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AP Physics Review Sheet

Unit 8: Potential Energy

Unit 8 in AP Physics focuses on Potential energy, building off of the previous units 'work" on Work. Potential energy refers to the energy stored in two systems we'll talk about: Gravitational potential energy and Elastic potential energy. This unit explores how energy is conserved in systems with only conservative forces, and how non-conservative forces, such as friction, affect the total mechanical energy in a system. Unit 8 also covers potential energy diagrams to understand motion and energy transformations.

Major Topics:

I. Gravitational and Elastic Potential Energy
II. Conservation of Mechanical Energy
III. Work done by non-conservative forces
IV. Potential energy diagrams
V. Energy transfer in systems

Key Vocabulary:

a. *Potential energy*: the stored energy in an object due to its position, properties, and forces acting on it.
    i. *Gravitational potential energy:* Energy stored due to an object's height above a reference point
    ii. *Elastic (spring) potential energy:* Energy stored in a stretched or compressed spring
    iii. *Conservative forces:* Forces that exist when the work done by that force on an object is independent of the object's path
    iv. *Nonconservative forces:* Forces such as friction or air resistance that take energy away from the system as the system progresses (energy that you can't get back). Nonconservative forces are dependent on the object's path.
    v. *Mechanical energy:* The sum of kinetic and potential energy in a system
    vi. *Work:* Energy transferred by a force through a distance

Useful Equations:

Gravitational PE: U_g = mgh

Elastic PE: $U_g = \frac{1}{2}kx^2$

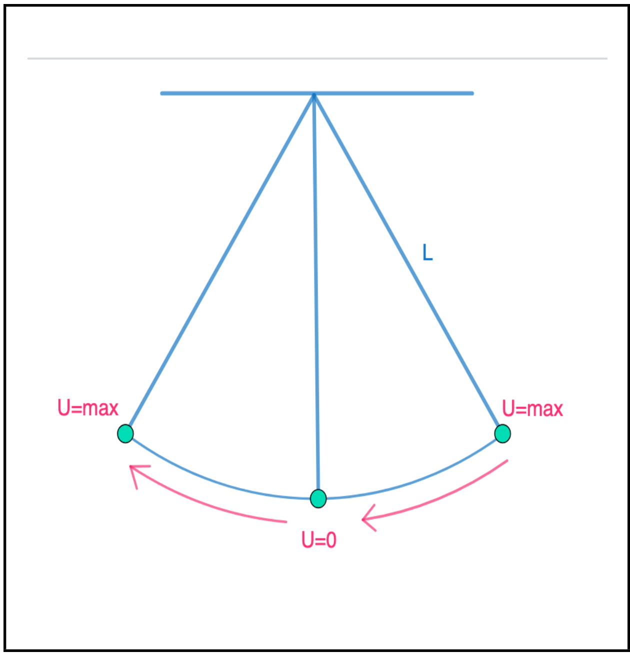
Conservation of energy: $\Sigma E_{initial} = \Sigma E_{final}$, where E = K + U

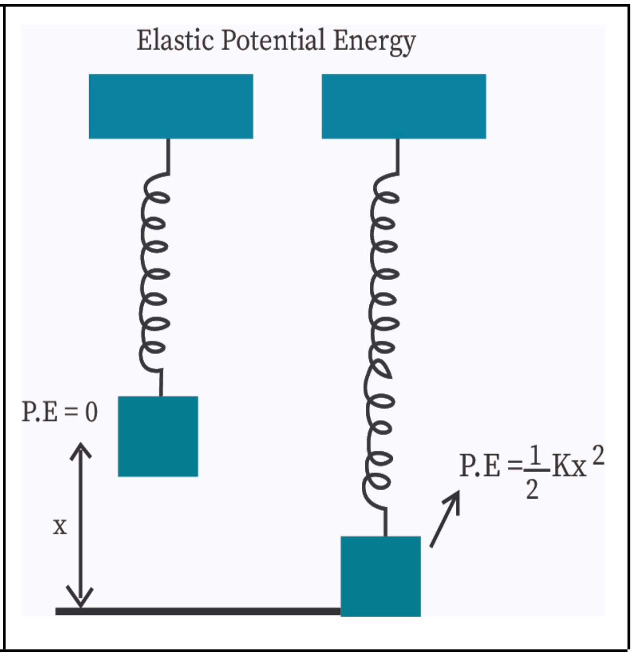
Work: $W_g = - \Delta U$

- $W_g = \int_{x_i}^{x_f} F_g \, dx$
- $W_g = \int_{x_i}^{x_f} F_s \, dx$

Energy changes due to kinetic friction: $\Delta E_{internal} = f_k d$

Force from potential energy (slope of U vs. x graph): $F = -\frac{dU}{dx}$





Practice problems:

(Easy) : Tarzan grabs a vine hanging vertically from a tall tree when he is running at 9.0m/s. (a) How high can he swing upward?

(Medium) : A baseball of mass 0.25 kg is hit at home plate with a speed of 40 m/s. When it lands in a seat in the left-field bleachers a horizontal distance 120 m from home plate, it is moving at 30 m/s. If the ball lands 20 m above the spot where it was hit, how much work is done on it by air resistance?

(Hard) : A block of mass 500 g is attached to a spring of spring constant 80 N/m (see the following figure). The other end of the spring is attached to a support while the mass rests on a rough surface with a coefficient of friction of 0.20 that is inclined at an angle of 30°. The block is pushed along the surface till the spring compresses by 10 cm and is then released from rest. (a) How much potential energy was stored in the block-spring-support system when the block was just released? (b) Determine the speed of the block when it crosses the point where the spring is neither compressed nor stretched. (c) Determine the position of the block where it just comes to rest on its way up the incline.

(Easy) :

$\Sigma E_i = \Sigma E_f$ ← conservation of energy

$KE_i + PE_i = KE_f + PE_f$

Tarzan is initially running on the ground so:

$\frac{1}{2}mv^2 + 0 = 0 + mgh$

↑ ground so no height

↳ once reaches max height, KE = 0

$\frac{1}{2}mv^2 = mgh = \left[\frac{1}{2}v^2 = gh\right]$

plug in values:

$v = 9.0 m/s$

$g = 9.81 m/s^2$

$\left(\frac{1}{2}\right)(9)^2 = (9.81)(h)$

$\frac{81}{2} = 9.81h$

$40.5 = 9.81h$

$4.13 \approx h$

Tarzan can swing to around 4.13m.

(Medium) :

$m = 0.25kg$

$V_i = 40m/s$

$V_f = 30m/s$

h gained = 20m

$g = 9.81m/s^2$

In order to find work done by non-conservative force (air resistance):

$W_{n.c} = \Delta KE + \Delta PE$

$\Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$= \left(\frac{1}{2}\right)(0.25)(30)^2 - \left(\frac{1}{2}\right)(0.25)(40)^2$

$(112.5) - (200) = -87.5J$

change in grav. PE

$\Delta PE = mgh$

$= (0.25)(9.81)(20) = 49J$

Plug both in:

$W_{n.c} = \Delta KE + \Delta U =$

$-87.5J + 49J =$

$-38.5J$

Work done by air resistance is −38.5J.

(Hard) :

This is a spring block system on an inclined plane with friction.
Use energy conservation and Work-energy principles:

$m = 500g = 0.5\,kg$

Spring constant $K = 80\,N/m$

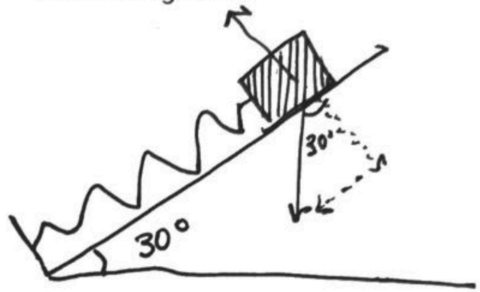
Spring compression $x = 10cm = 0.10m$

Coefficient of kinetic friction $\mu_K = 0.20$

Angle of incline $\theta = 30°$

$g = 9.81\,m/s^2$

Draw diagram:



a) Spring PE

$U_s = \frac{1}{2}Kx^2 \implies U_s = (\frac{1}{2})(80)(0.10)^2 = \boxed{0.4J}$

b)

$U_{s_{initial}} = KE + W_{fric} + \Delta U_g \implies (\frac{1}{2})Kx^2 = \frac{1}{2}mv^2 + f_K d + mg\sin(\theta)d$

distance traveled = 0.10m (compression)

loading up total available energy

$\Delta U_g = mg\sin\theta \cdot d$
$= (0.5)(9.81)(\sin 30)(0.10)$
$= \underline{0.245J}$

finding friction force:

$f_K = \mu_K F_N = \mu_K mg\cos\theta$
$(0.20)(0.5)(9.81)(\cos 30°)$
$= \underline{0.847N}$

So work done by friction:

$f_K \cdot d = 0.847 \times 0.10 =$
$\underline{0.0847J}$

Now we can plug in the values:

$0.4J = (\frac{1}{2})(0.5)(v^2) + 0.0847 + 0.245$

we're looking for

$0.4 = 0.25v^2 + 0.3297$

$0.0703 = 0.25v^2$

$\sqrt{0.2812} = \sqrt{v^2}$

$0.530 = v$

$\boxed{V = 0.53m/s}$