Last lecture

Energy principle:

$$\boxed{\Delta E_{sys} + \Delta E_{surr} = 0}$$

Kinetic Energy:

$$\boxed{K = \frac{1}{2} m v^2}$$

Work:

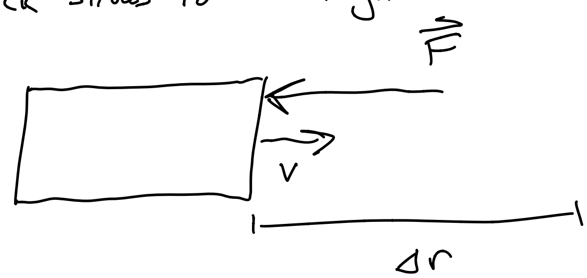
$$\boxed{\Delta E = W = \vec{F} \cdot \Delta \vec{r}}$$

Force × time changes momentum

Force × distance changes energy

Note: Work can be negative

Ex: block slides to the right while I push to the left



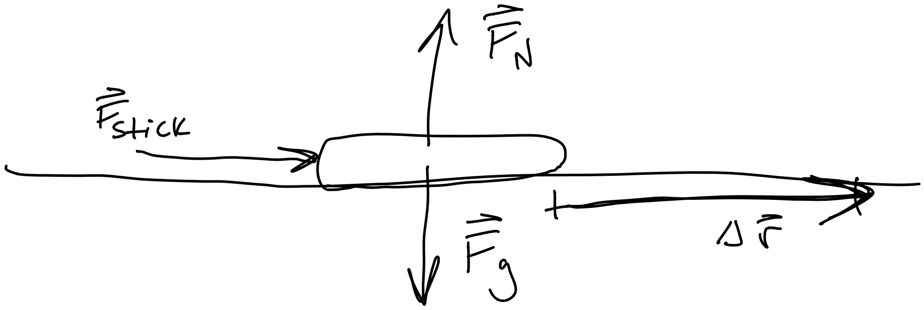
$$W = \vec{F} \cdot \Delta \vec{r} = |\vec{F}||\Delta \vec{r}| \cos(180°) = -|\vec{F}||\Delta \vec{r}|$$

Since $\Delta E = W$, energy will decrease; block slows down

of course it does!

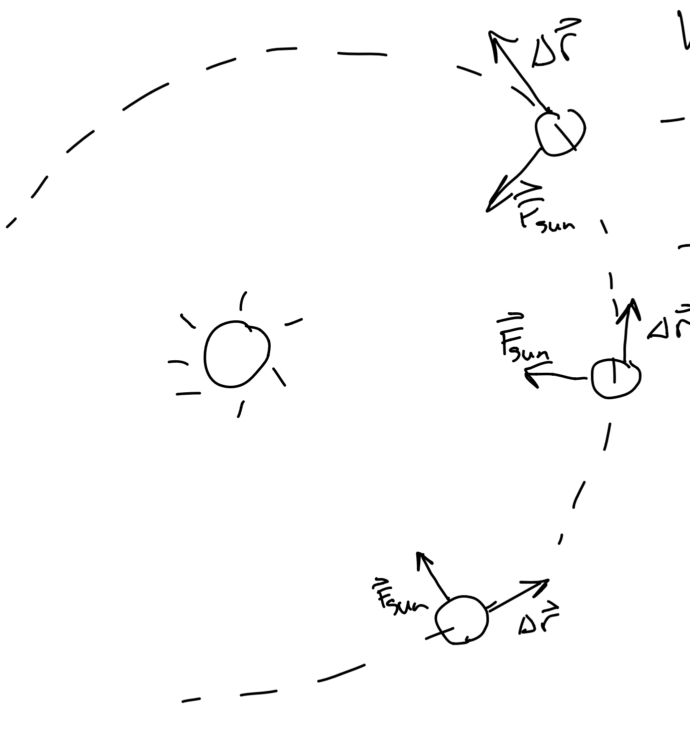
Not all forces do work

Ex: hockey puck being accelerated by a stick



$$W_{gravity} = \vec{F}_g \cdot \Delta\vec{r} = 0$$

Ex: Circular orbit



$$W_{sun} = \vec{F}_{sun} \cdot \Delta\vec{r} = 0$$

- The energy of the Earth does not change!
- The

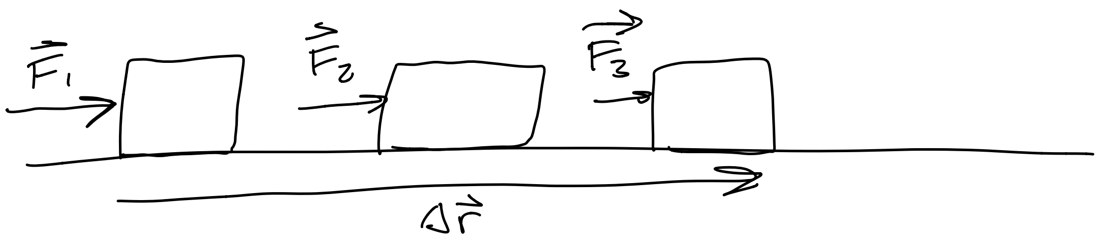
This confirms our result from Ch. 5:
perpendicular forces do not change $|\vec{p}|$ only $\hat{p}$

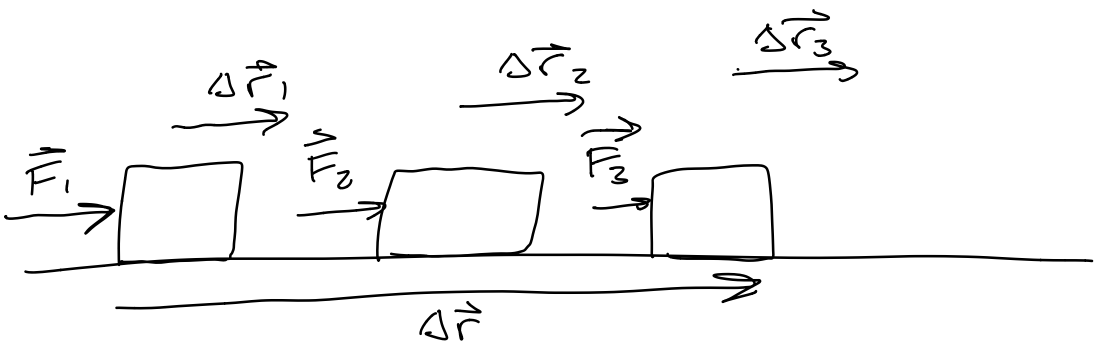
Our defn of W:

$W = \vec{F} \cdot \Delta \vec{r}$ is only valid if $\vec{F}$ is constant over $\Delta \vec{r}$

(like $\Delta \vec{p} = \vec{F} \Delta t$)

- If $\vec{F}$ is changing along $\Delta \vec{r}$





$$W = \vec{F}_1 \cdot \Delta \vec{r}_1 + \vec{F}_2 \cdot \Delta \vec{r}_2 + \vec{F}_3 \cdot \Delta \vec{r}_3$$

$$W = \sum_{\vec{r}_i}^{\vec{r}_f} \vec{F} \cdot \Delta \vec{r}$$

$$W = \int_i^f \vec{F} \cdot d\vec{r}$$

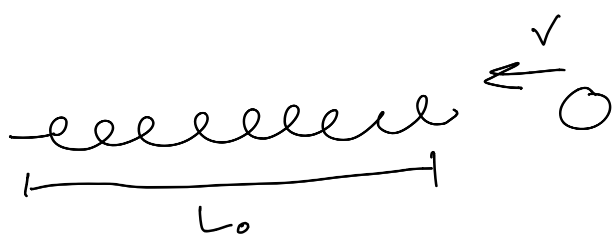
You haven't seen integrals like this yet... Don't worry

Ex: Work done by a spring

A ball is moving horizontally when it runs into a spring, compressing it by 20 cm

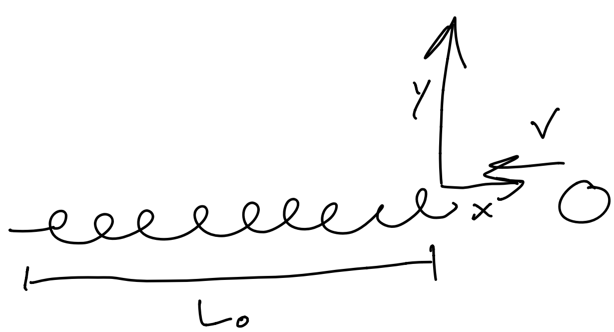
$K = 100 \ N/m$

How much work does the spring do on the ball?



Q: Will W be positive or negative?

pick coordinate system so $x = 0$ @ L_o



$$\vec{F}_{spring} = K|s|\hat{x} = -Kx\hat{x}$$

$$\Delta\vec{r} = dx\hat{x}$$

$$W = \int_{x=0}^{x=-.2} -kx\hat{x} \cdot dx\hat{x} = \int_{0}^{-.2} -kx\,dx = -\frac{1}{2}kx^2 \Big|_{0}^{-.2}$$

$$= -\frac{1}{2}k(-.2)^2 = -2\ N \cdot m$$

The spring did $-2\ J$ of work on the ball (the ball lost energy + transferred it to the spring)

$$\Delta E_{sys} + \Delta E_{surr} = 0$$

$$\Delta E_{sys} = -\Delta E_{surr}$$

$$\Delta E_{sys} = W_{surr}$$

" The change in energy of the system is equal to the work done on the system by the surroundings"

Work done ON vs work done BY

- The object applying the force is doing the work
- The object expiriencing the force is being worked ON

The systen is being worked ON, surr doing work

Ex: Ball & spring

System = spring

2 J of work done on spring by ball (surr)

System = ball

−2 J of work done on ball by spring

System = spring & ball

No work was done on the ball/spring system

If the ball was initially moving with speed $|\vec{v}| = 8$ m/s, what is its new speed? $m = 0.6$ kg

System: ball

$$\Delta E_{sys} = W_{surr}$$

$$E_f = E_i + (-2J)$$

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 - (2J)$$

$$v_f = \sqrt{v_i^2 - \frac{2}{m}(2J)} = \sqrt{8^2 - \frac{2}{0.6}(2)} = \sqrt{57.33}$$

$$\boxed{v_F = 7.6\ \tfrac{m}{s}}$$

$(m = 0.2\ kg)$

Ex: A pitcher throws a baseball from rest to a speed of 36 m/s (~80 mph).

How much work did pitcher do on ball?

Dont know $\vec{F}$ or $\Delta\vec{r}$

sys: ball
surr: pitcher

$$\Delta E_{sys} = W_{surr}$$

$$E_f - E_i = W_{surr}$$

$$\tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2 = W_{surr}$$

$$\left(\tfrac{1}{2}\right)(0.2\,kg)\left((36\,\tfrac{m}{s})^2 - 0^2\right) = 129.6\ J$$

$$W_{surr} = 129.6\ J$$