SAT II Physics Topics

MECHANICS

Simple Harmonic Motion

$SpringEnergy = \frac{1}{2}kx^2$

If amplitude is doubled then energy is quadrupled.

Mass on a Spring

$T = 2\pi\sqrt{\frac{m}{k}}$ where T = period m= mass k =spring constant

Pendulum

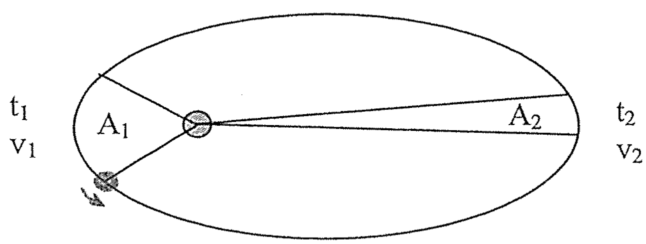
$T = 2\pi\sqrt{\frac{l}{g}}$ where T = period l = length g = acceleration due to gravity

- This equation is an approximation used for small angles only.
- Questions on the exam may pertain to conservation of energy, PE, KE, and velocity which do not require the use of the above equation.

Kepler's Laws

1st Law: The path of a planets orbit is an ellipse with the sun at one of the focus points.

2nd Law: As a planet moves in its orbit, a line drawn from the sun to the planet sweeps out equal areas in equal times.



When $A_1=A_2$

$t_1=t_2$ and

$v_1 > v_2$

3rd Law: $\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3$ for two planets orbiting the same sun.

WAVES and OPTICS

Doppler Effect $f_o = \frac{v \pm v_o}{v \pm v_s} f_s$ *o = observer s=source*

v_o+ when moving toward and v_s+ when moving away

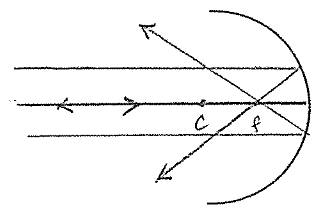
Questions may be conceptual, f_o increases when approaching, etc.

WAVES and OPTICS (continued)

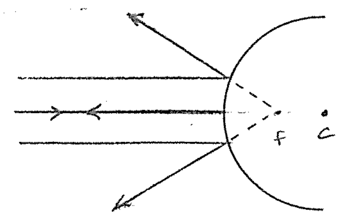
<u>Mirrors</u> produce an image by reflecting light.

<u>Spherical Mirrors</u> the mirror is a piece of a sphere with the mirrored surface either inside the ball or outside the ball. C=center of curvature=radius= 2x focal length

Spherical aberration occurs with mirrors, rays far from the p-axis do not meet at a clear focus. Parabolic mirrors do not have spherical aberration.



Concave Mirror
converging Positive F



Convex Mirror
diverging Negative F

Produces any size, real, inverted images and only virtual, erect, larger images.

Produces only virtual, erect, smaller images.

Mirror ray diagram rules:

- Principle Ray: parallel to the p-axis to the mirror and reflects through f
- Focal Ray: through F to the mirror and reflects parallel to the p-axis
- Central Ray: through C (2f) to the mirror and reflects through C (2f)

The lens equation and magnification equation used for lenses is used for spherical mirrors.

<u>Diffraction and Interference</u>

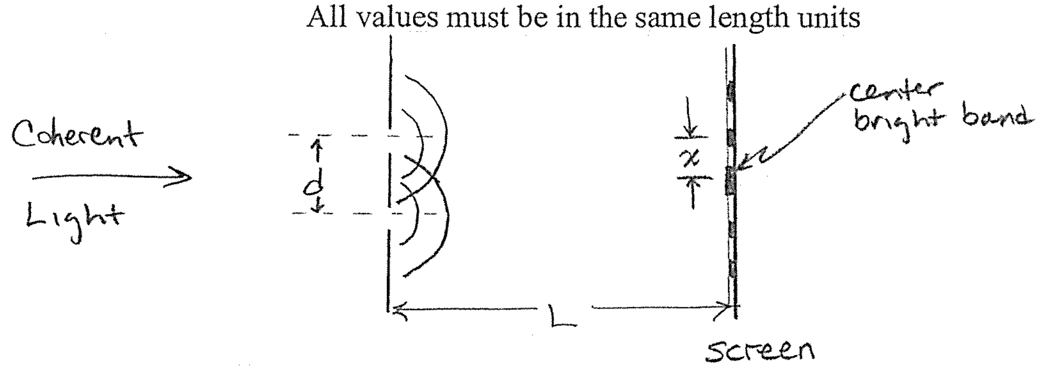
Double Slit Diffraction

$$\frac{\lambda}{d} = \frac{x}{L}$$

d=distance between slits x=distance between maxima

L=distance from the slits to the screen λ= wavelength

All values must be in the same length units



Single slit diffraction produces a wider center band. Bands further from the center are less bright.

Diffraction Grating, many slits, produces a stronger (brighter) pattern.

HEAT AND THERMODYNAMICS

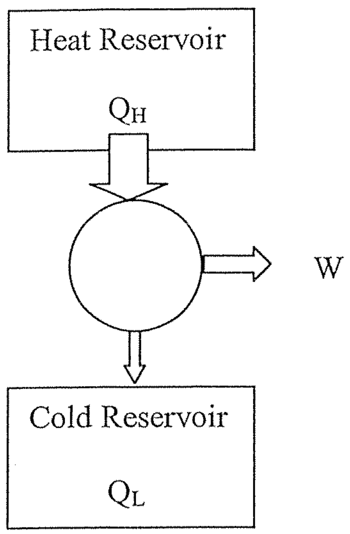
Laws of Thermodynamics

1st Law: The total increase in energy of a system is the sum of the work done on it and the heat added to it.

2nd Law: Natural processes proceed in the direction that increases the total entropy of the universe. Entropy is a measure of the disorder of the system.

3rd Law: Absolute zero can never be achieved.

Heat Engine Efficiency



$Q_H = W + Q_L$

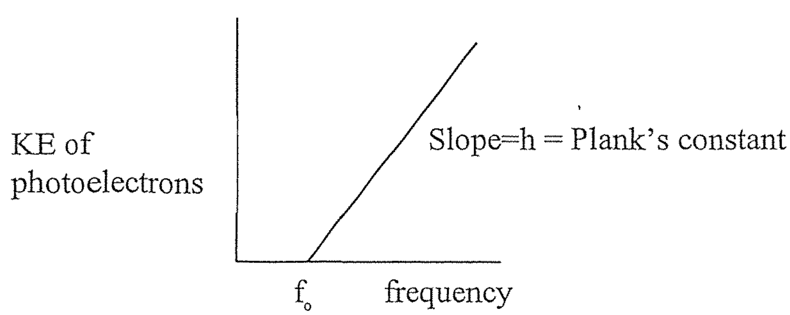
No engine can convert all energy into useful motion or work.

$$Efficiency = \frac{Work_{out}}{Work_{in}} \times 100\%$$

MODERN PHYSICS

Photoelectric Effect: When light falls on a photo emissive surface . . .

- If the frequency of the light is above the threshold frequency (f_o) electron are ejected (photoelectrons).
- When $f > f_o$ the photoelectrons are ejected with KE > zero
  $E_{phtoton} = KE_{max} - hf_o$
- Increasing the intensity of the light (more light)
  - below f_o does not produce photoelectrons
  - above f_o produces more electrons, higher photoelectric current, of the same KE.
- This is an example of waves behaving like matter; conservation of energy.



SAT II Physics Topics

Special Relativity (as the velocity of an object approaches the velocity of light)

Postulates of Special Relativity

1. The laws of physics are the same for all frames of reference moving at constant velocity with respect to one another.

2. The velocity of light in a vacuum is the same for all observers regardless of their state of motion or the motion of the light source

Leads to:

* Length contraction: The length, measured parallel to the direction of motion, of an object moving at a velocity approaching c will be shorter when measured by a fixed observer.

$L = L_o \sqrt{1 - (v^2/c^2)}$

L = length as measured by the fixed observer

L_o = proper length

* Simultaneity and time dilation: When travel approaches c, time, as measured by a fixed observer, slows down.

$t = t_o/\sqrt{1 - (v^2/c^2)}$

t = time as measured by the fixed observer

t_o = proper time in moving frame of reference

* Relativistic mass and energy: Inertial mass varies with velocity (objects become more massive as v approaches c)

$m = m_o / \sqrt{1 - (v^2/c^2)}$

m = mass as measured by the fixed observer

m_o = proper mass in moving frame of reference

Demonstrates why v cannot equal c. If c = v, mass would be undefined.

Relativistic momentum

$p = mv = m_o v / \sqrt{1 - (v^2/c^2)}$

Astrophysics

Currently, most of the understanding of astrophysics is based on Einstien's general theory of relativity.

A *light-year* is the distance light travels in 1 year, approximately 10^{13} km.

Distant stars are studied based on the light emitted years ago that is reaching Earth now.

Stars start as hydrogen clouds contracting into a *protostar*. The protostar contracts due to gravity. Fusion begins to occur. As the fusion occurs helium is formed. The helium is denser and accumulates in the core. The star expands and cools. It is now a *red giant.* If the star begins to lose mass as parts begin to drift into space, there is no longer mass to sustain fusion and the star becomes a *white dwarf* and burns out. If the star is more massive, it has the potential to become a *neutron star.* Gravitational potential energy increases and is released in a massive explosion called a *supernovae*. If the star continues to contract, it becomes a *black hole*. Gravity in a black hole is so intense that not even light can be emitted.

Faraday's Law: A magnetic field induces an electric field.

Lenz's Law: The direction of current induced opposes the motion of the magnetic field that induced the current. Lenz's Law is a special case of the conservation of energy.

Joule's Law: The heat generated in a circuit is proportional to the current squared multiplied by resistance and time.

$H = I^2Rt$

If R is constant and I is doubled during a given amount of time heat will be quadrupled.

In a parallel circuit the device with the least resistance draws the most current and produces the most heat

Capacitors

Capacitance is the ability to store electric charge. A capacitor consists of two conductor separated by an insulator or *dielectric.* Capacitance is measured in Farads (F).

Capacitance is proportional to the area of the plates and inversely proportional to the distance between the plates. For a parallel plate capacitor:

$C = \varepsilon A/d$

ε is the permeability of the material between the plates.

If a dielectric is used in between the plates (as opposed to air), the capacitance is higher, or, the same capacitance can be achieved with a smaller distance between plates. The dielectric strength refers to the maximum electric field before charge flows.

The charge stored by a capacitor is a product of the capacitance and the electric potential across the plates.

$Q = CV$

The energy stored is equal to the work done to charge the capacitor.

$W = PE = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2} Q^2/C$

A *CRT*, cathode ray tube, consists of a capacitor in a vacuum. The *anode*, or positive plate, has a small opening that allows the negative charge, or electrons, emitted fro the *cathode* to pass through.

Total capacitance of capacitors *in parallel* is the sum of the capacitances of each capacitor.

$C_T = C_1 + C_2 + \ldots$

Total capacitance of capacitors *in series* is the reciprocal of the sum of the reciprocal capacitances of each capacitor.

$1/C_T = 1/C_1 + 1/C_2 + \ldots$

A resistor and a capacitor in series are called an *RC circuit*. RC circuits control timing (on - off - on - off) ex. pacemaker, blinker, flashing light. The quantity of resistance multiplied by capacitance is called the time constant and is 63% of the maximum capacitor voltage (and charge).

<u>Semi conductors</u>

In a conductor, the valance band of electrons is adjacent to the conduction band.

In an insulator, there is a large energy gap between the valance and conduction bands.

In a semi conductor, the energy gap is small and when the material is heated many electrons have the energy to bridge the gap.

Doping is adding a small amount of material with either 1 valance electron (n type) or missing 1 valance electron (p type).

Combinations of n type semiconductors and p type semi conductors are *diodes*. In a combination of p type and n type, as the electrons cross the pn border, photons are emitted. The photons are in the red region of the spectrum (an *LED*, or light emitting diode). Diodes are non-Ohmic, a graph of I vs. V is not linear.

Transistors are semi conductor "sandwiches", either npn or pnp, capable of amplifying signals. The layers of the transistor are called the collector, base, and emitters.

An *IC*, or integrated circuit, is a chip with transistors, diode, and resistors created by carefully placing impurities within silicon.