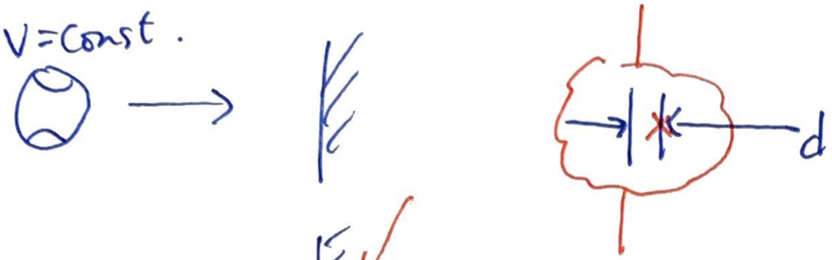
6B Energy

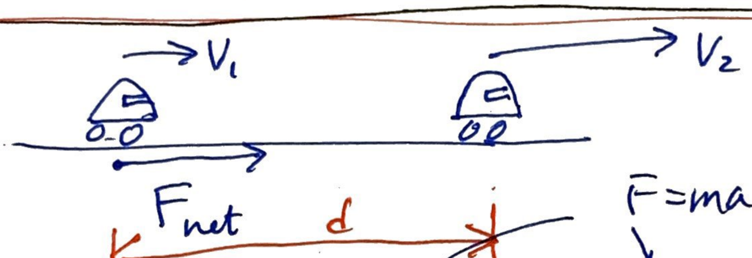
when a cannonball hits a deformable wall of clay



- wall slows the ball down
- wall resists the motion so the wall is exerting a force against the motion

The wall performed work to slow the ball down

Ex



F=ma

- apply a force to accelerate the car. ($\vec{a}$=const)
- Kinematics: $(V_2^2 = V_1^2 + 2ad) * m$

$mV_2^2 - mV_1^2 = 2amd$) ÷2

$\frac{1}{2}mV_2^2 - \frac{1}{2}mV_1^2 = (ma)d$

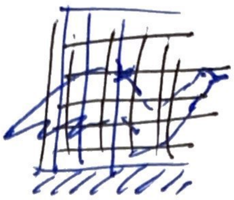
$F \cdot d$

$\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \boxed{\text{Work}}$ performed by the engine

After − Before = Work

$\boxed{\text{Kinetic Energy} = \frac{1}{2}mv^2}$ energy of motion $KE = \int mv\,dv$

⊛ Work-Energy Principle



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

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

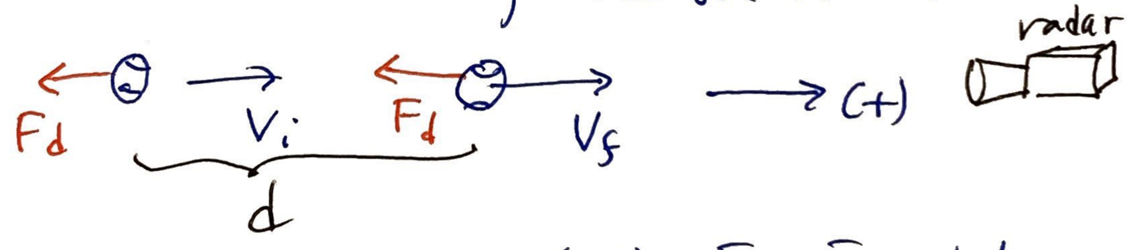
"change of" delta E

Ex A pitcher throws a base ball into hurrican 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

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

(iv)

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

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

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

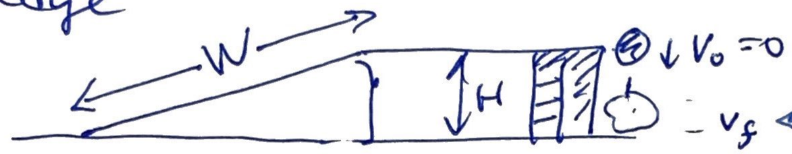
+6J done by Wind

Drag is to the left, opposes motion of ball

Energy tool is good for use when the details of all forces is too complicated.

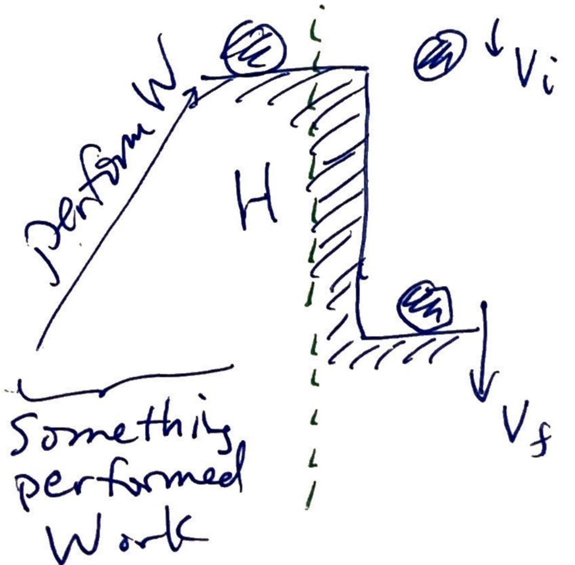
⊛ Potential Energy

- Recall when the hiker lifted his backpack up a hill? He performed work on the pack and elevated it H vertical units.
- Let watch what happens when he drops the pack off a ledge



$$W = \Delta KE$$
$$W = KE_f - KE_i$$
$$mgH = \tfrac{1}{2}mv_f^2 - 0$$

- we can cast the Work here as a $\boxed{\text{potential}}$ to perform work, or yeild energy later. {i.e. forget how the pack got to the top of the ledge}



throw it down

← @ this level the pack has potential energy

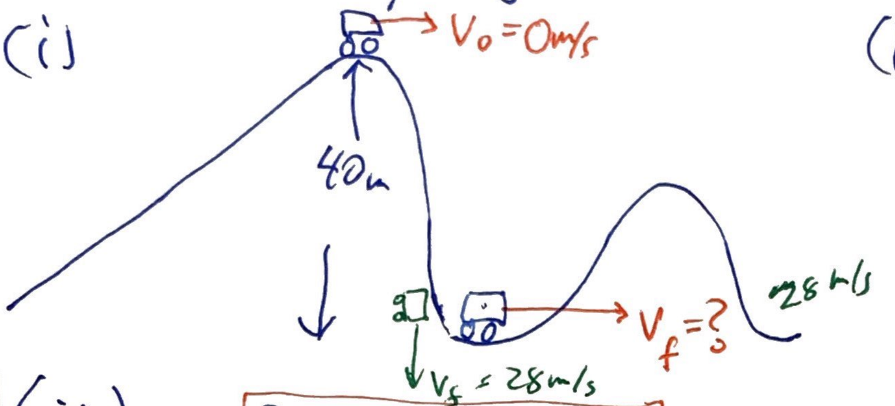
$$\boxed{PE_{Gravity} = mgH}$$

gravitational potential energy

Ex An empty roller coaster car is lifted to a height of 40m. It starts from rest and speeds up down towards the ground.

(a) If its mass is 100kg how fast will the car be going at the bottom.

(i)



(ii) NA

(iii) $\boxed{PE_{TOP} = KE_{BOTTOM}}$ potential energy principle.

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

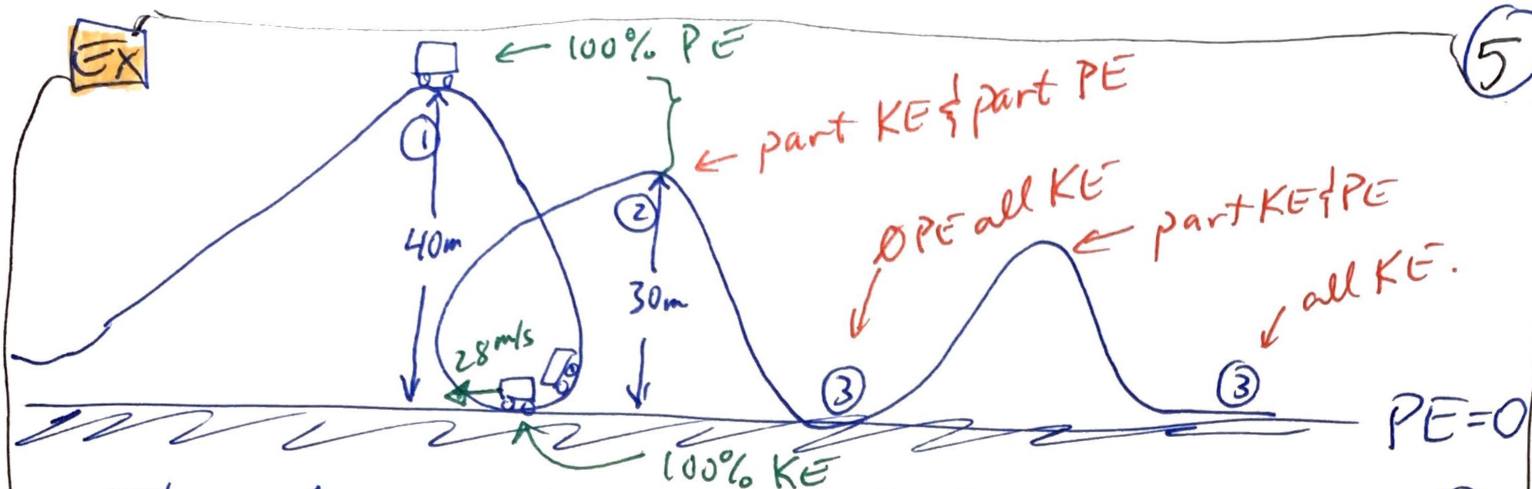
$$\boxed{V_f = \sqrt{2gH}} = \sqrt{2(9.8m/s^2)(40m)} = \boxed{28m/s} = 62.6mph$$

* **Conservation of mechanical energy**

> If only frictionless forces (call conservative forces) act in a system the net mechanical energy remains constant

Here potential energy was converted to KE.

Ex



The net energy is conserved from station ① to ②
from ② to ③. $E_1 = E_2 = E_3$

$\boxed{E_{TOT} = KE + PE}$ no friction } $m = 100\,kg$, $H_1 = 40\,m$, $H_2 = 30\,m$

Q: What is the speed at all stations

① $E_1 = E_{TOT} = mgH_1 + \cancel{\tfrac{1}{2}mv_1^2}^{\,0}$

$= (100\,kg)(9.8\,m/s)(40\,m) = \boxed{39{,}200\,J}$ } $PE = 39{,}200\,J$, $\boxed{V_1 = 0}$

$\boxed{\text{Since energy is conserved } E_{TOT} = E_1 = E_2 = E_3}$

② $E_2 = E_{TOT} = mgH_2 + \tfrac{1}{2}mV_2^2$

$39{,}200\,J = \underbrace{(100\,kg)(9.8\,m/s^2)(30\,m)}_{29{,}400\,J} + \tfrac{1}{2}(100\,kg)V_2^2$

$39{,}200\,J - 29{,}400\,J = \tfrac{100}{2}\,kg\ V_2^2 \rightarrow \sqrt{\dfrac{9{,}800\,J}{50\,kg}} = \boxed{14\,m/s} = V_2$ } $PE = 29.4\,kJ$, $V_2 = 14\,m/s$

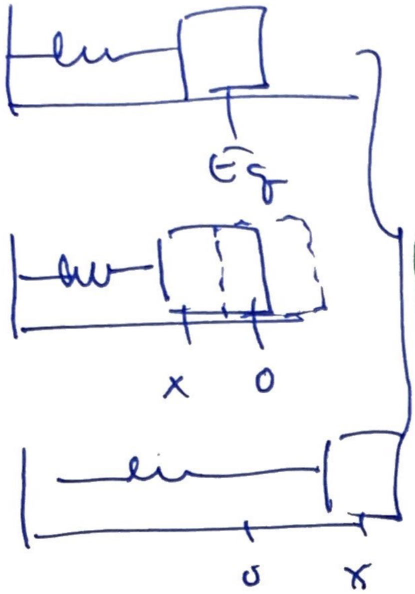
③ $E_3 = E_{TOT} = mg\cancel{H_3}^{\,0} + \tfrac{1}{2}mV_3^2$

$39{,}200\,J = \tfrac{1}{2}(100\,kg)V_3^2 \rightarrow V_3 = \sqrt{\dfrac{2(39{,}200\,J)}{100\,kg}} = \boxed{28\,m/s}$

} $PE_3 = 0$, $V_3 = 28\,m/s$

⊛ Spring Potential Energy

A spring can store energy also.

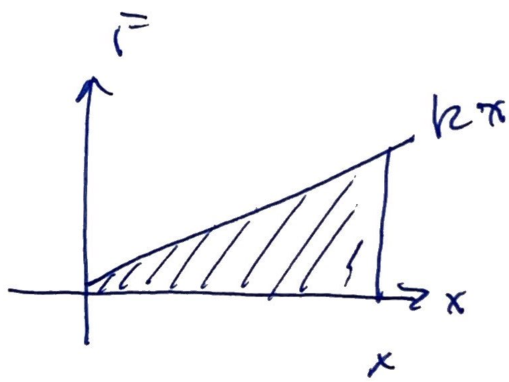


$$\boxed{PE_{sp} = \frac{1}{2}kx^2}$$

The work to stretch the spring $= Fd =$ area

$= \frac{1}{2}$ base · height

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



$$W_{sp} = \frac{1}{2}kx^2$$

The work we put into the spring to either stretch it or compress it is the stored energy

Summary

$PE_{grav.} = mgH$

$PE_{sp} = \frac{1}{2}kx^2$

$PE_{electrical}$ = capacitor, coil

$PE_{nuclear}$ = nuclear reactor takes the PE in U^{235}

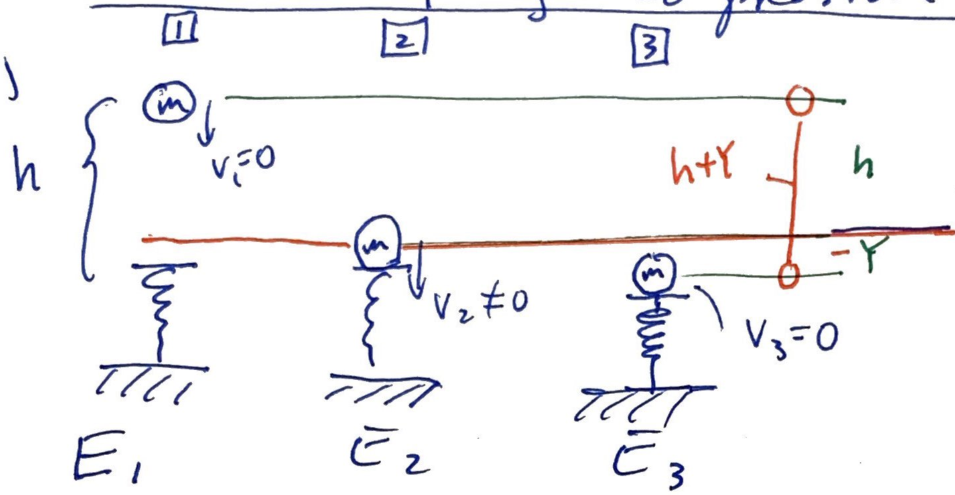
PE_{chem} = gasoline has the potential to do work.

Ex A bowling ball is dropped from a height "h" onto a pad that sits on top of a strong spring. The spring compresses Y units.

- If the mass of the bowling ball is 2.60 kg, the hieght is 55 cm, the spring's constant is $1590 \frac{N}{m}$

Find the spring's compression

(i)



$PE_{sp} = 0, PE_g = 0, y = 0$

(iii) $\boxed{E_{TOT} = PE_g + PE_{sp} + KE}$

(iv) To solve this we need not evaluate the parameters at station $\boxed{2}$. Jump straight to $\boxed{3}$

- Conserve mechanical energy:

$$\boxed{E_{TOT} = E_{TOT@1} = E_{TOT@3}}$$

$$E_{TOT} = PE_{g@1} + \cancel{KE_{@1}}^{0} + \cancel{PE_{sp@1}}^{0} = PE_{sp@3} + \cancel{KE_{@3}}^{0} + PE_{g@3}$$

$$mgh + 0 + 0 = \frac{1}{2}k(-Y)^2 + 0 + mg(-Y)$$

below our reference point

$$mgh + mgY = \frac{1}{2}kY^2 \Rightarrow \boxed{mg(h+Y) = \frac{1}{2}kY^2}$$

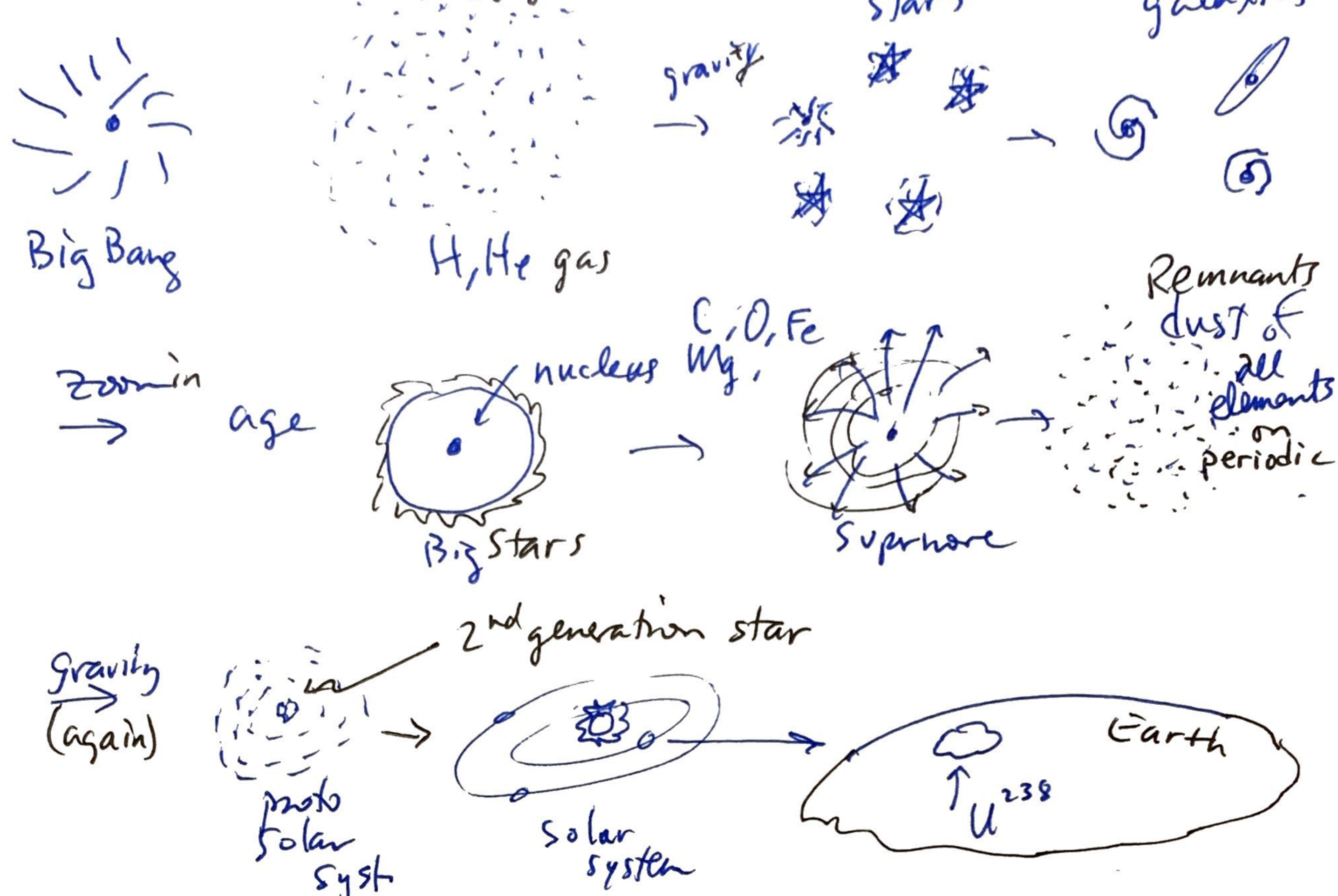
$$\Rightarrow kY^2 - 2mgY - 2mgh = 0 \quad \text{Quadratic Formula}$$

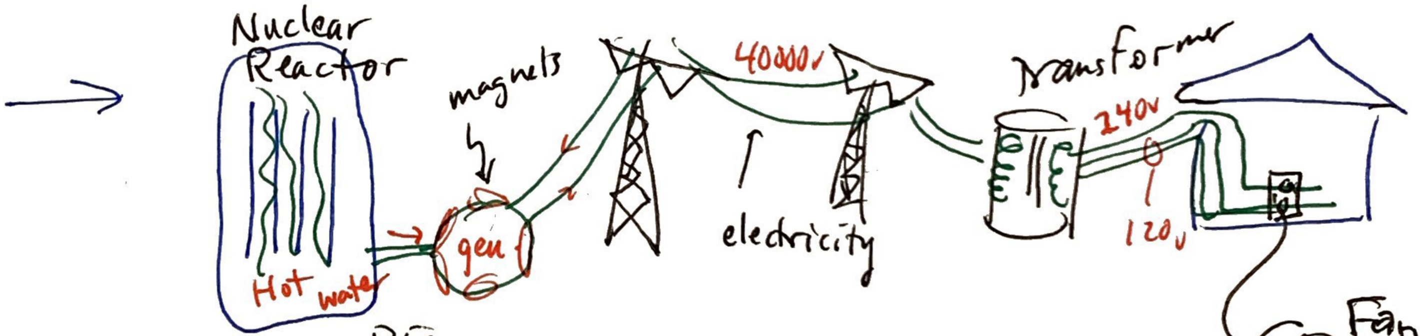
$$1590Y^2 - 2(2.60)(9.8)Y - 2(2.60)(9.8)(0.55\,m) = 0$$

$$\boxed{1590Y^2 - 50.96Y - 28.03 = 0}$$

$\hookrightarrow$ quadratic formula $Y = -0.118, 0.149\,m$ $\boxed{15\,cm}$ compressi

⊛ Source of all energy





PE.

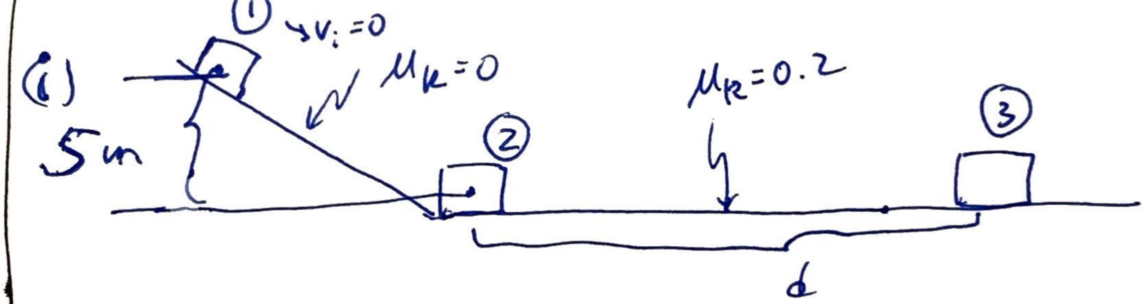
- gravitational P.E.
- nuclear P.E.
- chemical P.E.
  battery, stomach
- electrical P.E.
  capacitors

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

Ex We release an ice block on a hill of height 5 m. The coefficient of kinetic friction between the ice and the wet grass on the hill can be ignored. μ_k very small ≈ 0. (negligible)

When the block hits the horizontal ground it travels on dirt for a distance and due to the non-trivial friction, $\mu_k = 0.2$, the ice on dirt then slows to a rest.

Q: How far does the block travel on the horizontal ground?



all energy @ ① gets dissapated between station ② & ③

(iii) $E_① = E_③ + W_{ork}$

$$\boxed{PE_1 + KE_1 = PE_3 + KE_3 + W_f}$$

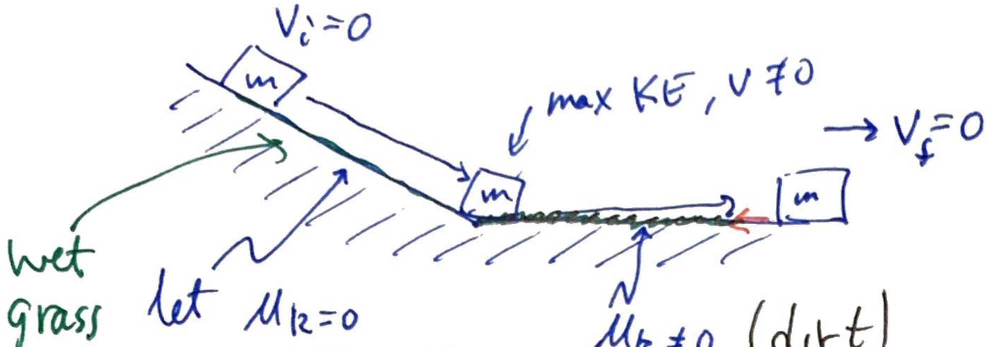
$$mgH + 0 = 0 + 0 + F_f \cdot d \qquad F_f = \mu_k F_N, \quad F_N = F_g = mg$$

(iv) $\Rightarrow \quad mgH = \mu_k (mg) \cdot d$

So $\dfrac{\cancel{mg}H}{\mu_k \cancel{mg}} = d \Rightarrow \boxed{\dfrac{H}{\mu_k} = d} \quad \dfrac{5\,m}{0.2} = \dfrac{5\,m}{1/5} = \boxed{25\,m}$

weight is not used.

* Non-Conservative (Dissapative) Forces {Friction or Drag}



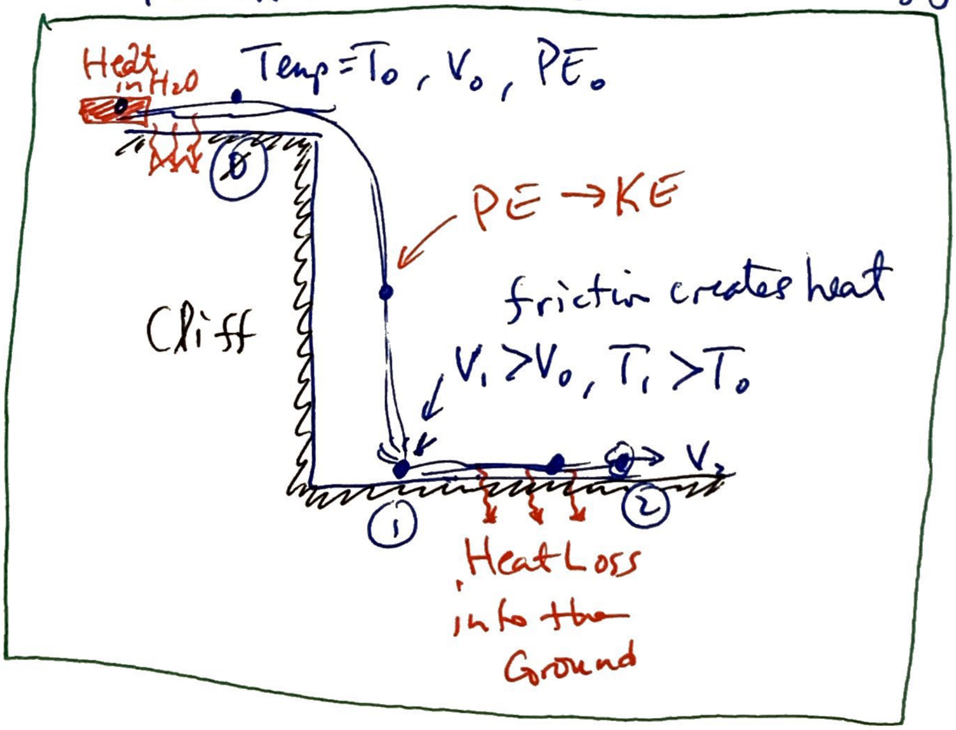
mechanical energy is conserved

Dissapative Forces
Mech. is NOT conserved.

The Law of Conservation of Energy

" The total energy of a system is neither increased nor decreased in any process "

Friction → Heat {Thermal energy}



E_{TOT} = same value everywhere in the box

$$E_2 = E_1 + \text{Work}$$

captures the dissapative forces

$$\Longrightarrow \boxed{W = \Delta K + \Delta P}$$

conservative forces.

Power

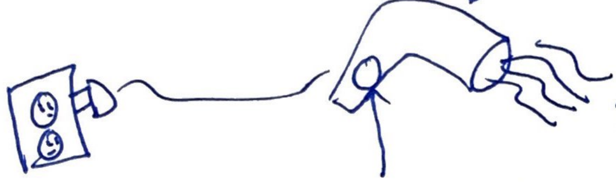
$\boxed{\text{Power is the rate of which energy is produced or consumed per unit time.}}$

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

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

ex

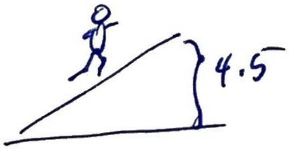
converts electricity to heat & kinetic energy



1000 J/s of heat

1000W appliance

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



(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.

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

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

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

⊛ Power in USCS

$$\frac{\Delta E}{\Delta t} = \frac{\text{Ft-lbs}}{\text{sec}},$$

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

{how much energy/time can one horse provide}

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

$\boxed{EX}$ (cont.)

(b) of previous example

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

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

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

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

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

⊛ we can reconfigure Power: Consider Frictional Work.

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

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

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

(i) $F_{drag} \longleftarrow$  $\longrightarrow F_{drive}$ @ max speed of 220 mph

(ii) • $F_{drag} = F_{drive}$

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

$$\boxed{\begin{aligned} F_{drag} &= 5690\ N \\ &= 1278\ lbs \end{aligned}}$$ ½ ton of forces