Story of Your Life

"What is Energy"

→ powering something up

→ moving

→ ... ? Force ?

Energy → Ancient Greek "Energia"
'activity, operation'

Leibniz: "vis viva" → living force.

Thomas Young to use first (1829)

But to know what energy is,
we need to familiarize with "Work"

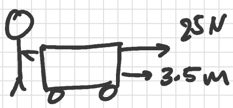
Applying a force to an object displaces it.

Const. force, same directi of displacement

$$W = F\Delta d$$

↑ constant force along directi

Example:



$25 \times 3.5 = 88\ N \cdot m$

Unit: ? $N \cdot m$

$= kg\, m^2/s^2$

$=$ Joule)

Eg. 2. Curler applies force of 15N

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accelerates stone from rest to 8 m/s in 3.5 s

$W = ?$

$F \Delta d = (4 \times 3.5) \times 15 = 210 \text{ J}$

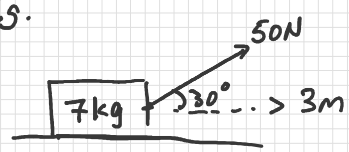
Work done if $\vec{F}$ not in direction of $\Delta\vec{d}$

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

Generally:

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

Eg.



$\vec{F} = \begin{bmatrix} 50\cos 30 \\ 50 \sin 30 \end{bmatrix}$ $\Delta\vec{d} = \begin{bmatrix} 3 \\ 0 \end{bmatrix}$

$W = 50 \cos 30 \cdot 3 = 129.9 \text{ J}$

Eg. 2.

Who does more work?

1. pulling a rock travelling same distance.

   100 N vs. 200 N

2. 100 N horizontal vs. 200 N at 60° above ground.

3. Failed to move the rock

   vs.

   I lift the rock above ground and walk with it.

How much force do I do to the bag if I carry it and go straight?

$0\ J$

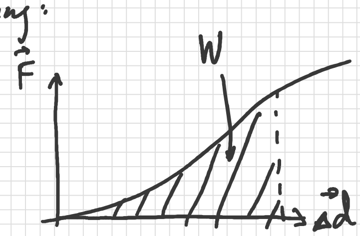
$W = \vec{F} \cdot \Delta\vec{d} = 0$ if $\vec{F} \perp \Delta\vec{d}$

Eg:

How much mechanical work is done on a stationary car if a student pushes on it with 300 N ?

$0\ J$

Graphing:



Kinetic Energy.

A working object can do work because it can apply force to other objects and displace it.

e.g. hammer and nail

$W = F\Delta d$

$= \vec{f} \cdot \left(\frac{v_i + v_f}{2}\right)\Delta t$

$= m\vec{a} \left(\frac{v_i + v_f}{2}\right)\Delta t$

$= m \left(\frac{v_f - v_i}{\ }\right)\left(\frac{v_f + v_i}{\ }\right)$

$\Delta d = v_{av}\,\Delta t$

$= \frac{v_i + v_f}{2}\,\Delta t$

$\vec{a} =$

$$= m\left(\frac{v_f - v_i}{\cancel{\Delta t}}\right)\left(\frac{v_f + v_i}{2}\right)\cancel{\Delta t}$$

$$= \frac{m(v_f^2 - v_i^2)}{2}$$

$$= \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$$

$$= \underbrace{\frac{mv^2}{2}}_{K}\Bigg|_{v_i}^{v_f}$$

Eg. 1. How much energy does it take to accelerate an F1 car from 0 to $\underbrace{100 \text{ km/h}}_{\downarrow}$ in 1.8s

$m = 800$ kg

$$\frac{800 \cdot 27.78^2}{2} = 308691 \text{ J}$$

2. A 165g hockey puck initially at rest is pushed by a const. horizontal force of 5N.

What's the pucks speed after pushing it 0.5m?
Use Kinetic Energy.

We can do

$\vec{F} = m\vec{a}$, $\quad \vec{v}_f = v_i + 2\vec{a}\Delta\vec{d}$ $\qquad v_f = 5.5$ m/s

$5 = 0.165\,\vec{a}$ $\qquad v_f^2 = 2\vec{a} \cdot 0.5$

$= 30.3$ $\qquad = 2 \cdot 30.3 \times 0.5$

But:

$$W_{net} = \vec{F}\Delta\vec{d} = \frac{m}{2}(v_f^2 - v_i^2)$$

5.5 m/s

$$0.5 \cdot 5 = \frac{0.165}{2} v_f^2$$

Gravitational Potential Energy

def: a form of energy that's dependent on its position in relation to forces in its equation

A "reserved" energy. It is not shown yet.

Gravitation ... : energy possed by an object due to its position to surface of earth

$$W = \vec{F} \cdot \Delta\vec{d}$$
$$= mg \cdot h$$

Note: it must be compared to a certain "reference level"

Ex:
What is the gravitational potential energy of a 48 kg student on the top of a 110 m tower relative to the ground?

$$U = mgh$$
$$= 48 \cdot 9.8 \cdot 110$$
$$= 51744 \text{ J}$$

A little more sauce

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

$$W = \int \vec{F} d\vec{r} = m \int \vec{a} \cdot d\vec{r} = \int \frac{d^2\vec{r}}{dt^2} \cdot d\vec{r}$$

$$= m \int \frac{d\vec{v}}{dt} \cdot d\vec{r}$$

$$= m \int \frac{d\vec{r}}{dt} \cdot d\vec{v}$$

$$= m \int \vec{v} \cdot d\vec{v}$$

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

$$W = -\int \vec{f} \cdot d\vec{r}$$

$$= -\int m\vec{g} \cdot d\vec{r}$$

$$= -mg\, \vec{r} \Big|_{\vec{r}_1}^{\vec{r}_2} = mg(\vec{r}_1 - \vec{r}_2)$$

$$= mg\Delta h$$

Conservation of energy:

Energy transfers from one to another

mechanical to kinetic

kinetic to potential

thermal energy to kinetic

thermal energy to kinetic

changes of form from one to another

Law of energy conservation:

the total amount of energy in the universe (or a closed system) is conserved. There is a certain total amount in the system, and energy cannot be created or destroyed.

Energy can only be changed via form exchange.

When energy transformation occurs, no energy is lost.

In our class for now, we only consider

potential - kinetic transformation

The sum of kinetic and potential energy in a conserved system remains the same (Hamiltonian)

Diver: 65 kg. 10m. What's his speed at half way and right before getting into water?

At the apex:

no kinetic energy, only gravitational potential

$H = U = mgh$

$= 65 \times 9.8 \times 10$

$= 6370 J$

at midway: part of potential energy transferred to kinetic energy.

Full amount is the same

$H = U + K$

$= mgh + \frac{1}{2}mv^2$

$6370 = 637.5 + \frac{1}{2} \times 65 \times v^2$

$\boxed{H = 6370}$

$\frac{6370}{2} \times \frac{2}{65} = v^2 =$

$v = 9.9\ m/s$

$V_f^2 = V_i^2 + \vec{a} \cdot 2 \times \Delta d$

$V_f = \sqrt{2 \times 9.8 \times 5}$

at the bottom:

$\boxed{H = 6370}$

$H = \frac{1}{2}mv^2 = 6370$

$v = 14\ m/s$

$V_f = \sqrt{2 \times 9.8 \times 10}$

Ex. A 1.1kg camera slips out of the photographer's hand

$\Delta d = 1.4m.$

(a) What is the gravitational potential energy at the hand of the photographer?

(b) what is the kinetic energy when the camera hits the ground?

(c) What is the velocity of the camera when it hits the ground?

(a) $U = mgh$

$= 1.1 \times 9.8 \times 1.4$

$= 15.1\,J$

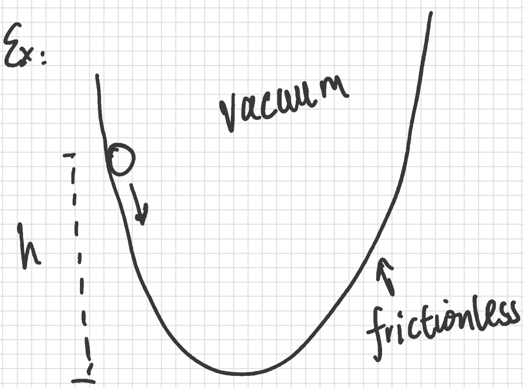
(b) $T = U = 15.1\,J$

(c) $mgh = \frac{1}{2}mv^2$

$v = \sqrt{2gh}$

$= 5.24\,m/s$

Ex:



1. if the ball rolls down from height of h, what's its velocity at the valley? $\frac{1}{2}mv^2 = mgh$ $\quad v = \sqrt{2gh}$

2. What is the maximum height it will reach on the other side?

h.

Why?
energy transformation

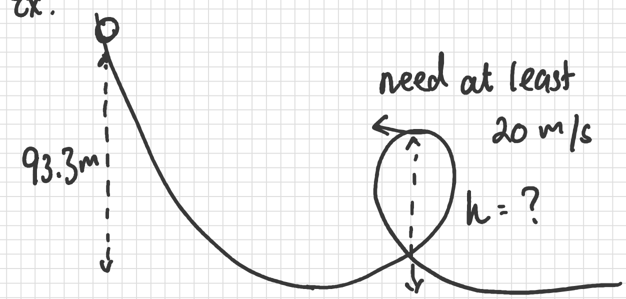
3. Is this the real case?

air resistance
friction
sound
heat

Ex.

Wonderland

Ex.



Wonderland Leviathan

tallest and fastest roller coaster

$$\mathcal{H} = U + K = \text{const.}$$

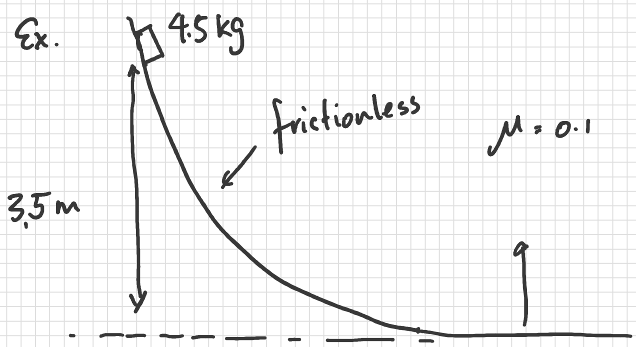
$$mgh_1 = mgh_2 + \frac{1}{2}mv^2$$

$$gh_1 = gh_2 + \frac{1}{2}v^2$$

$$h_1 - \frac{v^2}{2g} = h_2$$

$$h_2 \leq 72.9\text{m}.$$

Ex.

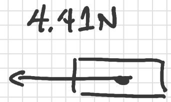


How far will the block slide?

1. $v = \sqrt{2gh}$

$= \sqrt{2 \cdot 9.8 \cdot 3.5}$

$= 8.28 \text{ m/s}$



$$\vec{f}_f = \vec{f}_g \mu = mg\mu = ma$$

$$g\mu = \vec{a}$$

$$\vec{a} = 0.98 \text{ m/s}$$

2. (a) $v_f^2 = 2\vec{a}\Delta d + v_i^2$

$0 = 8.28^2 + 2 \cdot (-0.98) \cdot \Delta d$

$1.96 \Delta d = 68.6$

$\Delta d = 35 \text{ m}$

(b) $\vec{f} \cdot d = \frac{1}{2}mv^2$