Chapter 6 Work and Energy

6A 6B

- So we have finished Newton's Law and before that Kinematics and after that rotational motion and Gravity. {We still need to discuss Newton's Laws in Rotational Motion [Chpt 8]}

We take a break from Newton's Laws and discuss other tools in our physics tool box:
- Conservation of Energy [Chpt 6]
- Conservation of Momentum. [Chpt 7]

Scenario I met the 25 y.o. engineer responsible for Getting the Mars Recon. Observer. from Earth Orbit to Mars Orbit.

They used traditional "Newton's Eqns, differential Eqns"

I mentioned that those accumulate error. So he mentioned that a 2nd team must review their work. That team used Energy to plot a trajectory to Mars. Results agreed!

Chpt 6 is broken into 2 parts
1. Work
2. Energy

6A Work: when a worker pushes a crate across the floor he is performing work.

$$W = \vec{F} \cdot \vec{d}$$

forces

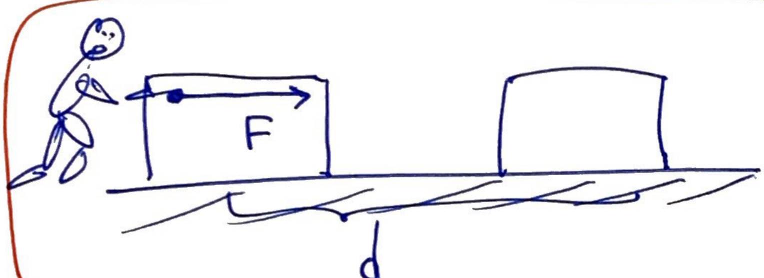
scalar

distance move

applied force

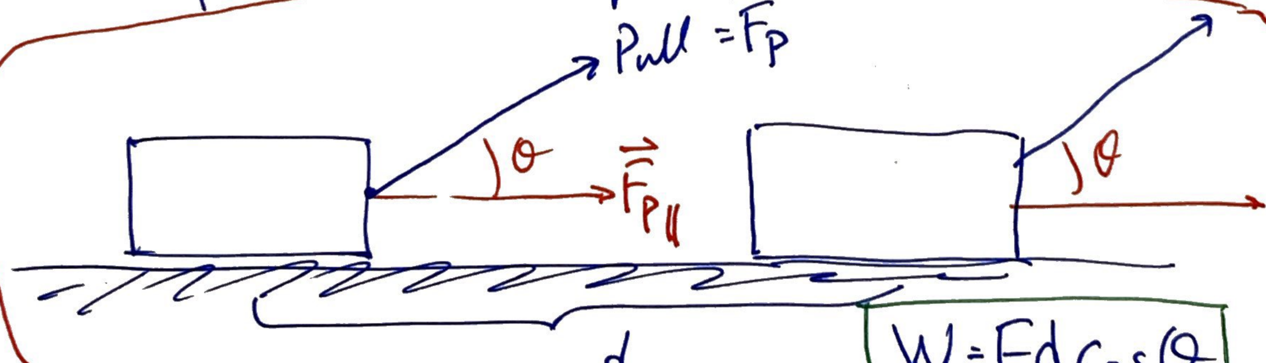
work $[W] = N \cdot m$

$$\boxed{W = \|\vec{F}\| \, \|\vec{d}\| \cos\theta}$$



Total work is
$W = Fd$ (if $F \parallel d$)

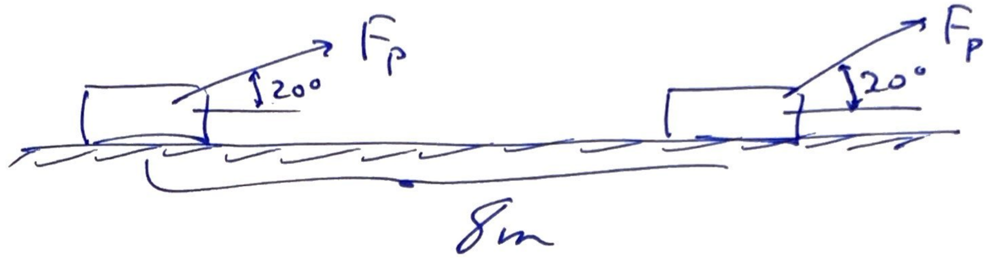
- If the force is not parallel to the motion then we need the cosine b/c work is the parallel component of F * dist



$$\boxed{W = Fd\cos\theta}$$

EX You pull with 30N at an angle of 20°, from the horizontal, over a distance of 8m

Q: What amount of Work was performed?



{ if θ changes or F_p changes during the pull then we need calculus }

$$W = \int_a^b \underbrace{\vec{F}\cdot d\vec{l}}_{F d \cos\theta\, dx}$$

$$\text{Work} = (30N)\cdot(8m)\cdot\cos 20° = \boxed{225.5\ Nm}$$

- We later see that work is incorporated into the conservation of energy: So we will introduce the Joule, the term we measure energy by:

$$\boxed{[J] = Nm}$$

- 1 Joule of energy = the force of 1 N pushed over 1 m.
- .. 1 hr or 1 sec ... same energy used.
- .. $\frac{\Delta \text{Work}}{\Delta t}$ = watt, J/s rate of energy use

* System International Units:

$$W = Fd\cos\theta$$
$$= (N)(m) \qquad W = Nm$$

* In USCU:

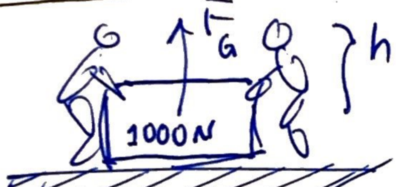
$$W = (lbs)(ft) = lb \cdot ft$$

• For small objects: $[F] = \text{dyne}$ $[d] = \text{cm}$

So $W = Fd$ $\quad [W] = \text{dyne} \cdot \text{cm}$

• Rockets: $W = \text{ton} \cdot \text{m}$

EX



$d = 0$ even though $F = 1000N$

• $\boxed{W_{\parallel} = 0\,J}$ to floor

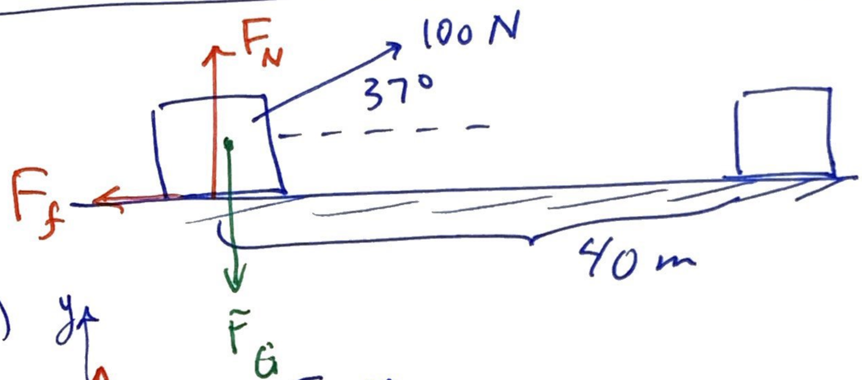
$W_{\perp} = F_G h$

• $\boxed{W = mgh}$ $\perp$ floor

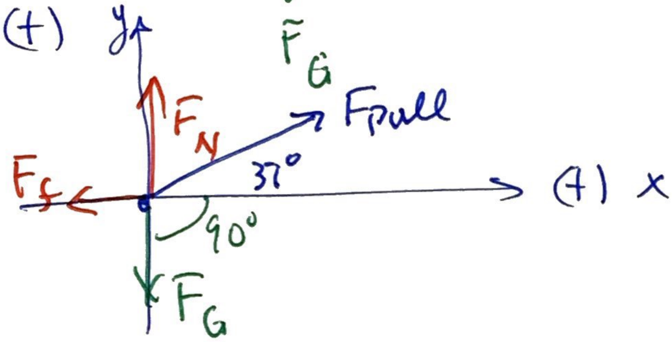
Ex A person pulls a 50kg crate along a 40 m path. They do so by applying a force of 100N at 37° above the horizontal. There is a friction between the crate and the floor of 50N.

(a) what is the work done by each force on the crate

(i)



(ii)



(iii) $\boxed{W = F \cdot d \cdot \cos\theta}$

(iv)
- $W_G = -F_G \cancel{d} \cancel{\cos\theta} = 0$ (down; $\cos\theta = 0$, $\theta = -90°$)
- $W_{Norm} = +F_N \cancel{d} \cancel{\cos\theta} = 0$ ($\theta = +90°$, $\cos\theta = 0$)

} ⊥ to motion

- $W_{pull} = F_p d \cos 37° = 100N(40m)\cos 37° = \underline{\underline{3195J}}$ ≈ 3200J
- $W_{friction} = F_f d \cos 180° = (50N)(40m)(-1) = \underline{\underline{-2000J}}$

(+)

Net Work = 0 + 0 + 3195 − 2000 = $\boxed{1200J}$ done on the crate

We applied 3200 J but friction consumed 1200 J
{ the latter being converted into heat }

Ex Cont.

- Alternative approach: Find Net Force 1st.

$$\vec{F}_{Net} = \vec{F}_{pull} + \vec{F}_{friction}$$

$$\vec{F}_{Net} \cdot \vec{d}$$

different angles...

$$W_{net} = \vec{F}_{pull} \cdot \vec{d} + \vec{F}_f \cdot \vec{d} = (\vec{F}_{pull_{\parallel}} + \vec{F}_{f_{\parallel}})\, d$$

$$= \boxed{[100\,N \cos(37°) + (50\,N)\cos 180°]} \cdot 40\,m$$

$$= 3195\,J + 2000\,J \cdot (-1)$$

Forces $\parallel$ to motion

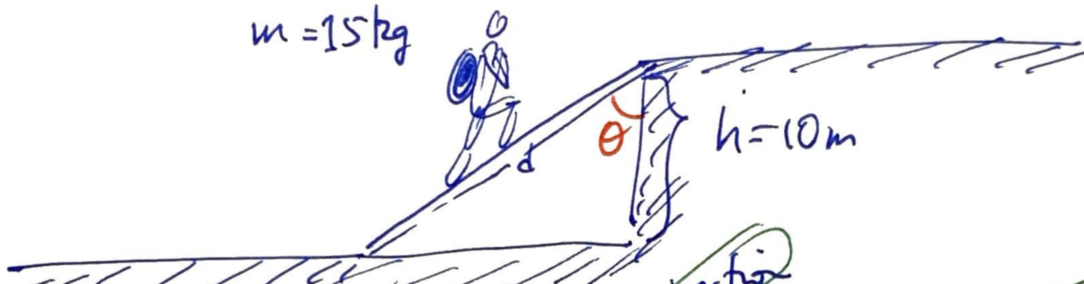
$$W_{Net} = \boxed{1200\,J}$$

EX A stair climber hauls a back pack up a ramp that is θ degrees off of ~~the~~ verticle. The ramp is "d" meters long and ends at an upper terrace "h" meters above the lower level.

Q: what is the work applied by the climber on the pack?

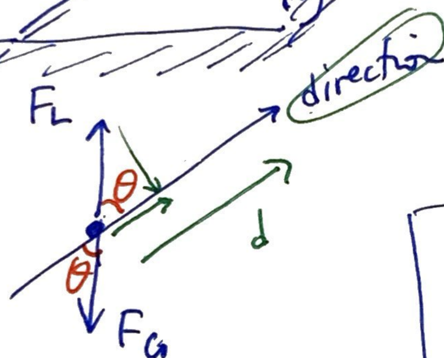
In this Instance $h = 10\,m$, $\theta = 25°$, mass of pack $= 15\,kg$

(i)



$h = d\cos\theta$

(ii)



(iv) do the math

$$W = (15\,kg)(9.8\,m/s^2)(10\,m)$$

$$\boxed{W = 1470\,J}$$

Work needed to oppose gravity & move the backpack.

(iii)

$$W = (F_{Lift})_{\parallel}\, d$$

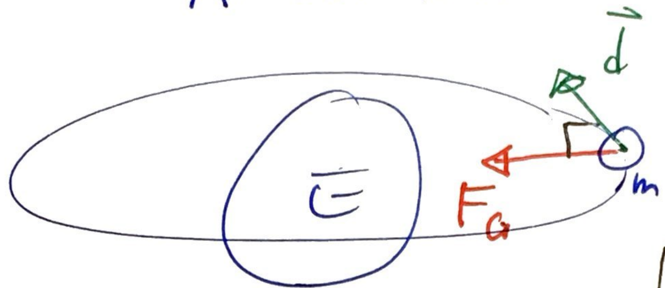
$$= [F_L \cos\theta]\, d$$

$$= F_L \underbrace{[d\cos\theta]}_{h}$$

$$\boxed{W = mgh}$$

so steep ramp, or ladder or shallow ramp is all the same.

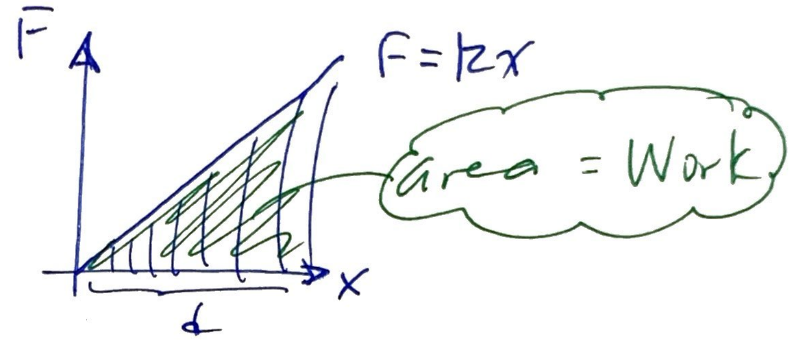
• Notes: Q: Work needed to oppose gravity?
A: Dist. traveled is $\perp$ to Force of Gravity



So no component of Gravity is $\parallel$ to F_G

$$\boxed{W = 0}$$

⊗ Variable Forces



• Area $= \frac{1}{2}$ base · height

$$\boxed{W = \frac{1}{2} F_s d}$$

Work in a spring

kx $\quad$ x

So work is non-linear $\boxed{W = \frac{1}{2} kx^2}$

stored in spring compressed x units.