ENERGY

KINETIC AND POTENTIAL ENERGY

- **KINETIC ENERGY** IS ENERGY A MOVING OBJECT HAS BECAUSE OF ITS MOTION.
- **POTENTIAL ENERGY** IS THE ENERGY STORED IN AN OBJECT.
- **MECHANICAL ENERGY** IS THE SUM OF THE KINETIC AND POTENTIAL ENERGY IN A SYSTEM.
- ENERGY IS A SCALAR.
- SI UNIT: **JOULE** (J)

$$E_k = \frac{1}{2}mv^2$$

E_k: KINETIC ENERGY (J)
m: MASS (kg)
v: VELOCITY ($\frac{m}{s}$)

$$E_p = mgh$$

E_p: GRAVITATIONAL POTENTIAL ENERGY (J)
m: MASS (kg)
g: ACCELERATION DUE TO GRAVITY ($9.8 \frac{m}{s^2}$)
h: HEIGHT (m)

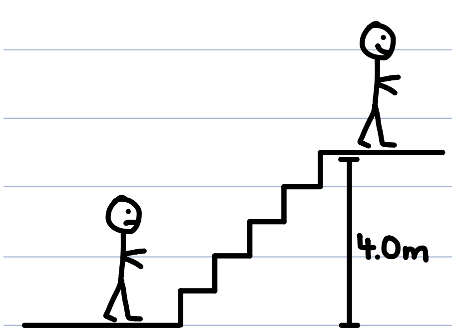
- GRAVITATIONAL POTENTIAL ENERGY IS MEASURED RELATIVE TO A "ZERO" SUCH AS THE GROUND. UNLESS SPECIFIED IN A QUESTION, THIS IS A POINT/HEIGHT OF YOUR CHOOSING.

$$E_p = \frac{1}{2}kx^2$$

E_p: ELASTIC POTENTIAL ENERGY (J)
k: SPRING CONSTANT ($\frac{N}{m}$)
x: DISPLACEMENT FROM EQUILIBRIUM POSITION (m)

EXAMPLE

HOW MUCH GRAVITATIONAL POTENTIAL ENERGY IS GAINED WHEN AN 80 kg PERSON CLIMBS A 4.0 m HIGH STAIRCASE?



EXAMPLE

WHICH HAS MORE KINETIC ENERGY?

a) A 50 g BULLET AT 700 $\frac{m}{s}$

b) A 2000 kg CAR AT 3.5 $\frac{m}{s}$

WORK

- WORK IS THE SCALAR PRODUCT BETWEEN FORCE AND DISPLACEMENT.

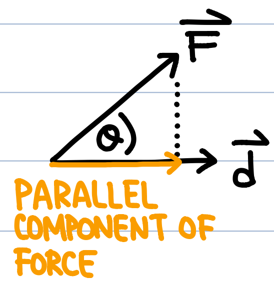
$$W = \vec{F} \cdot \vec{d}$$

W: WORK (J)

$\vec{F}$: FORCE (N)

$\vec{d}$: DISPLACEMENT (m)

- SCALAR PRODUCT: AKA DOT PRODUCT
  - TWO PARALLEL VECTORS THAT MULTIPLY TO A SCALAR
  - IF NOT PARALLEL, USE THE PARALLEL COMPONENT.



$$W = \vec{F} \cdot \vec{d}$$
$$= Fd\cos\theta$$

- WORK IS THE AREA UNDER AN F-d GRAPH

- A CONSERVATIVE FORCE IS ONE FOR WHICH WORK DONE DEPENDS ONLY THE STARTING AND ENDING POINTS OF MOTION AND NOT ON THE PATH TAKEN.

  EXAMPLE

  GRAVITATIONAL FORCE, SPRING FORCE

- A NONCONSERVATIVE FORCE IS ONE FOR WHICH WORK DEPENDS ON THE PATH TAKEN.

  EXAMPLE

  FRICTION

- **WORK ENERGY THEOREM**: THE WORK DONE BY ALL NONCONSERVATIVE FORCES IS EQUAL TO THE CHANGE IN THE MECHANICAL ENERGY OF THE SYSTEM.

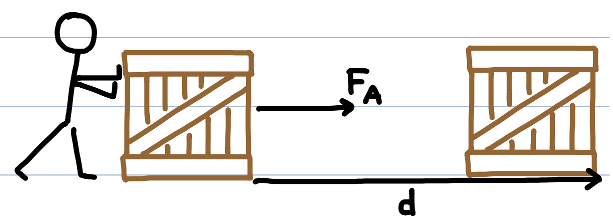
$$\boxed{W_{NC} = \Delta E}$$

$$= \Delta E_K + \Delta E_P$$

- POSITIVE WORK: FORCE IS IN THE SAME DIRECTION AS DISPLACEMENT.
- POSITIVE WORK MEANS THE OBJECT GAINS ENERGY.

EXAMPLE

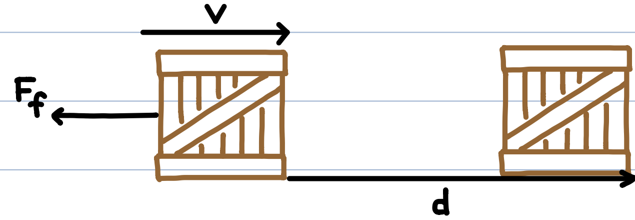
PUSHING A CRATE ACROSS THE FLOOR



- NEGATIVE WORK: FORCE IS IN THE OPPOSITE DIRECTION OF DISPLACEMENT.
- NEGATIVE WORK MEANS THE OBJECT LOSES ENERGY.

EXAMPLE

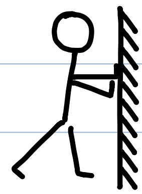
FRICTION ON A SLIDING OBJECT



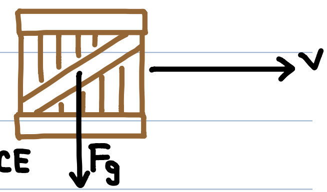
- NO WORK IS DONE IF THE OBJECT DOES NOT MOVE.
- NO WORK IS DONE IF THE FORCE AND DISPLACEMENT ARE PERPENDICULAR.

EXAMPLE

PUSHING A WALL



GRAVITY ON AN OBJECT SLIDING ACROSS A HORIZONTAL SURFACE



DERIVING POTENTIAL ENERGY

HOW MUCH WORK IS REQUIRED TO LIFT A MASS m UP TO A HEIGHT h?

DERIVING KINETIC ENERGY

HOW MUCH WORK IS REQUIRED TO ACCELERATE A MASS m FROM REST TO A SPEED v?

EXAMPLE

A 20 kg CRATE IS PUSHED ACROSS A FRICTIONLESS FLOOR WITH A FORCE OF 80 N. IF THE CRATE STARTS FROM REST, WHAT WILL BE ITS SPEED AFTER IT HAS BEEN PUSHED FOR 5.0 m?

CONSERVATION OF MECHANICAL ENERGY

- IF ONLY CONSERVATIVE FORCES ACT ON A SYSTEM, THE TOTAL MECHANICAL ENERGY IS CONSTANT.

$$\sum E_i = \sum E_f$$

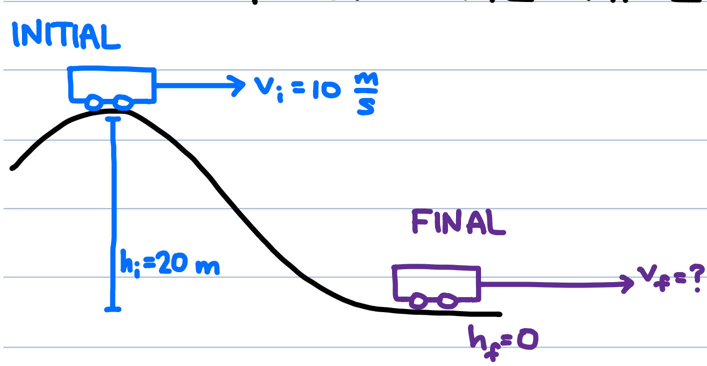
$$E_{k_i} + E_{p_i} = E_{k_f} + E_{p_f}$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

MASS WILL OFTEN CANCEL OUT.

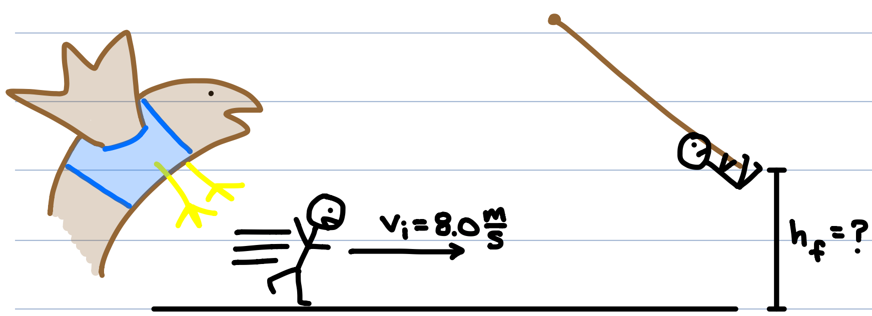
EXAMPLE

A ROLLER COASTER IS AT THE TOP OF A 20 m HIGH HILL WITH A SPEED OF 10 $\frac{m}{s}$. WHAT IS ITS SPEED AT THE BOTTOM OF THE HILL?



EXAMPLE

THE THOMPSON TROJAN IS RUNNING FROM THE HAMBER GRIFFIN AT A SPEED OF 8.0 $\frac{m}{s}$. HE GRABS AN OVERHEAD ROPE AND SWINGS UPWARD. HOW HIGH DOES HE SWING?



- THE WORK DONE BY FRICTION, A NONCONSERVATIVE FORCE, RESULTS IN A TRANSFER OF MECHANICAL ENERGY INTO THERMAL ENERGY.

$$E_i = E_f + Q$$

$$Q = F_f d$$

$$W = F d$$

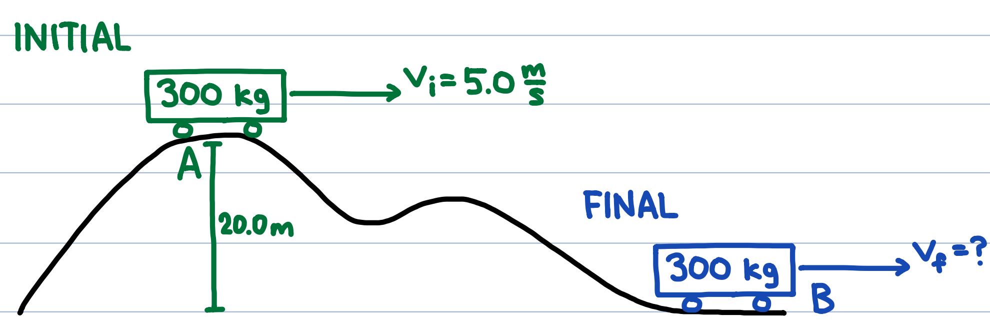
Q : HEAT (J)

F_f : FORCE OF FRICTION (N)

d : DISPLACEMENT (m)

EXAMPLE

A 300 kg ROLLER COASTER CAR IS TRAVELLING ALONG A TRACK AS SHOWN WITH A SPEED OF 5.0 $\frac{m}{s}$ AT POINT A. WHAT IS THE SPEED OF THE CAR AT POINT B IF IT LOSES 29000 J OF ENERGY TO HEAT (DUE TO FRICTION)?



POWER

- POWER IS THE RATE AT WHICH ENERGY IS ADDED OR USED.
- SI UNIT: WATT (W)

$$P = \frac{W}{t}$$

P: POWER (W)
W: WORK (J)
t: TIME (s)

EXAMPLE

AN ELEVATOR CAN LIFT A LOAD OF 1000 kg TO A HEIGHT OF 30 m IN 40 s. WHAT IS THE POWER OUTPUT OF THE ELEVATOR?

EFFICIENCY

$$\text{EFFICIENCY} = \frac{E_{OUT}}{E_{IN}} = \frac{P_{OUT}}{P_{IN}}$$

E_{OUT}: OUTPUT ENERGY (J) USEFUL ENERGY

E_{IN}: INPUT ENERGY (J) ENERGY REQUIRED

P_{OUT}: OUTPUT POWER (W)

P_{IN}: INPUT POWER (W)

- EFFICIENCY IS EXPRESSED AS A PERCENTAGE (×100 %)

EXAMPLE

AN ELECTRIC MOTOR REQUIRES 850 J TO MOVE A 10 kg MASS UP TO A HEIGHT OF 5.0 m. WHAT IS THE EFFICIENCY OF THE MOTOR?