesn't depend on its path
      2. **liberal forces** do work not easily reversed (i.e. friction) and depend on its path
   D. **conservation of mechanical energy**, mechanical energy is conserved should conservative forces interact only, (see equation 5 & 6)
   E. **power** is the rate at which work is done, units—J/s or W (see equation 9)

F. equations

1. $W = (F\cos\theta)s$
2. $kE = mv^2/2$
3. $W = kE_f - kE_0$
4. $PE_g = mgh$
5. $E_0 = E$
6. $\partial kE = W_C + W_{NC}$
7. $F_S = -kx$
8. $PE_S = kx^2/2$
9. $P = \partial E/t$

IV. Momentum and Impulse

A. **impulse** is the product of the average force applied to an object and the time interval that force acts, symbol—*J*, units—*Ns* (see equation 1)

B. **linear momentum** is the product of an object's mass and its velocity, symbol—*p*, unit—*kgm/s* (see equation 2)

C. when a net force acts on an object, its impulse is it's change in momentum (see equation 3-5)

D. collisions

1. an **elastic** collision conserves kinetic energy; an **inelastic** one doesn't do so
2. the total **linear momentum** of an isolated system (where the vector sum of the average external forces be zero) **is conserved**

E. the average location for the total mass of an object is at its **center of mass**; if momentum is conserved, the velocity of the center of mass of particles remains constant

F. equations

1. $J = F\partial t$
2. $p = mv$
3. $J = \partial p$
4. $F\partial t = \partial p$
5. $F\partial t = mv$

V. Simple Harmonic Motion

A. **Hooke's Law** states that for an ideal spring, the restoring force it applies to an object is defined by equation III.7 and that they have an elastic potential energy noted in equation III.8

B. objects are in **SHM** if they move repetitively though an equilibrium position due to a restoring force

1. **amplitude** (*A*) is the maximum displacement of an object from the equilibrium
2. **period** (*T*) is the time it takes the object to make one cycle (there and back)
3. **frequency** (*f*) is the number of cycles per unit of time measured in *Hz*

C. **waves** are disturbances that transfer energy from one location to another

1. **transverse** waves disturb particles perpendicular to direction of travel; i.e. seismic, light, and oceanic
2. **longitudinal** waves distribute particles parallel to the direction of travel
3. speed depends on string's tension and linear density (see equation 3); pitch is frequency
4. reflect one another by Newton's third law
5. an interference between individual waves and their reflections cause **standing waves**
   a) appear to oscillate perpendicularly
   b) points of no movement are **nodes**; points of amplitude are **antinodes**
   c) a single was of the string's length is the 1st harmonic ($f = v/2L$)
   d) longitudinal standing waves
      (1) pipe open at both ends—$f_n = nv/2L$
      (2) pipe closed at one end—$f_n = nv/4L$, only odds
6. sound waves
   a) when a speaker's diaphragm moves outwards, it compresses air ahead resulting in increased air pressure called **condensation**
   b) inward movement creates opposite effect called **rarefaction**
   c) λ is the distance between the condensations
   d) frequencies
      (1) a pure tone sound wave has one frequency
      (2) <20 *Hz* waves are **infrasonic**, >20 *Hz* are **ultrasonic**
      (3) ear receives frequency in **pitch** form; the two are proportional (i.e. high-pitched)
   e) **pressure amplitude** is the maximum change in pressure; proportional to loudness

f) intensity
  (1) the **intensity** I of a sound wave is the power, P, that passes perpendicularly though the surface A (see equation 5), unit—W/m^2
  (2) spherical uniform radiation is noted on equation 6
g) the **doppler effect** is the change in frequency detected by an observer because of different velocities of the sound source and the observer (see equation 7)
h) interference
  (1) waves supplement one another in **constructive** interferences and do otherwise in **destructive** interferences
  (2) waves that meet at nodes or antinodes are **in-phase**, others are **out-phase**
i) difference between the frequency in the waves is the **beat frequency**

D. equations

1. $v = f\lambda$
2. $T_S = 2\pi\sqrt{(m/k)}$
3. $v = \sqrt{(TL/m)}$
4. $T = 1/f$
5. $I = P/A$
6. $P = 4\pi r^2$
7. $f_0 = f_s(1 \pm v_0/v)/(1 \pm v_s/v)$

VI. Electrostatics and Resistance

A. electric force and conduction
1. charge of an **electron** is $e = 1.6 \bullet 10^{-19}\ C$; charges are quantized and only electrons can move/trade
2. like charges repel one another; net electric charge of a system stays constant during any process; **electroscopes** measure charge
3. an **electric conductor** conducts charge readily, an **electric insulator** does so poorly
4. **Coulomb's Law** fives an electric force F that points of charge exert on one another (see equation 1)

B. electromotive force/current
1. there must be ≥1 source/generator of electrical energy (i.e. battery); its **electromotive force** is the maximum potential difference between the terminals of the generator
2. the rate of flow is **electric current** measured in amperes (A) (see equation 2)

C. resistivity and resistance
1. **Ohm's Law** states that resistance is calculated by equation 3 and measured in ohms, Ω
2. the **resistance** of a material is given by equation 4, where p is the **resistivity** of the material and a is the temperature coefficient of resistivity
3. the resistivity is dependent on temperature as demonstrated by equation 5; as is resistance (equation 6)
4. **internal resistance** is the resistance within a generator/source
  a) **terminal voltage** is the voltage between the terminals of a generator/source and is equal to the EMF only when there is no current through the device
  b) with current I, the internal resistance r causes there terminal voltage to be less than the EMF by Ir

D. **series**—each device receives the same current; the summative resistance in a series is given by equation 7

E. **parallel**—same voltage is applied across each device, usually different currents; resistance can be found with equation 8

F. Kirchoff's Rules
1. **junction rule**—sum of currents directed into a junction is equal to the sum of the currents directed out
2. **loop rule**—the sum of potential energy "used" by each component equals the voltage supplied

G. equations

1. $F = k|q_1||q_2|/r^2$
2. $I = \partial q/\partial t$
3. $R = V/I$
4. $R = pL/A$
5. $p = p_0[1+ a(T-T_0)]$
6. $R = R_0[1+ a(T-T_0)]$
7. $R_s = \sum R_n$
8. $1/R_p = \sum 1/R_n$

VII. Circular Motion and Gravitation

A. centripetal force
1. an object in circular motion experiences **centripetal acceleration** (see equation 1), force is equation 2

2. movement toward center is positive, movement outwards is negative (conventionally)

B. **Universal Gravitation Law**—see equation 4, where the gravitational constant G is *6.67 • 10-11 Nm²/kg²* and r is the distance between the two centers

C. **gravitational fields** are models to explain and show regions of space where a force acts on an object (see equation 5)

D. **gravitational potential energy**—see equation 6

E. orbits

1. in circular orbits, PE is constant because constant radius; therefore, KE is constant because conservation of energy
2. in elliptical orbits, projectiles are faster when closer to the object being orbited because of the above reasoning except 'proportional' instead of 'constant'

F. equations

1. $a_c = v^2/r = 4\pi r/T$
2. $F_c = mv^2/r$
3. $v = 2\pi r/T$
4. $F_g = Gm_1m_2/r^2$
5. Gm/r^2
6. $PE_g = Gm_1m_2/r$

VIII. Rotational Motion

A. **angular displacement** is the angle $\partial\theta$ travelled when rotating perpendicularly, conventionally negative clockwise and visa versa, see equation 1 where s is arc length; units—*rad*

B. **angular velocity**—see equation 2 in *rad/s*

C. **angular acceleration**—see equation 3 in rad^2/s

D. **torque** of a force has a magnitude F of the force time the lever arm l, see equation 7 for τ

E. **equilibrium** is achieved if there is no angular nor translational acceleration aka equation 8

F. the **center of gravity** is where the entire weight can be considered to act when calculating the torque due to weight; it's just like center of mass

G. Law 2

1. **moment of inertia** I of a body of n particles is given by equation 9
2. **second law for rotational motion** is given by equation 10

H. **rotational work** done by constant torque is given by equation 11

I. **rotational kinetic energy** is given by equation 12

J. **angular momentum**—$L = I\omega$

K. equations

1. $\theta = s/r$
2. $\omega = \partial\theta/\partial t$
3. $a = \partial\omega/\partial t$
4. $\omega = \omega_0 + at$
5. $\theta = \theta_0 + \omega_0 t + at^2/2$
6. $\omega^2 = \omega_0^2 + 2a\partial\theta$
7. $\tau = Fl$
8. $\sum F = 0$ & $\sum\tau = 0$
9. $I = \sum m_n r_n^2$
10. $\sum\tau = Ia$
11. $W_R = \tau\theta$
12. $kE_R = I\omega^2/2$