# Energy

- many types
- energy is conserved

energy never appears or disappears but flows from one system to another and from one type to another

- motion (kinetic energy)
- electrical
- chemical
- elastic
- gravitational
- thermal
- light
- sound
- mass

$$E = mc^2$$

E: mass energy

m: mass

c: speed of light $3 \times 10^8$ m/s

# Conservation of Energy

$$E_f = E_i + \Delta E$$

$E_f$: final energy

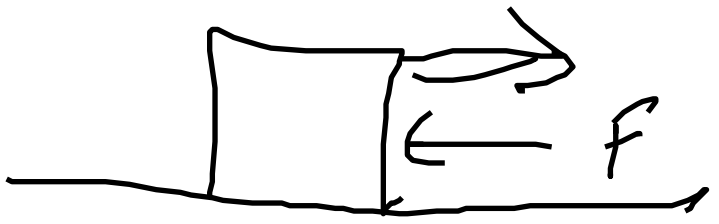
$E_i$: initial energy

$\Delta E$: energy that flowed into (+) or out of (−) the system

# Two types of energy flow

- heat: flow of energy from hot to cold (later)
- work: transfer of energy through forces
  - always motion involved


force in direction of motion
"positive work"
force gives energy to object




Force opposite motion

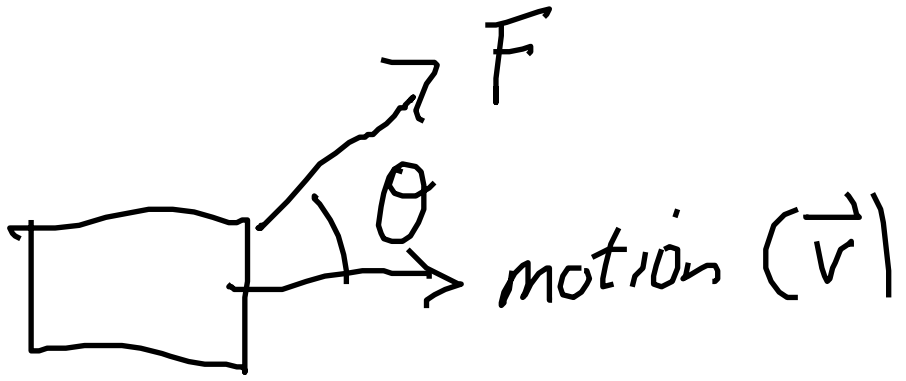
"negative work"

Force steals energy from object

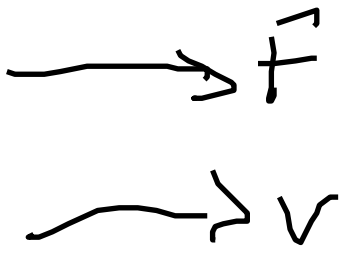
More generally,
work equation:

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

- $W$: work done by a force $F$
- $F$: force magnitude
- $d$: distance object moves
- $\theta$: angle between force & motion

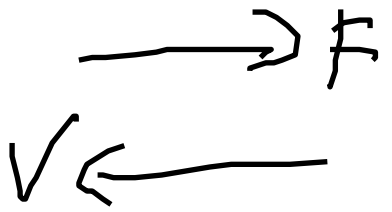



$\theta = 0$



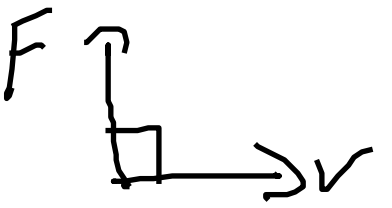

$\cos 0^0 = 1$

$\theta = 180^0$




$\cos 180^0 = -1$

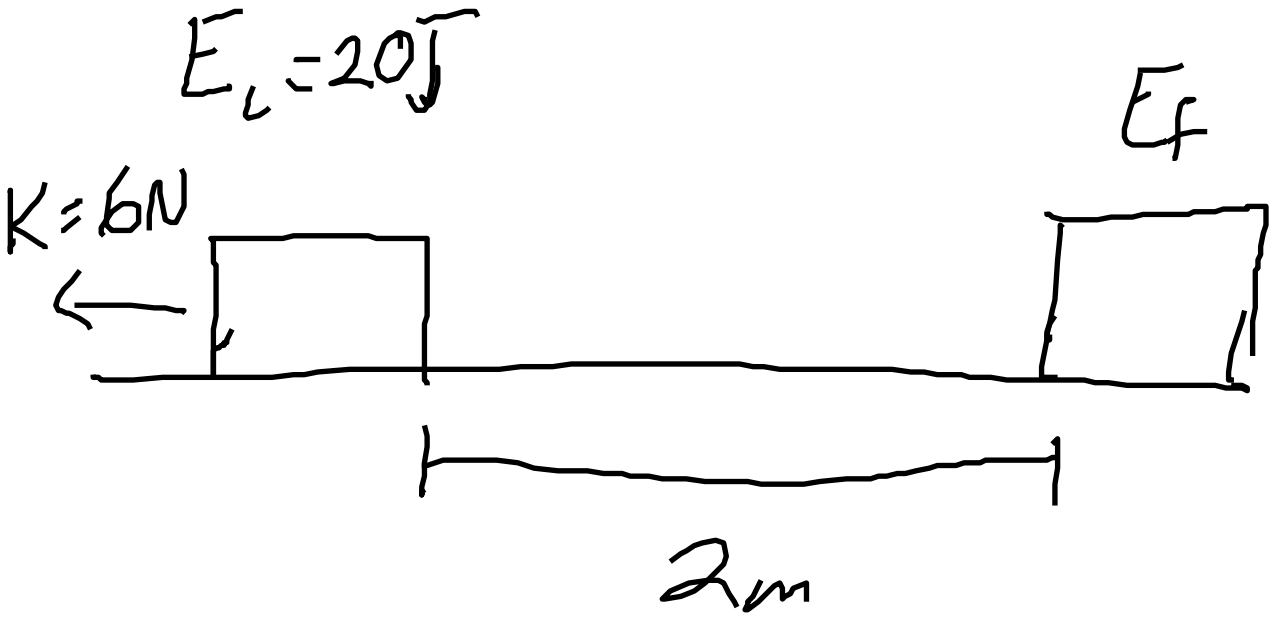
$\theta = 90^0$




$\cos 90^0 = 0$

$W = +Fd$ $W = -Fd$ $W = 0$

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




$$E_f = E_i + \Delta E$$

$$\boxed{E_f = E_i + W}$$

$$E_f = 20 + fd\cos\theta$$

$$W_k = (6N)(2m)\cos 180^\circ$$

$$= -12\,Nm = -12J$$

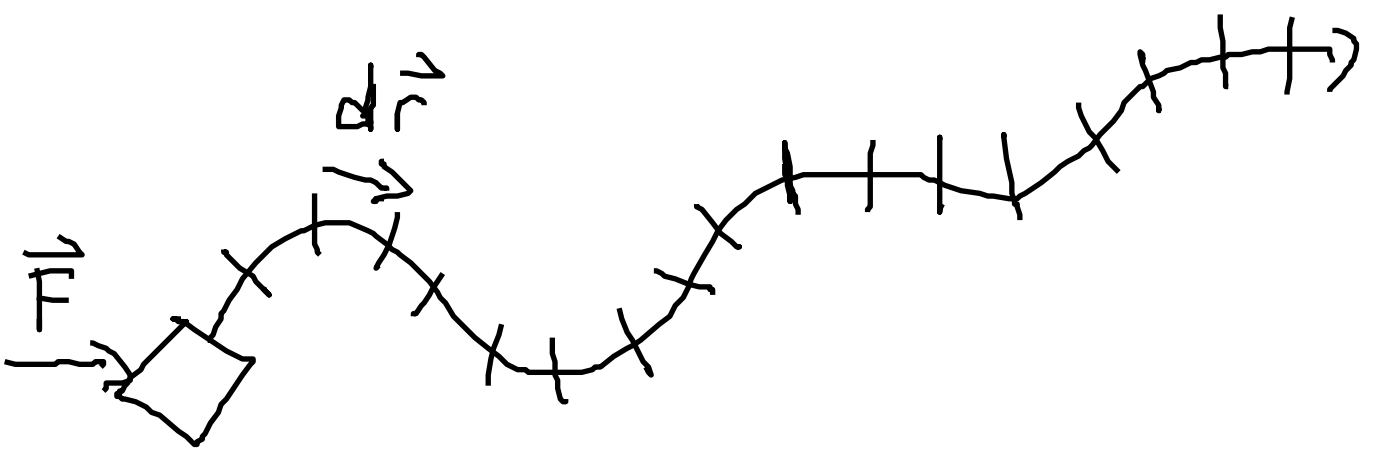
$$E_f = 20J - 12J = \boxed{8J}$$

# Unit of Energy

1 Joule (J)

$1\,J = 1\,Nm$

If force or $\theta$ change as object moves.



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

For kinetic friction,

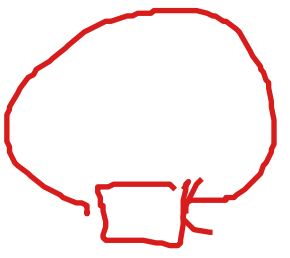
$\theta = 180^\circ$ always

so $\int \vec{F} \cdot d\vec{r} = \int F \cos\theta \, dr$

$= K \cos\theta \int dr$ ] Sum of all little pieces = length of path

$= K d \cos\theta = -Kd$

Note: $d$ is distance (length of path) not displacement



# Kinetic Energy

motion energy

$$E_k = \frac{1}{2} m v^2$$

Sometimes written $KE$

or even ~~$K$~~

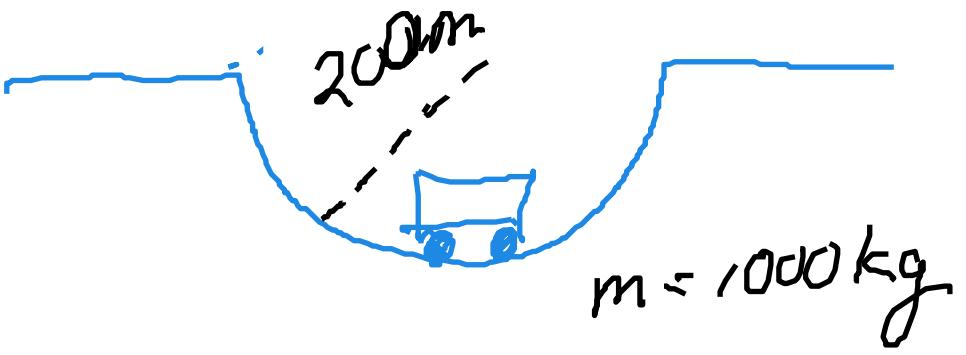
(or even $\overline{T}$ in advanced physics which is weird)

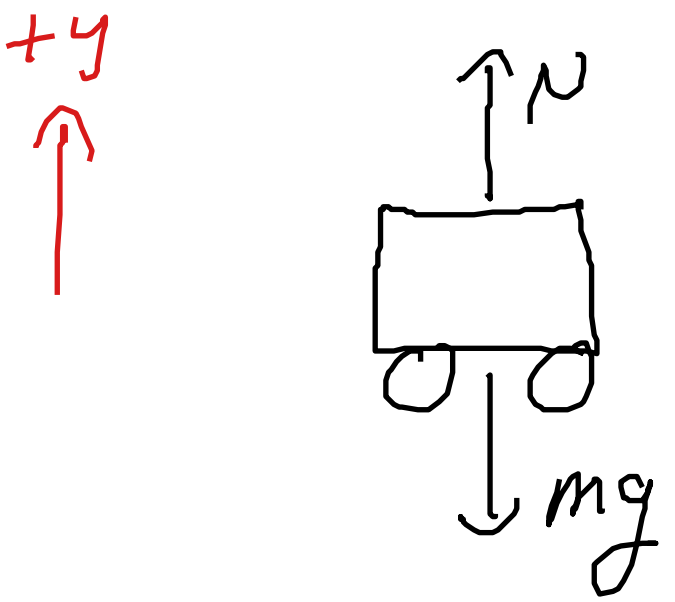
Energy is a Scalar

not a vector! no direction

$$E_k \geq 0$$

# Aside: centripetal motion problem




$\vec{F}_{net} = m\vec{a}$

$(+N - mg) = +m\frac{v^2}{r}$

$N = mg + m\frac{v^2}{r} = m\left(g + \frac{v^2}{r}\right)$

N: force of road on car but also force of car on road (N3L)

Stored energy: can be easily converted into other forms

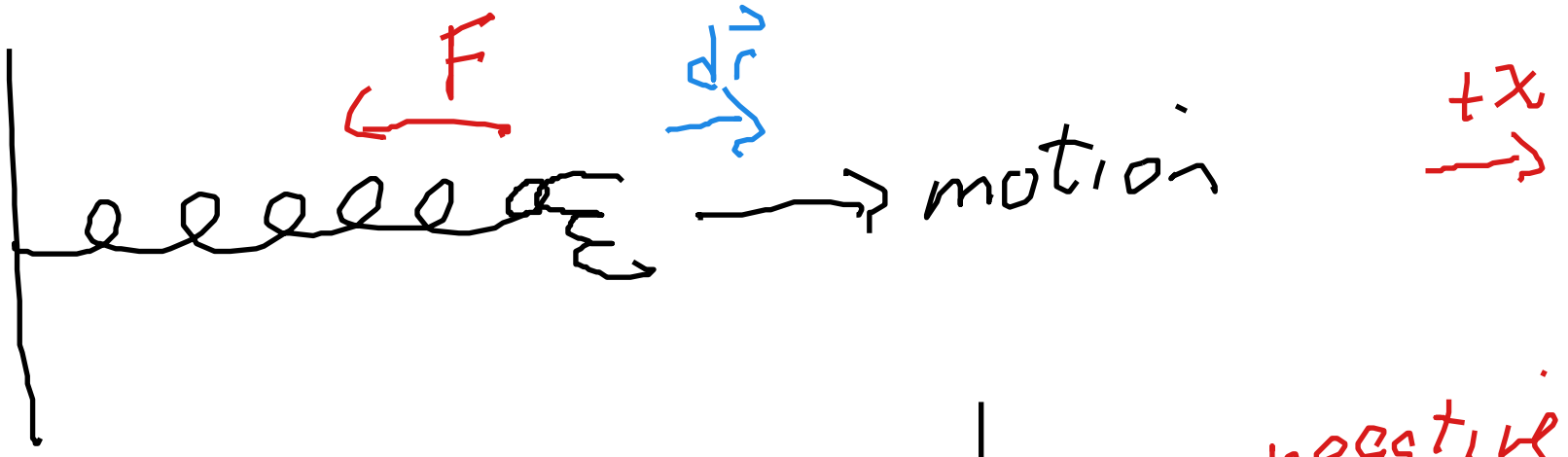
- chemical energy in rechargeable battery
- electrical energy
- elastic energy
- gravitational energy

dissipated energy:
hard to gather and convert into other forms

- sound
- light
- thermal energy

Potential Energy is
a type of stored energy

Elastic Potential Energy
$E_s$ (s for spring)




The spring is doing negative
work on my hand.

Energy is flowing from my hand into the spring.

Spring stores this as elastic potential energy. which can be released later.

Work done on my hand

$$W = \vec{F} \cdot \vec{d} \qquad F = k(L - L_0)$$

$$= -Fd$$

$$W = \int \vec{F} \cdot d\vec{r} = \int -k(L - L_0)\, dx$$

Let $x = 0$ where $L = L_0$

then $x = L - L_0$

$$W = -\int_0^{x_f} kx \, dx$$

$\int x \, dx$

$\frac{1}{2}x^2$

$$= -k\left[\frac{1}{2}x^2\right]_0^{x_f}$$

$$= -k\left[\frac{1}{2}x_f^2 - 0\right]$$

$$= -\frac{1}{2}kx_f^2$$

this is work done by spring

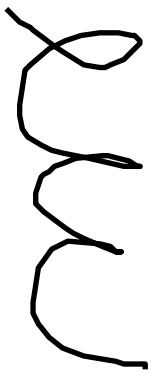
on hand → the energy

stolen.

$$E_s = \frac{1}{2}k(L - L_0)^2$$

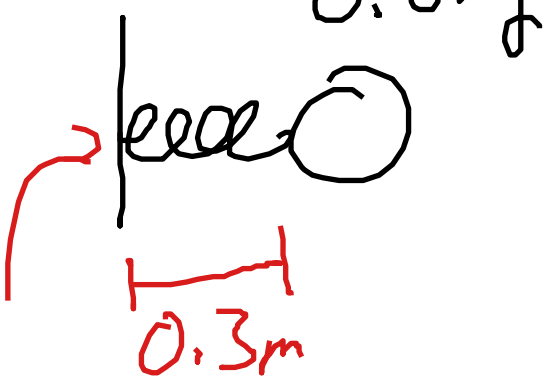
An "ideal spring" can also be compressed.

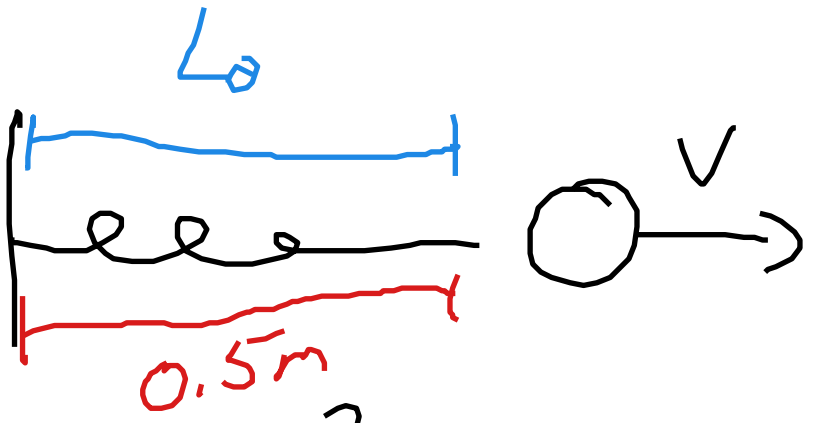
eg. bedspring



In practice, a lot of springs can't be compressed.

# Example problem




$k = 2000 \frac{N}{m}$

What is $V$?

$$E_f = E_i + W$$

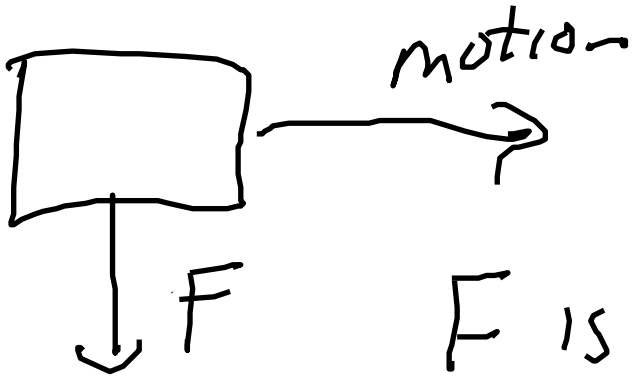
| $E_f$ | $E_i$ | $W$ |
|---|---|---|
| $E_k = \frac{1}{2}(0.5)v^2$ | $E_k = 0$ | weight: 0 |
| $E_s =$ 0 relaxed | $E_s = \frac{1}{2}k(L-L_0)^2$ | normal F: 0 |
| | $= \frac{1}{2}(2000)(0.3-.5)^2$ | friction? : ignore |
| | $= \frac{1}{2}(2000)(.2)^2$ | Spring: ignore because we used spring P.E. |

$$\frac{1}{2}(0.5)v^2 = \frac{1}{2}(2000)(.2)^2 + 0$$

$$\frac{1}{4}v^2 = 40$$

$$v^2 = 160$$

$$v = \sqrt{160} = 12.6\ m/s$$

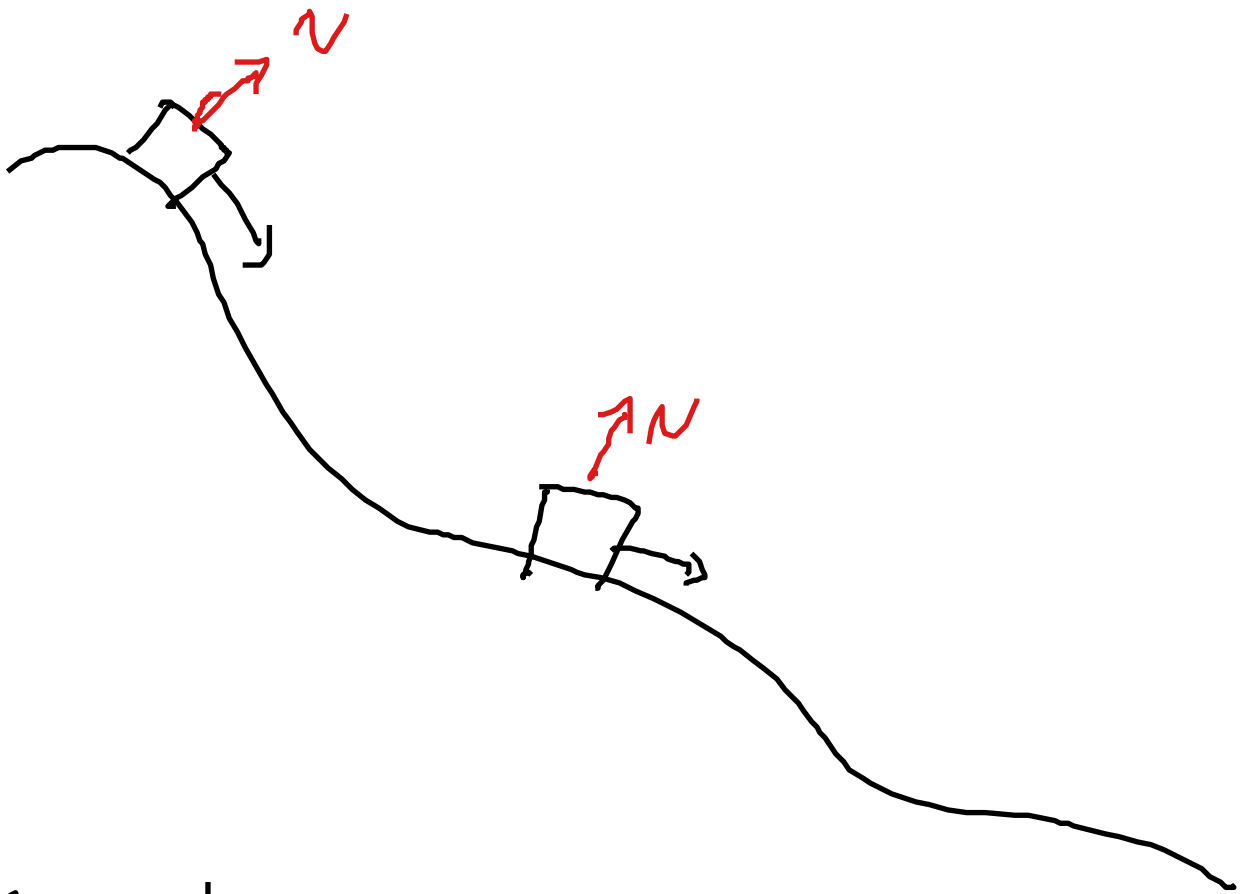



F is $\perp$ to motion

$$W = Fd\cos\theta$$

$$= Fd\cos 90^\circ$$

$$= Fd(0) = 0.$$



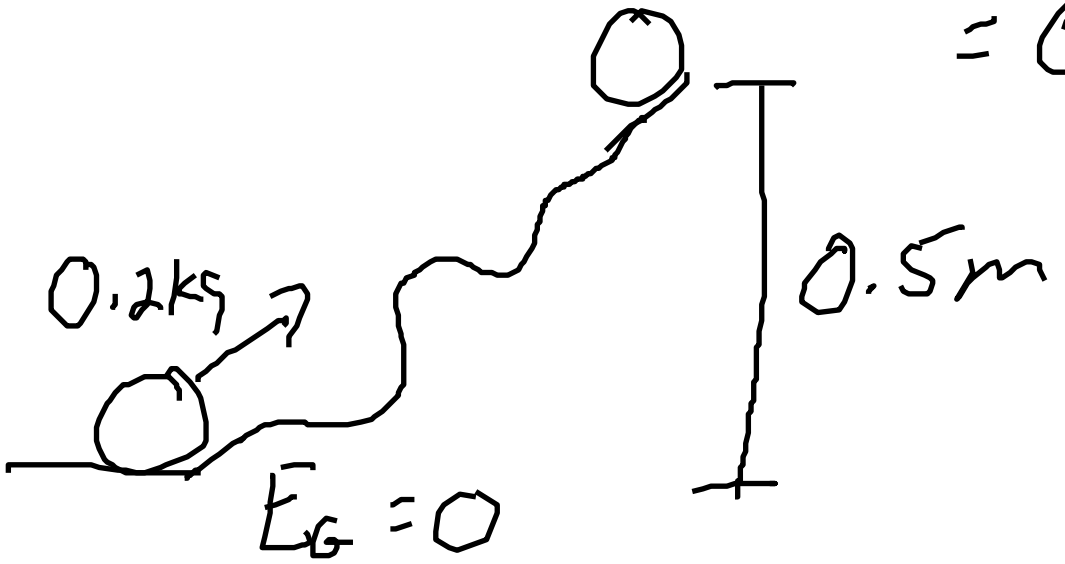

As block moves along a track, normal force from track is always ⊥ to motion, so that normal force does not do work.

# Gravitational Potential Energy

$$E_G = mgh$$

$E_G = (0.2kg)(9.8)(0.5)$

$= 0.98J$




If we use $E_G$, ignore work done by gravity in problems.

# Three Types of Energy

$$E_k = \frac{1}{2} m v^2$$

$$E_s = \frac{1}{2} k (L - L_0)^2$$

$$E_G = mgh$$