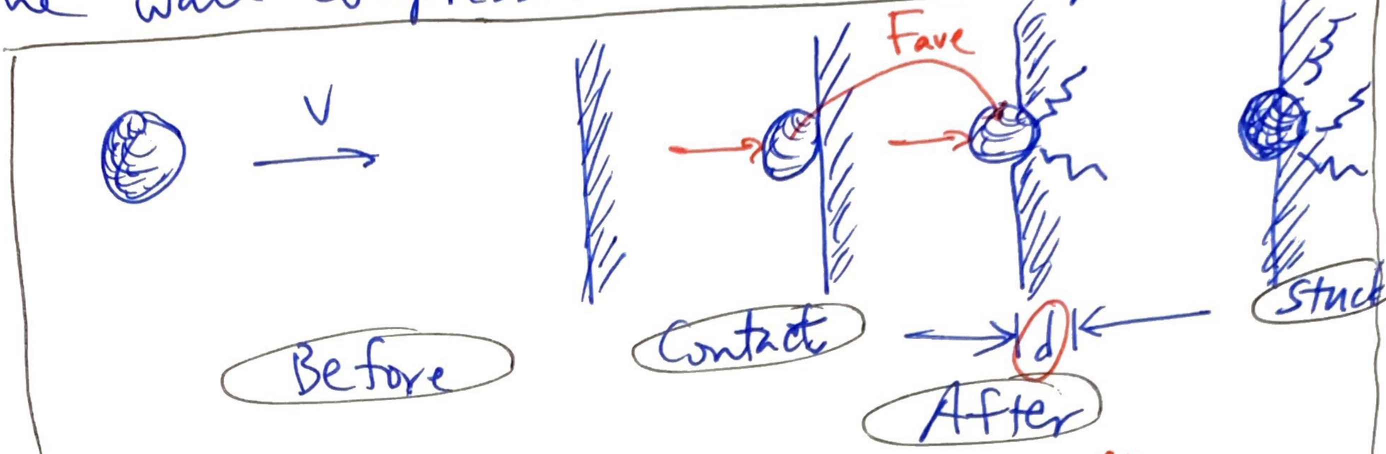
6B

When a cannon ball hits the wall, the wall compresses and cracks apart.



Work done by ball on wall is

$$\boxed{W = F_{ave} \cdot d}$$

- The initial state of the ball flying through the air has "energy" which will get converted to work. Then the work energy gets converted to thermal energy ...

(*) **Conservation of "energy"**:

motion → work → thermal (heat)

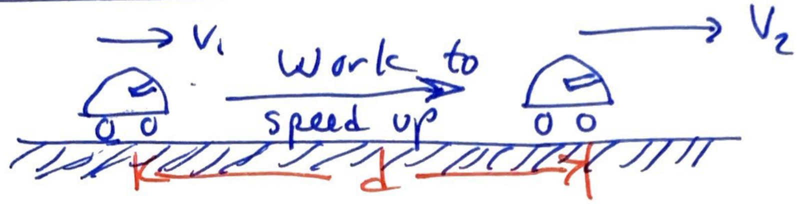
- Motion energy is called **Kinetic Energy**

$$\boxed{KE_{final} - KE_{initial} = \text{Work performed}}$$

Work → thermal (Heat) of ball & wall

Ex A car is speeding @ v_1 and the engine delivers work to speed the car to v_2. What was the work delivered by the engine?

(i)



(iii) $v_f^2 = v_i^2 + 2ad$ Kinematics

$*m$

$\Rightarrow mv_f^2 = mv_i^2 + 2amd$

$\div 2$

$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + \underbrace{(am)}d$

$F = ma$

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = F_{ave} \cdot d$

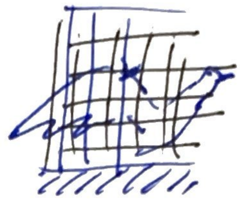
$= W_{total}$

$$\boxed{KE_f - KE_i = W_{performed}}$$ Energy–Work Formula.

where $\boxed{KE \equiv \frac{1}{2}mv^2}$ we call this energy Kinetic (Motion) Energy

- We revise this further into the chapter to include potential energy.

⊛ Work-Energy Principle



$$\boxed{W_{net} = \Delta KE}$$

$\boxed{\Delta E = E_f - E_0}$, or $E_2 - E_1$, etc.

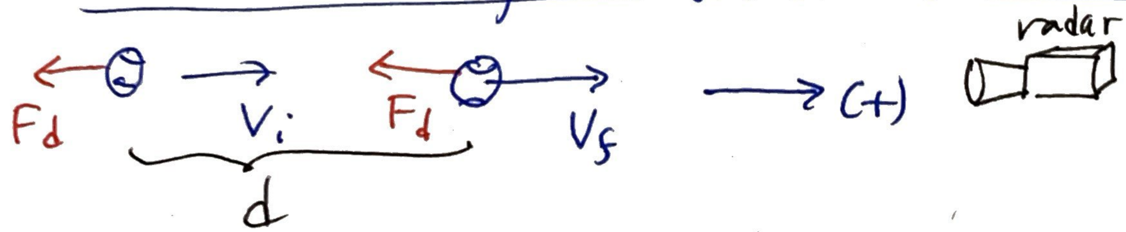
"change of" delta E

Ex A pitcher throws a base ball into hurricane winds. The wind force slows the ball (and may even reverses its motion)

if
- $V_i = 98$ mph $= 43.81$ m/s
- $V_f = 96$ mph $= 42.92$ m/s
- $d = 17.0$ m
- $m = 0.145$ kg

Q: What is the drag force on the ball due to the wind?

(i)



(ii)

(iii) $E_f - E_i = W_{wind}$ — F_d & d in the same direction

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = F_d \cdot d \ ; \ \theta = 0°$$

(iv)

$$F_d = \frac{\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2}{d} = \frac{\frac{1}{2}(0.145\text{ kg})(42.92\text{ m/s})^2 - \frac{1}{2}(0.145)(43.81)^2}{17.0\text{ m}}$$

$$\boxed{F_d = -0.33\text{ N}}$$

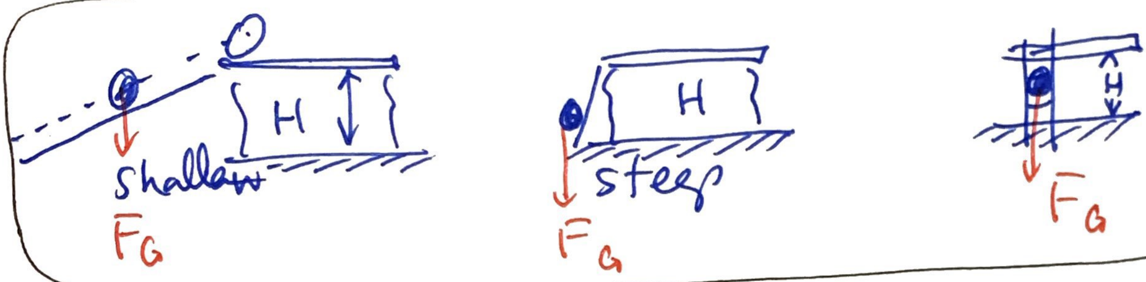
$W_d = (F_d)(d) = (-0.33)(17) \approx \underline{\underline{-6J}}$ on ball

+6J done by Wind

Drag is to the left, opposes motion of ball

Potential Energy

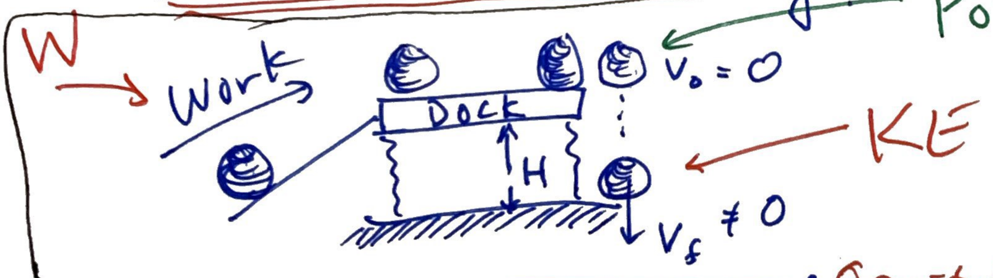
In 6A we studied a hiker hauling a backpack up an incline. The work the hiker performed ended up using <u>only the Height difference</u>, and not the inclination of the ramp.



$W = mgH$

- Now consider a mass at an altitude of H above the ground. If that mass is dropped it will speed up and <u>strike the ground with a final velocity</u>.

Potential to perform work ((release))



$$\boxed{PE = mgH}$$

- Gravitational P.E.

- Likewise

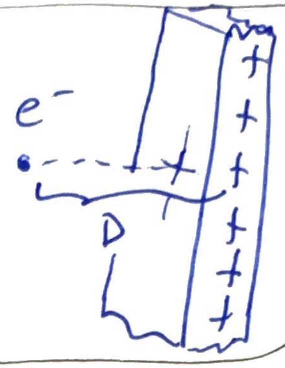
Chemical Potential energy

Before

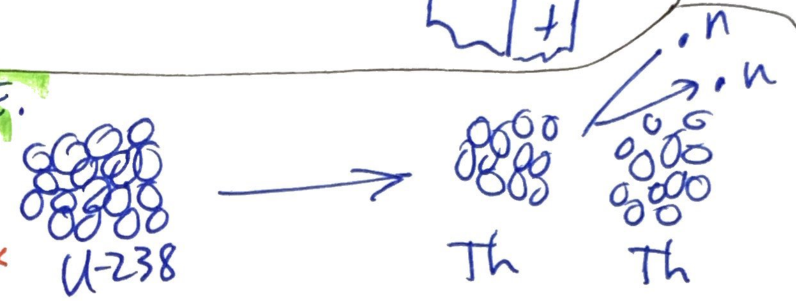
After

Possess Potential energy $\Rightarrow KE_T = \sum_{i=1}^{1000} KE_i$

- Possesses Electrostatic P.E.



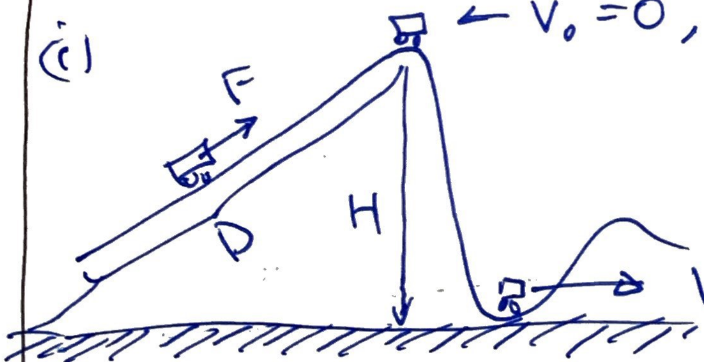
- Nuclear P.E.



Possesses Nuclear potential energy

EX An empty roller coaster cart is lifted to a height of 40 m. If it starts from rest what is its speed when the track runs along the ground momentarily?

(i)



- energy

$$PE_{TOP} = KE_{BOT}$$

$$\cancel{m}gH = \frac{1}{2}\cancel{m}v^2$$

(ii)

$$\boxed{v_f = \sqrt{2gH}}$$

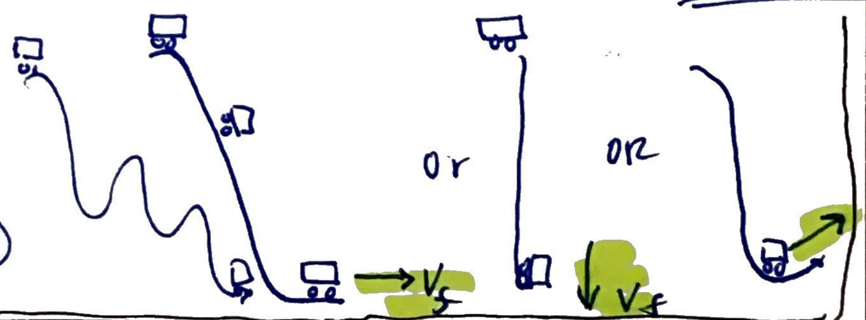
- Kinematics

Recall Chpt 2 $\left\{ \begin{array}{l} v_f^2 = v_0^2 - 2gH \\ \Delta KE = \text{Work} \end{array} \right.$

(iv)

$$v_f = \sqrt{2(9.8\,m/s^2)(40\,m)}$$

$$= 28\,m/s = \underline{62.6\,mph}$$

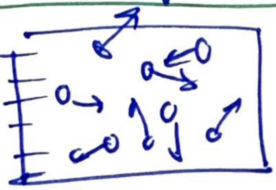


* Conservation of mechanical energy

No Friction

If only friction-less forces are involved, in a closed system the net energy remains constant.

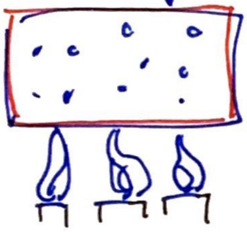
Conservative forces



particles in a box

$\sum KE + \sum PE = E_{TOT}$ mechanical energy = fixed.

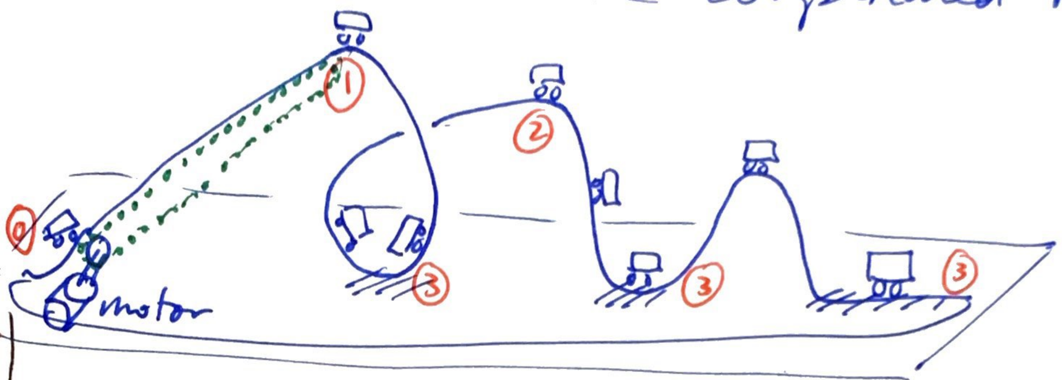
- not-closed:



But this is closed

Energy is best used when we need initial vs. final results and we are not concerned with the transient (in between) states.

Idea a more complicated Rollercoaster



Find the KE and P at each station ①, ② and ③

• Note that w/o friction energy is conserved so E_{TOTAL} @ ① is equal to E_{TOT}, @ 2 and @ 3 the same.

$\boxed{PE + KE = E_{TOT}}$ let $m = 100kg$, $H_1 = 40m$, $H_2 = 30$

① $W_{0\to1}$ $\quad v_1 = 0$

$E_{TOT_1} = PE_1 + KE_1$

$\Rightarrow E_1 = mgH_1 + \frac{1}{2}m\cancel{v_1}^2 \to 0$

$E_1 = (100kg)(9.8 m/s^2)(40m) = \boxed{39,200 J}$

② $E_1 = E_2$

$39,200 = mgH_2 + \frac{1}{2}mv_2^2$

$39,200 = (100kg)(9.8 m/s^2)(30m) + \overbrace{\frac{1}{2}(100kg)(V_2)^2}^{KE}$

$\boxed{39,200} = \boxed{29,400 J} + \boxed{9,800 J}$

E_{TOT} PE. KE

$$\begin{array}{r} 39,200 \\ -29,400 \\ \hline 9,800 J \end{array}$$

speed $V_2 = \sqrt{2KE/m} = \sqrt{2(9800J)/100kg} = \underline{14 m/s}$

③ $E_3 = E_2 = E_1 = 39,200 J$

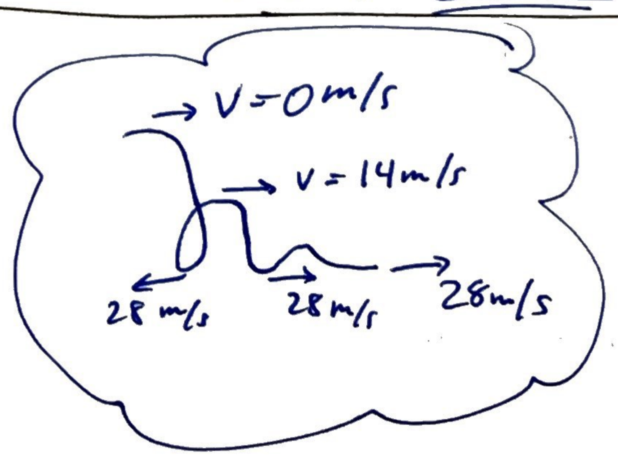
$39200J = PE_3 + KE_3$

$E_3 = 0 + \frac{1}{2}mv_3^2$

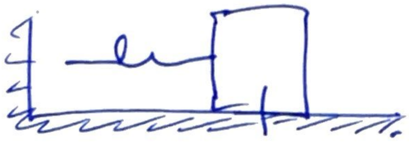
$39,200 J = \frac{1}{2}(100kg)V_3^2$

$V_3 = \sqrt{\frac{2(39,200J)}{100kg}}$

$\boxed{V_3 = 28 m/s}$ all KE, No PE.

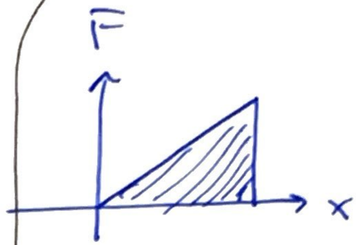


Spring PE



$x=0$
equilibrium

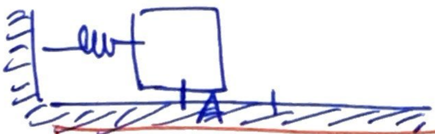
$PE_s = 0$



W = area

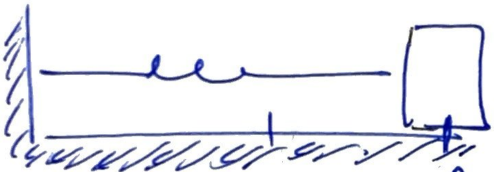
$W = \frac{1}{2} x F$
$= \frac{1}{2} x (kx)$

$\boxed{W_s = \frac{1}{2} k x^2}$



$PE_s = $ max compression

$\boxed{PE = \frac{1}{2} k A^2}$

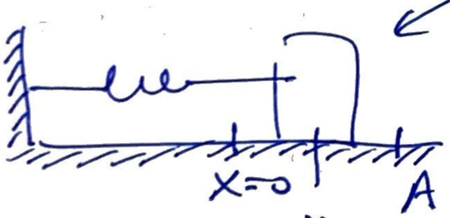


amplitude

$\boxed{PE = \frac{1}{2} k A^2}$

max stretch

In between:

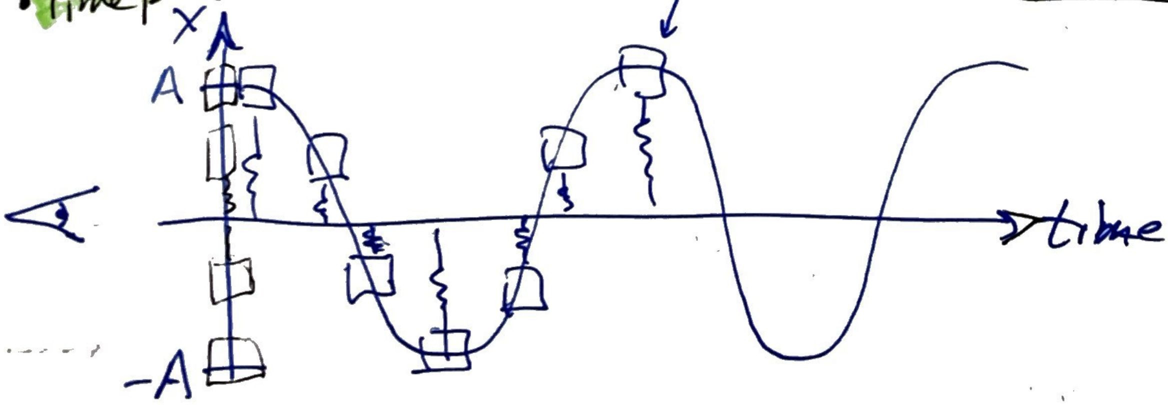


$$\left.\begin{aligned} KE &= \frac{1}{2} m v^2 \\ PE &= \frac{1}{2} k x^2 \end{aligned}\right\} = E_{TOT} = \frac{1}{2} k A$$

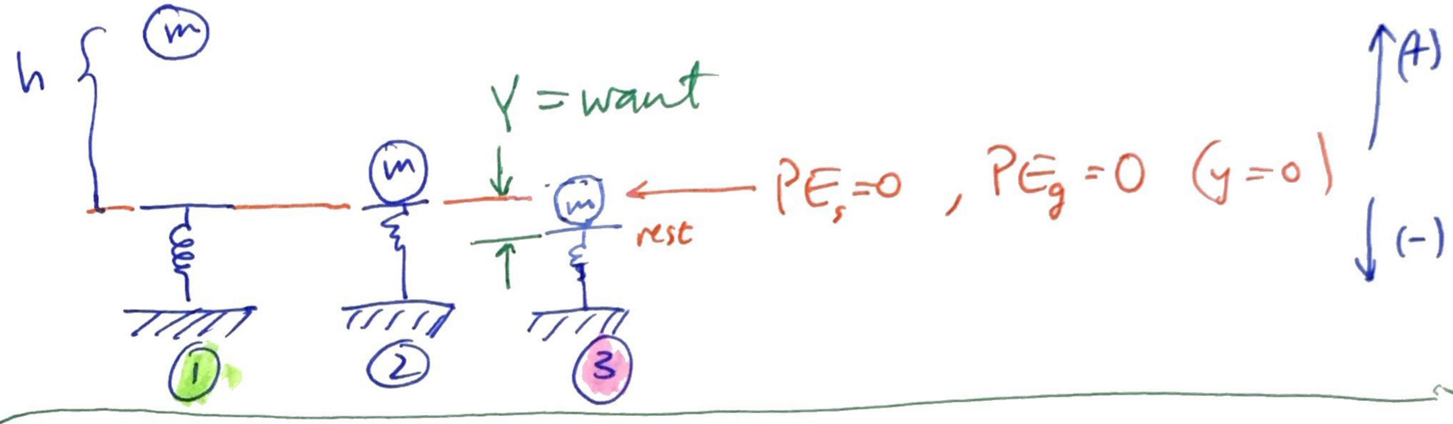
$$\Rightarrow \boxed{\frac{1}{2} k x^2 + \frac{1}{2} m v^2 = \frac{1}{2} k A^2}$$

If we start from position A with no initial velocity.

• Time plot:



Ex: A bowling ball is dropped from height "h" on to a rubber pad that is supported from below by a spring. Find the springs max displacement, Y. Data: $m = 2.60\,kg$, let $h = 55\,cm$, let $k = 1590\,\frac{N}{m}$



• strategy: $PE_1 = KE_2$

$KE_2 = PE_3$ ← spring + height

$$E_{TOT} = PE_{g@1} + \cancel{KE_{@1}}^{0} + \cancel{PE_{s@1}}^{0} = \cancel{PE_{g@2}}^{0} + KE_{@2} + \cancel{PE_{s@2}}^{0} = PE_{g3}^{<0} + \cancel{K_3}^{0} + PE_{s3}^{>0}$$

choices: { (I) Find PE_1 set to KE_2 to get V and find Y
(II) use work to slow ball to 3

OR (I) $E_1 = E_3$ ← lot less work

$$\bullet\; E_1 = mgh + \underset{KE}{0} + \underset{PE_s}{0} = \underset{PE_s}{\tfrac{1}{2}k(-Y)^2} + \underset{KE}{0} + \underset{PE_g}{mg(-Y)} = E_3$$

$$\boxed{mgh = \tfrac{1}{2}kY^2 - mgY}$$

$$0 = \tfrac{1}{2}kY^2 - mgY - mgh \quad)*2$$

$$\Rightarrow \quad 0 = kY^2 - 2mgY - 2mgh$$

$k = 1590$, $m = 2.6$, $g = 9.8$, $m = 2.6$, $g = 9.8$, $h = 0.55\,m$

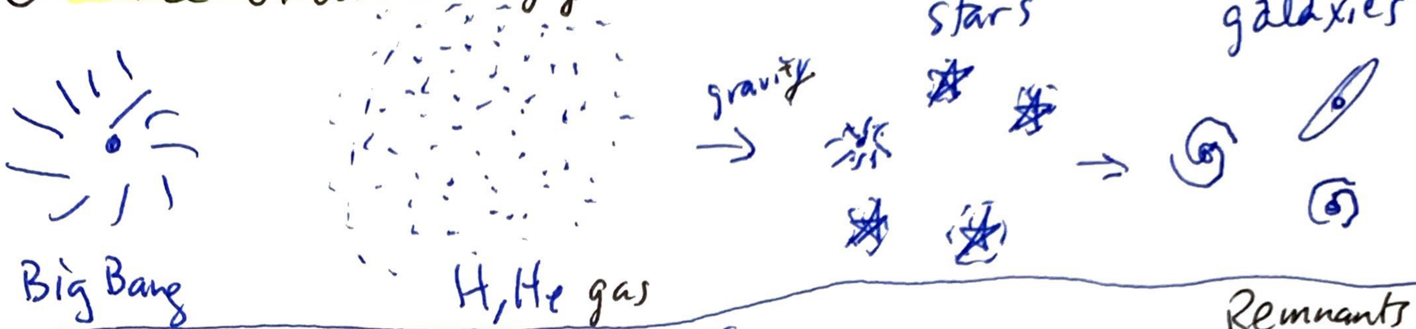
$$0 = 1590Y^2 - 50.96Y - 28.03$$

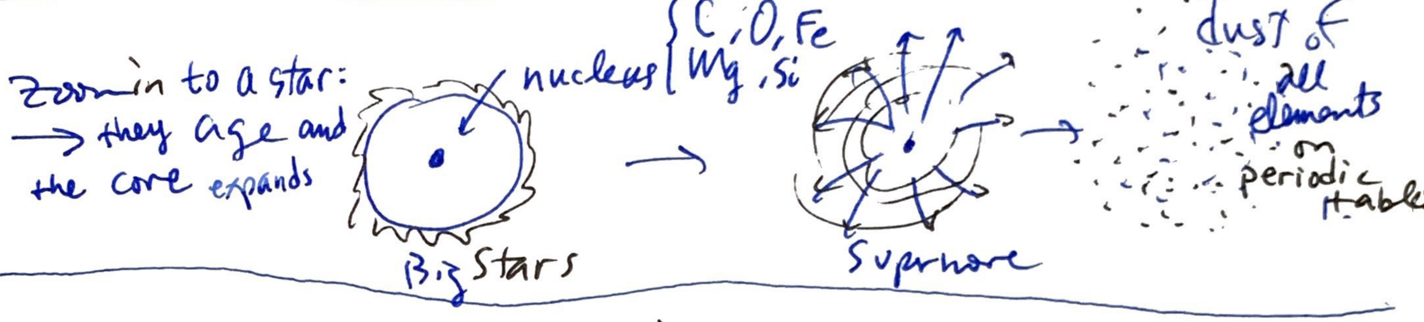
$$Y = \frac{-(-50.96) \pm \sqrt{50.96^2 - 4 \cdot 1590 * -28.0}}{2 \cdot 1590}$$

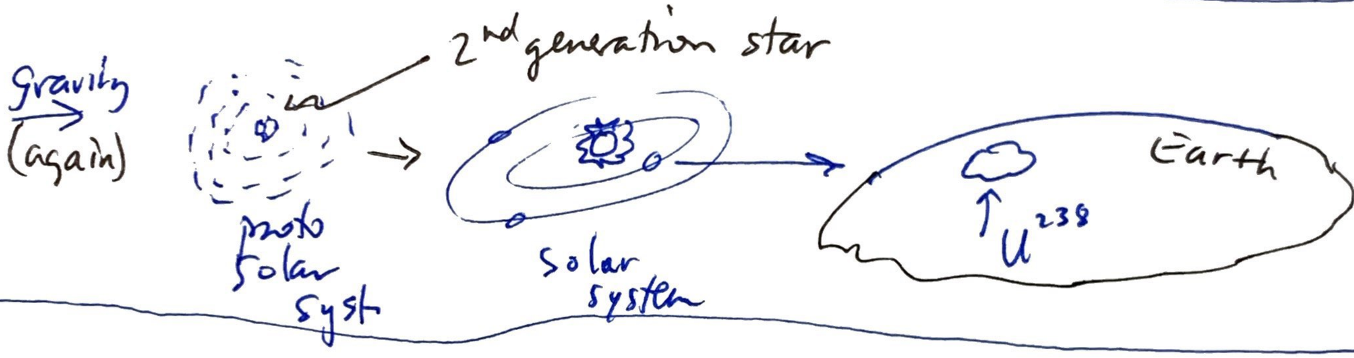
$$Y = -0.18\,m,\ +0.149\,m$$

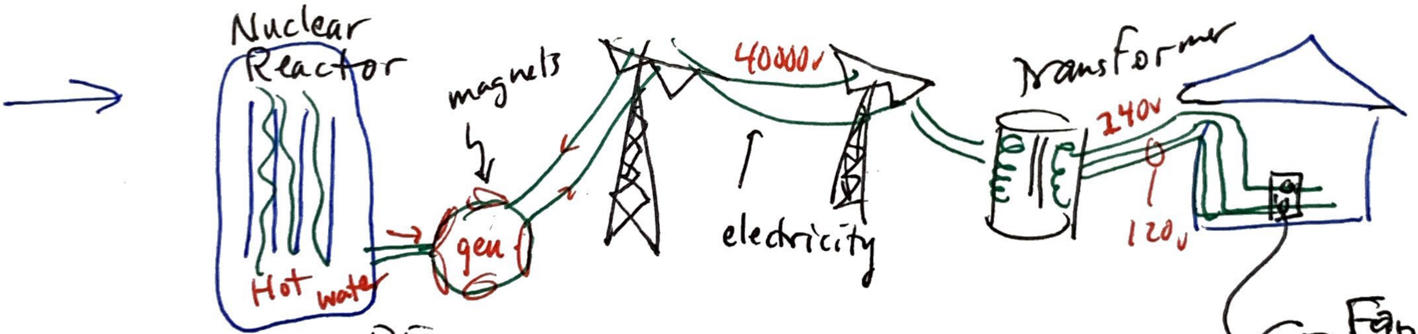
$$\boxed{Y = 15\,cm \text{ below the equilibrium}}$$

Source of all energy









PE.

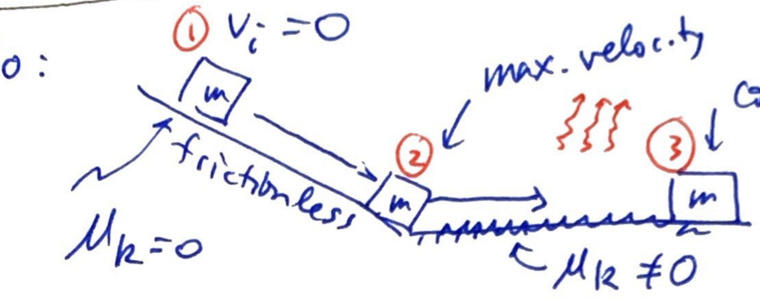
- gravitational P.E.
- nuclear P.E.
- chemical P.E.
  battery, stomach
- electrical P.E.
  capacitors

- KE any mass that moves.
- Thermal (radiation)
- magnetic energy
- Flow of electrons

⊛ Adding in Non-Conservative forces (friction)

Dissapative forces

- scenario:



Friction does work on the block

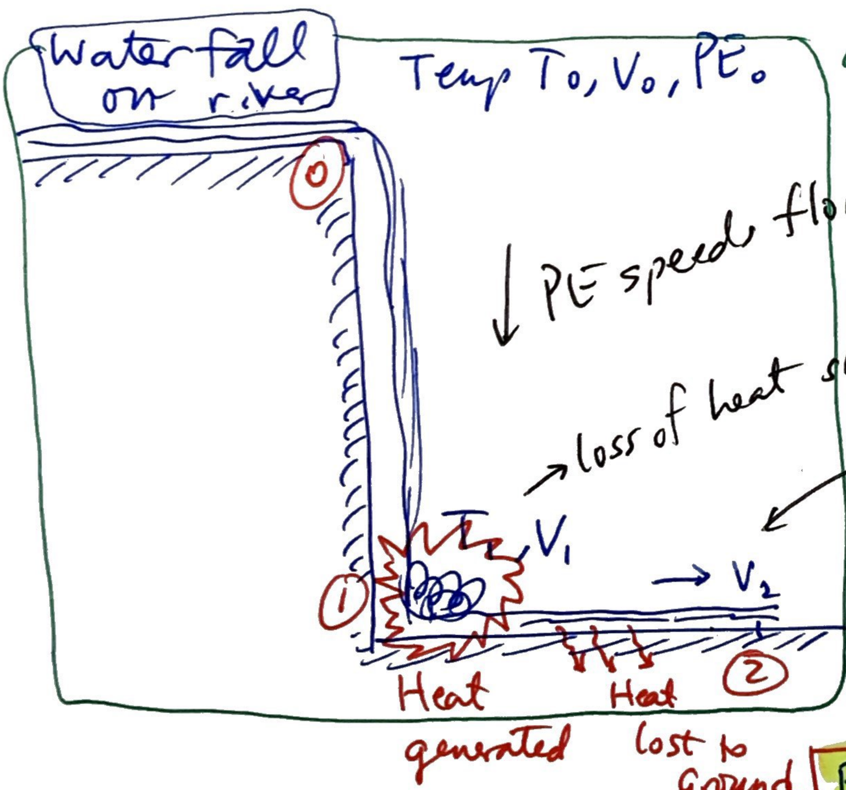
1→2: mechanical energy is conserved

2→3: Dissapative energy is transformed to heat.

- modified Conservation of energy statement:

$\boxed{\text{"The total energy of a system is neither increased nor decreased in any process"}}$

The Law of Conservation of Energy



$$E_0 = E_1$$

$$E_2 = E_1 + \text{Work due to friction}$$

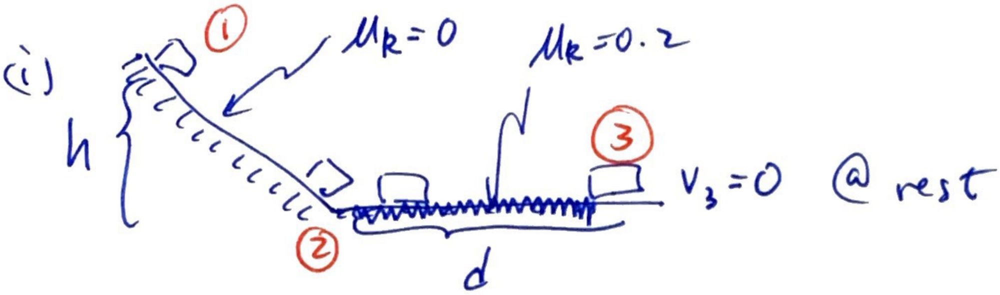
$$\boxed{PE_0 + KE_0 + W_f = PE_1 + KE_1}$$

initial ⊕ work = final

EX We release an ice block on a hill of height 5 m. The coefficient of kenetic friction on the hill is negligable. But when the block hits the horizontal dirt, we have $\mu_k = 0.2$ friction.

Q: How far does the block slide on the level ground?

(i)



(iii) $E_1 + W_f = E_3$

taking energy out of E_1 $\quad W_f < 0$

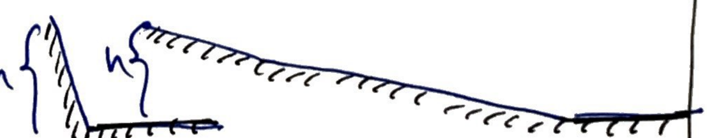
$P_1 + K_1 - \boxed{W_f}^{2-3} = P_3 + K_3$

$mgh + 0 - F_f \cdot d = 0 + 0$

$\Rightarrow mgh = F_f d$

$\cancel{mg}h = [\cancel{mg}\mu_k]d$

$\boxed{d = h/\mu_k}$



(iv) $d = 5\,m / 0.2$

$= 5/\frac{2}{10}$

$= 50/2$

$\boxed{d = 25\,m}$

Power

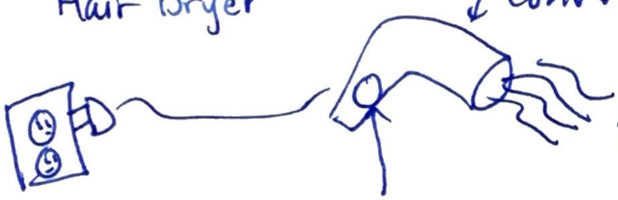
Power is the rate of which energy is produced or consumed per unit time.

$$P_{ave} \equiv \frac{\text{Work}}{\text{time}} = \frac{\text{energy transfered}}{\text{time of transfer}}$$

$$[P] = J/s \equiv \text{Watt}$$

ex Hair Dryer

converts electricity to heat & kinetic energy



1000 J/s of heat

1000W appliance

ex A 60kg runner climbs an embankment in 4.0s the vertical height changes by 4.5m

(a) What is the power expended by ~~the~~ runner.

$$\text{Power} = \frac{\Delta \text{Energy}}{\Delta t} = \frac{mgh}{t}$$

No KE change if they maintain speed.

$$= \frac{(60kg)(9.8m/s)(4.5m)}{4.0s}$$

$$= \boxed{661.5\ J/s} \text{ or } \boxed{660\ W}$$

So his body is giving of 660W of heat loss.

Power in USCS

$$\frac{\Delta E}{\Delta t} = \frac{\text{ft-lb}}{\text{sec}},$$

But the traditional units are <u>horsepower</u>.

{how much energy per time can one horse provide}

$$\boxed{746\,\text{W} = 1\,\text{hp}}$$

EX (cont.)

(b) of previous example

Total energy in J $= P \cdot t = (660\,\text{J/s})(4.0\,\text{s})$

$= \underline{\underline{2600\,\text{J}}}$ total energy needed to climb

(c) convert runner's power consumption to "hp".

$$(660\,\text{W})\left(\frac{1\,\text{hp}}{746\,\text{W}}\right) = \underline{\underline{0.9\,\text{hp}}}$$

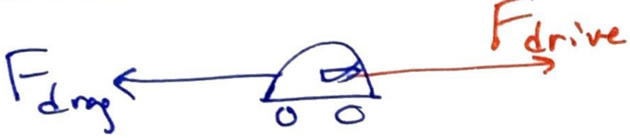
So the runner is putting out $9/10$ of a horse?

(*) We can reconfigure, Power : Consider Frictional Work.

$$P_{ave} = \frac{\Delta Work}{\Delta t} = \frac{F \Delta d}{\Delta t} = F \cdot \left(\frac{\Delta d}{\Delta t}\right) = \underline{\underline{F \cdot V}}$$

$$\boxed{P_{ave} = F_{ave} V}$$

Ex A race car running @ a max speed of 220 mph consumes 750 hp. What are the total frictional forces.

(i) 

@ max speed of 220 mph

(ii) • $F_{drag} = F_{drive}$

(iii) $$F_{drag} = \frac{P_{ave}}{V} = \frac{750\,hp\left(\frac{746\,W}{hp}\right)}{220\,mi/hr\left(\frac{1609.3\,m}{mi}\right)\left(\frac{1\,hr}{3600\,s}\right)}$$

$$\boxed{\begin{aligned} F_{drag} &= 5690\,N \\ &= 1278\,lbs \end{aligned}}$$ $\frac{1}{2}$ ton of forces