PHYS 107 - Week 7 - Monday

* Work $W = F d \cos\theta$

  $W > 0$ is work done by the force on the system such that energy in the system increases

* Kinetic energy $KE = \frac{1}{2} m v^2$

  energy of motion of an object with mass m

* Potential energy PE

  capacity of an object to do work based on its configuration (position, extension)

  ↳ $PE = mgy$ (gravity)

  $PE = \frac{1}{2} k x^2$ (spring)

* Work/energy theorem:

$$W_{net} = KE_f - KE_i = \Delta KE$$

for any force always true

If there is a potential energy:

$$W_{net} = -(PE_f - PE_i) = -\Delta PE$$

$$\rightarrow KE_i + PE_i = KE_f + PE_f$$

conservation of energy

~~Q8 Bowling ball~~ Q10 dropped marbles

* Conservative forces vs. non-conservative forces

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work W_{net} only depends on the initial and final state (position, extension of spring)

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there exists a PE

Non-conservative forces: depend on the path taken
example: friction

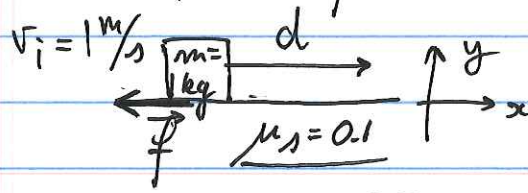
$$W_{net} = \underbrace{W_c}_{-(PE_f - PE_i)} + W_{nc} = KE_f - KE_i$$

$$\Rightarrow KE_f - KE_i = -(PE_f - PE_i) + W_{nc}$$

or $$\underline{\underline{KE_f + PE_f = KE_i + PE_i + W_{nc}}}$$
general energy conservation

Q 8 bowling ball

* Example: friction: An object starts sliding with a speed of 1 m/s. How far does it slide? $\mu_s = 0.1$



$$\underbrace{KE_f}_{\substack{0 \\ (v_f=0)}} + \underbrace{PE_f}_{\substack{0 \\ (y=0)}} = \underbrace{KE_i}_{\substack{\frac{1}{2}mv_i^2 \\ = 0.5\,J}} + \underbrace{PE_i}_{\substack{0 \\ (y=0)}} + \underbrace{W_{nc}}_{\substack{-fd \\ (\theta=180^\circ)}}$$

$$\rightarrow \quad 0 = 0.5\,J - fd$$

$$\text{or } d = \frac{0.5\,J}{f}$$

$$f = \mu_k N = \mu_k m g = (0.1)(1\,kg)(10\,m/s^2) = 1\,N$$

$$\longrightarrow \quad \underline{d = 0.5\,m}$$

Q 9 air cart

* Breaking distance of a car:

$$W_{NC} = -fd$$

$$f = \mu_k m g$$

For a car with initial speed $v_i = 40\,m/s$ (≈ 90 mph) and rubber tires skidding on the road ($\mu_s = 0.8$)

$$\hookrightarrow \quad \frac{1}{2} m v_i^2 - fd = 0$$

$$\frac{1}{2} m v_i^2 - \mu_k m g d = 0$$

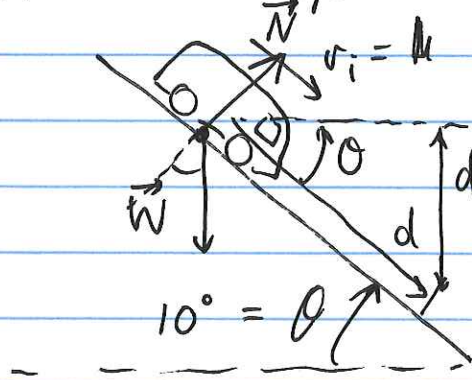
$$d = \frac{v_i^2}{2\mu_k g} = \frac{(40\,m/s)^2}{2(0.8)(10\,m/s^2)} = \frac{1600\,m^2/s^2}{(1.6)(10\,m/s^2)}$$

$$= 100\,m$$

Observations :

- braking distance d depends on v_i^2
  - $\rightarrow$ 2x higher speed $\rightarrow$ 4x higher distance
- independent of mass m of car
  - why does a truck have a longer stopping distance? the $N = mg$ only has part of the mass (tractor) but $\frac{1}{2}mv_i^2$ has the full mass of the entire tractor/trailer
- μ_k small, for example rubber on ice
  - $\rightarrow$ d becomes much longer

* What happens when you brake downhill?



$KE_i = \frac{1}{2}mv_i^2$

$PE_i = mgd\sin\theta$

$KE_f = 0$

$PE_f = 0$

$W_{NC} = -fd = -\mu_k N d$

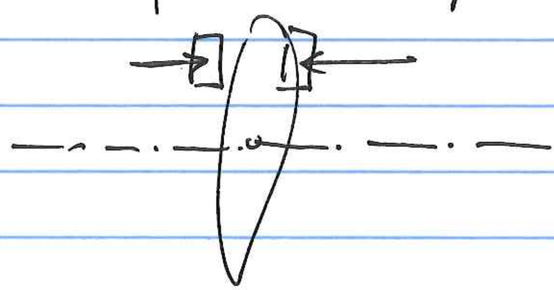
$= -\mu_k mg\cos\theta . d$

$$\rightarrow \frac{1}{2}mv_i^2 - \mu_k mgd\cos\theta + mgd\sin\theta = 0$$

$$\hookrightarrow d = \frac{v_i^2}{2(\mu_k\cos\theta - \sin\theta)g} = 130\text{ m} > 100\text{m}$$

Notice that for $\theta = 0°$: $d = \frac{v_i^2}{2(\mu_k 1 - 0)g}$ as found earlier

* Actual brakes: independent of gravity/normal force since pneumatic system pushes against a disk → much higher N can be achieved



* ABS systems: when wheels block → slipping on the road is dependent on μ_k
when wheeld don't block: μ_s → $\mu_s > \mu_k$

Q16 loop

* Power : rate at which work is done :

lifting a 1 kg mass slowly versus quickly :
same amount of work, but over a
different time interval

Power $P = \dfrac{W}{\Delta t}$

units: $1\,\text{Watt} = 1\,\dfrac{J}{s}$

Example : energy in a cereal bowl = 1200 kJ

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work done by a hiker to raise a 60 kg mass
to a height of 2000 m (perfect efficiency)

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if this takes half a day, 6 hours

$\hookrightarrow P = \dfrac{1200\,kJ}{(6\,hrs)(3600\,\frac{s}{hr})} = \underline{55.6\ W}$

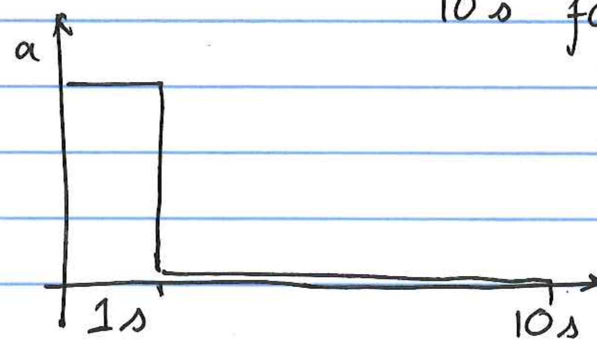
Example: push-ups : $W_{net} = -(PE_{up} - PE_{down})$

$W_{net} = mgh = (80\,kg)(10\,m/s^2)(\frac{1}{4}\,m)$
$= 200\,J$

1 push-up per second ($\Delta t = 1\,s$)

$\longrightarrow P = \dfrac{200\,J}{1\,s} = \underline{200\,W}$

* Sprinter Usain Bolt



10 s for 100 m dash

$v = 10\ m/s$ maximum velocity

$a = 10\ m/s^2$ in first second

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(60\,kg)(10\,m/s)^2 = 3000\,J$$

Reaches this energy in 1 s $\rightarrow$ $P = \frac{3000\,J}{1\,s}$

$= 3000\,W$