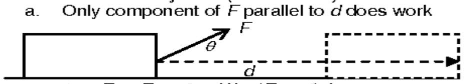
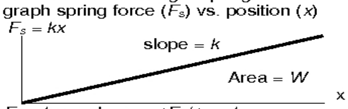
AP Physics 4: Linear Momentum and Energy **Name** ______________________________

A. Momentum and Energy formulas
   1. impulse changes object's momentum: $\boldsymbol{F\Delta t = m\Delta v = \Delta p}$
   2. quantity of motion (vector quantity): $\boldsymbol{p = mv}$ (kg•m/s)
   3. work changes object's energy: $\boldsymbol{W = F_{||}d}$ (J)
      a. measured in joules (1 J = 1 N•m)
      a. Only component of F parallel to d does work



         1. $F_{||} = F\cos\theta$ ∴ $W = (F\cos\theta)d$
         2. include sign ∴ $W > 0$ when $F \rightarrow d \rightarrow$
         3. $F \uparrow\downarrow$ when $d \rightarrow$ (orbit)
      b. variable force—stretching a spring
         1. graph spring force (F_s) vs. position (x)



         2. $F_s = kx$ ∴ slope = $\Delta F_s/\Delta x = k$
         3. $W = F_s x$ ∴ area = $\frac{1}{2}x(kx) = \frac{1}{2}kx^2 = W$
      c. power is the rate work is done: $\boldsymbol{P = W/t}$ (W)
         1. measured in watts (1 W = 1 J/s)
         2. $P = W/t = F(d/t) = Fv_{av}$ (v is average)
         3. graphing
            a. $P = W/t$ ∴ slope of W vs. t graph
            b. $P = Fv_{av}$ ∴ area under F vs. v graph
         4. kilowatt-hour, 1KWh = 3.6×10^6 J
   4. mechanical energy
      a. work-energy theorem: work done <u>to</u> an object increases mechanical energy; work done <u>by</u> an object decreases mechanical energy
      b. scalar quantity, like work
      c. kinetic energy—energy of motion
         1. positive only
         2. $\boldsymbol{K = \frac{1}{2}mv^2 = p^2/2m}$

Steps	Algebra
start with	$v^2 = v_0^2 + 2ad$
assume $K_0 = 0$ ∴ $v_0 = 0$	$v^2 = 2ad$
solve for ad	$ad = \frac{1}{2}v^2$
start with	$K = W = Fd$
substitute ma for F	$K = (ma)d = m(ad)$
substitute $\frac{1}{2}v^2$ for ad	$K = m(\frac{1}{2}v^2)$
rearrange	$\boldsymbol{K = \frac{1}{2}mv^2}$
start with	$mv = p$
square both sides	$m^2v^2 = p^2$
divide both sides by 2m	$m^2v^2/2m = p^2/2m$
substitute K for $\frac{1}{2}mv^2$	$\boldsymbol{K = p^2/2m}$

      d. potential energy—energy of relative position
         1. gravitational potential energy
            a. based on arbitrary zero (usually closest or farthest apart)
            b. $\boldsymbol{U_g = mgh}$ (near the Earth's surface)

Steps	Algebra
start with	$U_g = W = Fd$
substitute mg for F	$U_g = (mg)d$
substitute h for d	$\boldsymbol{U_g = mgh}$

            c. $\boldsymbol{U_g = -GMm/r}$ (orbiting system)
               1. $G = 6.67 \times 10^{-11}$ N•m^2/kg^2
               2. r = distance from center to center
               3. $U_g = 0$ when r is ∞ ∴ $U_g < 0$ for all values of r because positive work is needed reach $U_g = 0$
         2. spring (elastic) potential energy, $\boldsymbol{U_s = \frac{1}{2}kx^2}$
            a. $U_s = W$ to stretch the spring
            b. see work by a variable force above