1-Work

February-01-19 8:58 AM

Work

Energy: the capability to do work → (Change something's motion or store energy)

Work and Energy are scalar values.

Units: Joules (J) $J = \frac{kg\,m^2}{s^2}$

$kg \frac{m}{s^2} \cdot m$

$m \cdot a \cdot d$

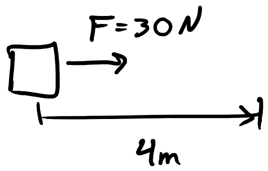
$F \cdot d$

Work: the change in energy

$$\boxed{W = \Delta E = E_f - E_i}$$

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

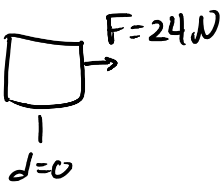
Ex. Tom pushes a box with 30N of force and it slides 4m. How much work did Tom do on the box?



$W = F \cdot d = 30 \cdot 4$

$\boxed{W = 120\,J}$

Ex. Jerry pushes a box with 24N of force and it does not slide. How much work did Jerry do on the box?

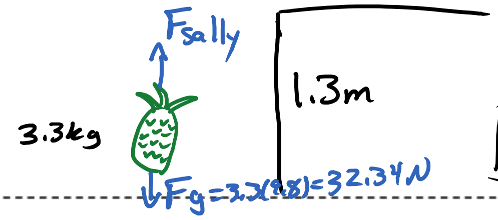


$W = F \cdot d$

$\boxed{W = 0\,J}$

* No movement, no work *

Ex. Sally lifts a 3.3kg pineapple onto a 1.3m tall table. How much work did Sally do on the pineapple?



$W = F \cdot d$

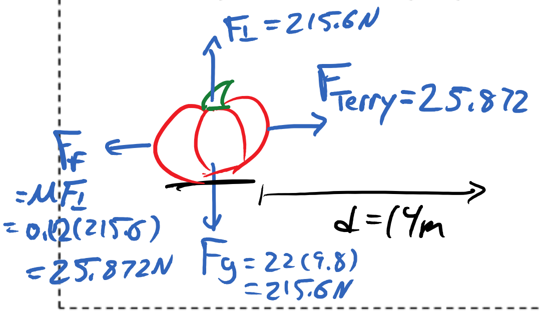
$W = 32.34(1.3)$

$\boxed{W = 42J}$

* When pulling the force will average to equal gravity*

+ If starts and ends at rest +

Ex. Terry slides a 22kg pumpkin across a floor with a coefficient of friction of 0.12 at a constant velocity. How much work did Terry do if she slid the pumpkin 14m?



$W = F \cdot d$

$W = F_{Terry} \cdot d$

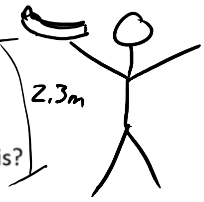
$W = 25.872(14)$

$\boxed{W = 360J}$

Use the force of the named source to calculate work.

Ex. Barry holds a 4.7kg banana at 2.3m in the air for 3 minutes. How much work did Barry do on the banana?

Was energy used to do this?



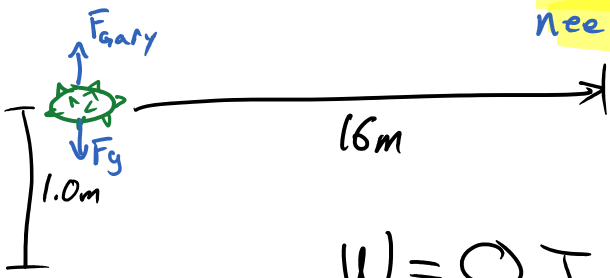
No movement, no work!

$\boxed{W = 0J}$

Yes. The work is done inside his muscles.

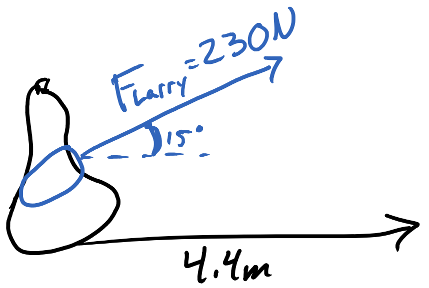
Ex. Gary is holding a 3.7kg dragon fruit 1.0m above the ground. Gary walks horizontally 16m. How much work did Gary do on the dragon fruit?

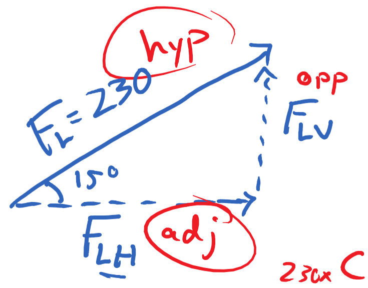
* The force and displacement need parallel portions to have any work done*



$W = 0J$

Ex. Larry is dragging an 88kg squash by pulling on a rope. He pulls with 230N on a rope at an angle of 15° above the ground. The squash is pulled 4.4m horizontally. How much work did Larry do on the squash?





SOH
CAH
TOA

$230 \times \cos 15 = \frac{F_{LH}}{230} \times 230$

$230 \times \cos 15 = F_{LH}$

$F_{LH} = 222.16N$

$W = F_{LH} \times d$

$W = 222.16 \times 4.4$

$\boxed{W = 978J}$

Work: Idea Summary

Work is change in energy

To do work an object must move or change its velocity

Work is a Scalar

To do work the Force and the Distance traveled must be ~~x~~ parallel

Work can be positive or negative (even though it is a scalar):

- Positive Work means putting energy in.
  - pushing /pulling
  - motors
- Negative Work means: getting energy out.
  - generators

Forms of Energy (Potential Energy & Kinetic Energy)

Potential Energy: Energy that is stored and capable of doing work.

Types of Potential Energy

Nuclear
Chemical
→Gravity←

Kinetic Energy: Movement energy

Types of Kinetic Energy

Electric
Sound
Thermal
Hydro
Solar
Wind

Potential Gravitational Energy

From our Work Formula:

$$W = \Delta E = F \cdot d$$

$$\Delta PE = F_g \cdot \Delta h \rightarrow \boxed{PE = m \cdot g \cdot h}$$ or weight × h

Deriving the formula for Kinetic Energy

From our Work definition and Kinematics:

An object starts at rest and get sped up.

$$W = \Delta KE = KE_f - \cancel{KE_i}\ 0$$

$v_i = 0$
$v_f -$
$a -$
$d -$
t

$$v_f^2 = \cancel{v_i^2}\ 0 + 2ad$$

$$\frac{v_f^2}{2} = \frac{2 \cdot a \cdot d}{2}$$

$$\frac{v_f^2}{2} = (a \cdot d)$$

$$F \cdot d = KE_f$$

$$m(a \cdot d) = KE_f$$

$$\frac{m v_f^2}{2} = KE_f \rightarrow KE_f = \frac{1}{2} m v_f^2 \Rightarrow KE = \frac{1}{2} m v^2$$

$$\boxed{PE = m \cdot g \cdot h}$$

E_p
U

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

E_k
T

Ex. Determine the kinetic energy of a 0.50kg football that was kicked 3.4m/s West?

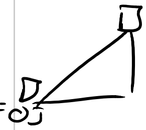
$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(0.5)(3.4)^2 = \boxed{2.89\,J}$$

How much kinetic energy does it have when it is kicked 3.4m/s South?

$$2.89\,J$$

Ex. How much gravitational potential energy does Steve (66kg) have when he is hung by his ankles 13m above the ground?

$$PE = m \cdot g \cdot h = 66 \cdot (9.8) \cdot 13 = \boxed{8400\,J}$$



$PE_f = m \cdot g \cdot h$

$W = PE_f - PE_i$

$PE_i = 0J$

Work-Energy Theorem

- If a non-zero net force is acting on an object, the object will accelerate.
- Acceleration is the rate of change of velocity.

Therefore velocity changes → KE changes

$W = \Delta KE$

∴ Work done is proportional to the change in KE.

Ex. Joe (53kg) accelerates from 1m/s using a 378N force over 12m. What is his final velocity?

$$W = \Delta KE$$

$$W = KE_f - KE_i$$

$$F \cdot d = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$378(12) = \frac{1}{2}(53)v_f^2 - \frac{1}{2}(53)(1)^2$$

$$4536 = 26.5v_f^2 - 26.5$$

$$\boxed{v_f = 4.1\,m/s}$$

Proportionality

$KE \propto m$ — Directly proportional

x2 mass → x2 KE

$KE \propto v^2$ — Squared proportional

x2 speed $\xrightarrow{(\times 2)^2}$ x4 KE

4-Conservation

February-01-19 8:59 AM

Law of Conservation of Energy

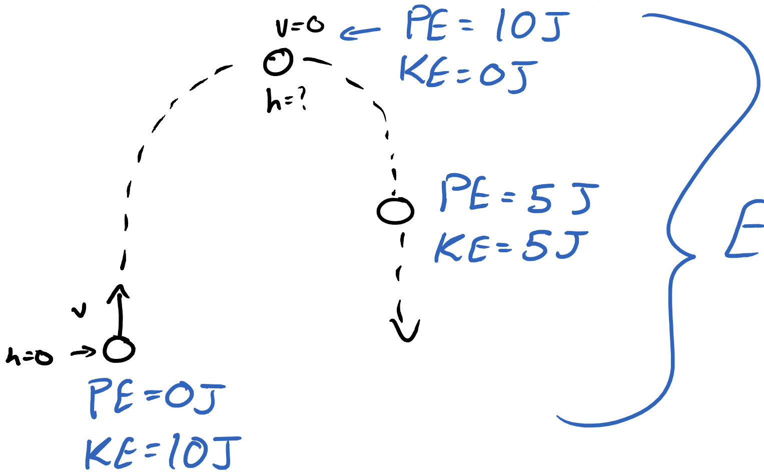
Law of Conservation of Energy: Energy can neither be created nor destroyed, only transformed from one type into another.

This means: Total amount of energy in a closed system will never change.

As a formula:

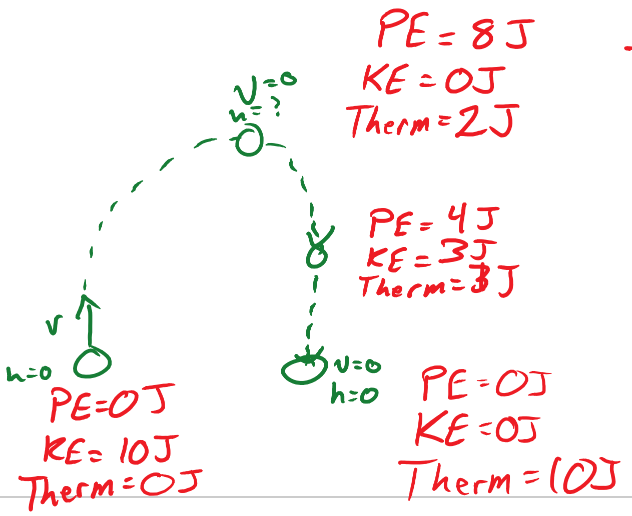
$$E_{\substack{Total \\ Initial}} = E_{\substack{Total \\ Final}}$$

Let's look at the energy of ball thrown into the air (no air resistance)



E_{Total} is always the same.

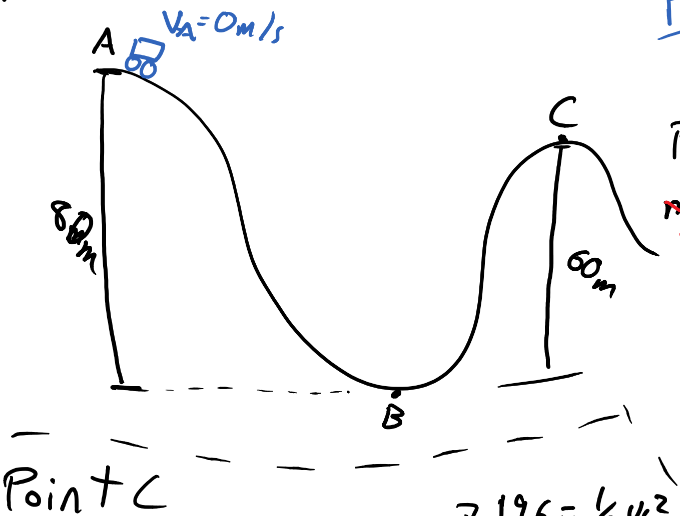
What if there was air resistance?



E_{Total} is always the same.

Ex. Draw in a roller coaster with the rest of the class. Determine the velocity of the cart at point B and point C.

Frictionless



Point B

$$E_{Total\,A} = E_{Total\,B}$$

$$PE_A + KE_A = PE_B + KE_B$$

$$\cancel{m}gh_A + \tfrac{1}{2}\cancel{m}v_A^2 = \cancel{m}gh_B + \tfrac{1}{2}\cancel{m}v_B^2$$

$$9.8(80) + \tfrac{1}{2}(0)^2 = (9.8)(0) + \tfrac{1}{2}v_B^2$$

$$2\times 784 = \tfrac{1}{2}v_B^2 \times 2$$

$$\sqrt{1568} = \sqrt{v_B^2}$$

$$\boxed{v_B = 39.6\,m/s}$$

Point C

$$E_{TA} = E_{TC}$$

$$PE_A + KE_A = PE_C + KE_C$$

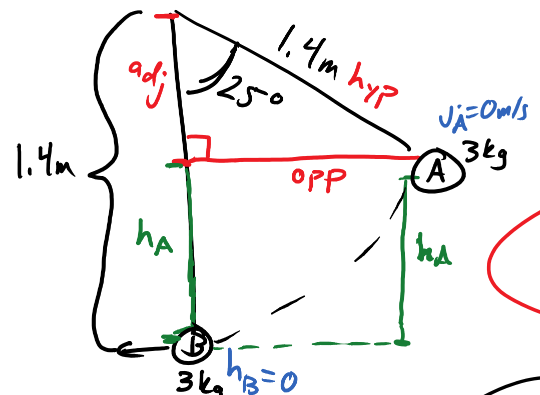
$$\cancel{m}gh_A + \tfrac{1}{2}\cancel{m}v_A^2 = \cancel{m}gh_c + \tfrac{1}{2}\cancel{m}v_c^2$$

$$784 = 9.8(60) + \tfrac{1}{2}v_c^2$$

$$196 = \tfrac{1}{2}v_c^2$$

$$\boxed{v_c = 19.8\,m/s}$$

Ex. A 1.4m long pendulum with 3kg of mass. Is lifted 25°. What will the velocity of the pendulum be when it reaches the bottom of its swing?



$$E_{Tot\,A} = E_{Tot\,B}$$

$$PE_A + KE_A = PE_B + KE_B$$

$$mgh_A + \tfrac{1}{2}mv_A^2 = mgh_B + \tfrac{1}{2}mv_B^2$$

$$3(9.8)(0.13) + \tfrac{1}{2}(3)(0) = 3(9.8)(0) + \tfrac{1}{2}(3)v_B^2$$

$$\frac{3.822}{1.5} = \frac{1.5\,v_B^2}{1.5}$$

$$\sqrt{2.548} = \sqrt{v_B^2}$$

$$\boxed{v_B = 1.6\,m/s}$$

$$1.4 \times \cos 25 = \frac{adj}{\cancel{1.4}} \cancel{\times 1.4}$$

$$1.27\,m = adj$$

$$1.4 = adj + h_A$$

$$1.4 = 1.27 + h_A$$

$$h_A = 0.13\,m$$

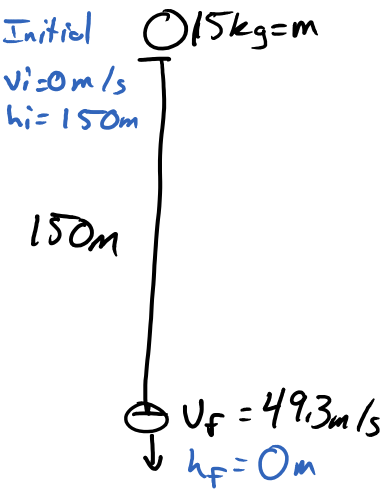
Energy Conservation with Friction and Challenge Problems

Friction → Changes energy into Thermal Energy ⇒ W_F ↓ Work done by friction

Use this formula for Law of Conservation of Energy:

$$E_{Total\ Initial} = E_{Total\ Final}$$

Ex. A 15kg ball is dropped from 150m high. Its velocity as it reaches the ground is 49.3 m/s. How much energy was lost to air resistance?



$PE_I + KE_I = PE_f + KE_F + W_F$ ← air resistance

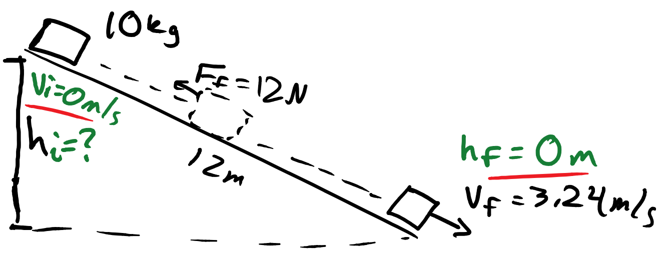
$mgh_i + \cancel{\tfrac{1}{2}mv_i^2} = \cancel{mgh_f} + \tfrac{1}{2}mv_f^2 + W_F$
0 0

$15(9.8)150 = \tfrac{1}{2}(15)(49.3)^2 + W_F$

$22050 = 18229 + W_F$

$$\boxed{W_F = 3821\ J}$$

Ex. A 10kg box starts at rest on the top of a 12m long ramp. The box slides down the ramp, experiencing 12N of friction, and has a velocity of 3.24m/s at the bottom of the ramp. How high off the ground is the top of the ramp?



$PE_i + \cancel{KE_i} = \cancel{PE_f} + KE_f + W_F$
0 0

$mgh_i = \tfrac{1}{2}mv_f^2 + F_f \times d$

$10(9.8)h_i = \tfrac{1}{2}(10)(3.24)^2 + 12 \times 12$

$98h_i = 52.488 + 144$

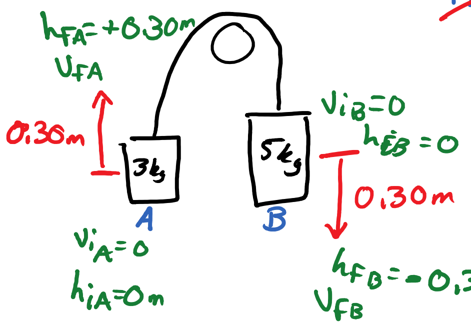
$\frac{98h_i}{98} = \frac{196.488}{98}$

$$\boxed{h_i = 2.0m}$$

$*$ you choose where $h=0.$ $*$

Challenge Problems

Ex. An Atwood machine connects a 5kg mass and a 3kg mass. Determine the velocity of the 5kg mass after it has dropped 30cm.



$$\cancel{PE_{iA}} + \cancel{KE_{iA}} + \cancel{PE_{iB}} + \cancel{KE_{iB}} = PE_{fA} + KE_{fA} + PE_{fB} + KE_{fB}$$

$$0 = m_A g h_{fA} + \tfrac{1}{2} m_A v^2 + m_B g h_{fB} + \tfrac{1}{2} m_B v^2$$

$$0 = 3(9.8)(0.30) + \tfrac{1}{2}(3)v^2 + 5(9.8)(-0.30) + \tfrac{1}{2}(5)v^2$$

$$0 = 8.82 + 1.5v^2 - 14.7 + 2.5v^2$$

$$0 = -5.88 + 4v^2$$

$$\frac{5.88}{4} = \frac{4v^2}{4}$$

$$v^2 = 1.47$$

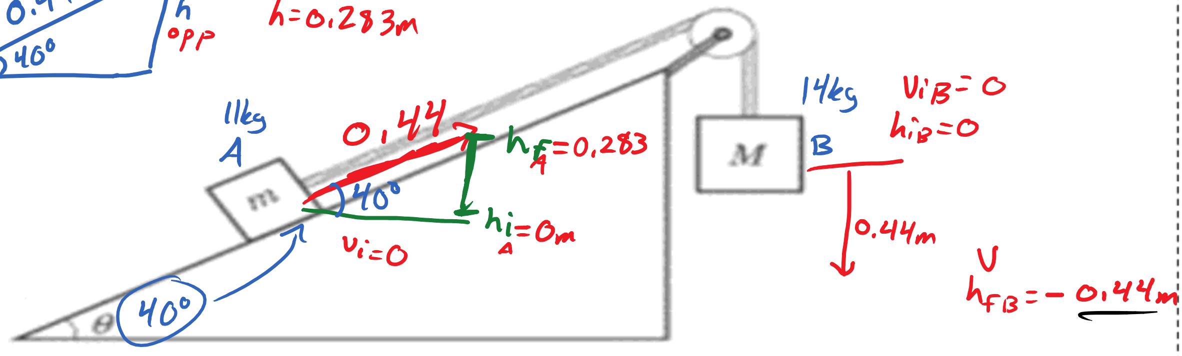
$$\boxed{v = 1.2\, m/s}$$

$$v_{fB} = v_{fA} \Rightarrow v$$

Ex. Two masses (m=11kg and M=14kg) are connected as shown. The angle of the ramp is θ=40°. Determine the velocity of the masses when M drops 44cm. Assume the ramp and pulley are frictionless.

$$0.44 \times \sin 40 = \frac{h}{\cancel{0.44}} \cancel{\times 0.44}$$

$$h = 0.283m$$



$$\cancel{PE_{iA}} + \cancel{KE_{iA}} + \cancel{PE_{iB}} + \cancel{KE_{iB}} = PE_{fA} + KE_{fA} + PE_{fB} + KE_{fB}$$

$$0 = m_A g h_{fA} + \tfrac{1}{2} m_A v^2 + m_B g h_{fB} + \tfrac{1}{2} m_B v^2$$

$$0 = 11(9.8)(0.283) + \tfrac{1}{2}(11)v^2 + 14(9.8)(-0.44) + \tfrac{1}{2}(14)v^2$$

$$0 = 30.5074 + 6.5v^2 - 60.368 + 7v^2$$

$$0 = -29.8606 + 13.5v^2$$

$$\frac{29.8606}{13.5} = \frac{13.5v^2}{13.5}$$

$$v^2 = 2.21$$

$$\boxed{v = 1.49\, m/s}$$

7-ThermalEnergy

February-01-19 9:00 AM

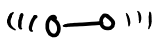
Thermal Energy

Kinetic Molecular Theory:
- All matter is made of particles
- The particles are always moving
- The more energy in the matter the faster the particles are moving.

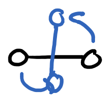
The thermal energy of an object comes from random motion of the molecules in the object.

The three types of motion for molecules:

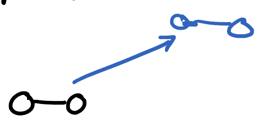
Vibration



Rotation



Translation



Definitions

Thermal Energy: Total amount of energy caused by random particle motion.

Which has more thermal energy:

A glass of cold water or a glass of warm water?

Why? ↳ the particles are moving faster.

A large iceberg or a glass of warm water?

Why? ↳ The iceberg has Many more particles

Temperature: The measure of the average kinetic energy of the particles in a substance.

Heat: the change or transfer of thermal energy.

Heat Formula

$Q \rightarrow$ Heat $= \Delta E$

$m \rightarrow$ mass

$c \rightarrow$ specific heat capacity

$\Delta T \rightarrow$ change in Temperature $(T_f - T_i)$

$$\boxed{Q = m \cdot c \cdot \Delta T}$$

Specific Heat Capacity:

The energy required to raise 1kg of mass by 1°C

Medium	Specific Heat Capacity (J/kg·°C)
Water	4180 J/kg·°C
Carbon	720
Iron	460
Copper	390
Lead	130

Units of Temperature:

°C or K (kelvin) ← Use the same scale

0K = -273 °C

Ex. A pot of water (0.770kg) was at 87°C and cooled to 22°C. Determine the heat given off by the pot of water.

$$Q = m \cdot c \cdot \Delta T$$

$$Q = 0.770 \cdot 4180 \cdot (\overset{T_f}{22} - \overset{T_i}{87})$$

$$Q = 0.770 \cdot 4180 \cdot (-65)$$

$$Q = -210{,}000 \text{ J}$$

Where did this energy go? What did the energy do?

The air. The air's temperature increases.

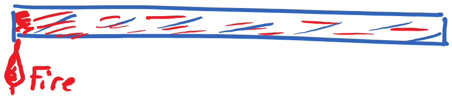
8-ThermEqulibrium

February-01-19 9:01 AM

Thermal Transfer and Thermal Equilibrium

How Thermal Energy Transfers

Conduction

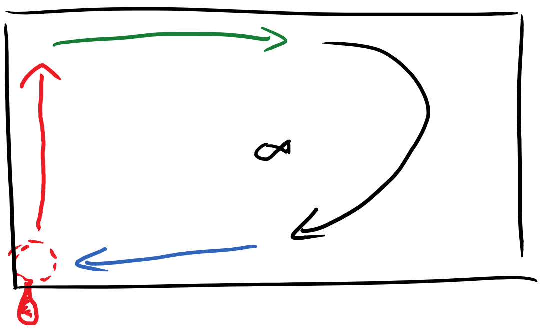


State(s): Primarily solids

also liquvds

also a little with gasses

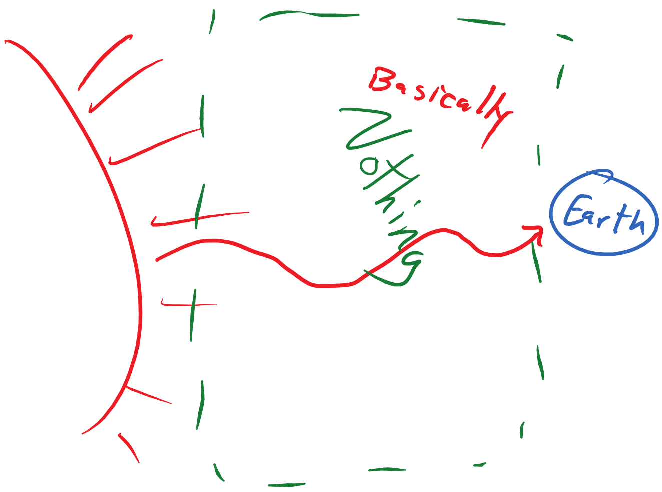
Convection



States(s): ~~Solids~~

Liquids & Gasses

Radiation



State(s): Matter is not required for energy to travel by radiation.

Thermal Energy ***ALWAYS*** transfers from an area of high concentration *Temperature to low concentration *Temperature.

Equilibrium:

The state where the tranfer of energy between two objects is balanced.

Equilibrium Temperature:

The temperature of both objects when they are at equilibrium.

Ex. 3kg of water at 88°C is added to a 44kg bucket of water at 8°C. Determine the final temperature of the water.

A $\boxed{3kg}$ T_i 88°C

B $\boxed{44kg}$ T_i 8°C

T_f is the same

$$-Q_A = Q_B$$

$$-m_A c(T_F - T_{iA}) = m_B \cdot c(T_F - T_{iB})$$

$$-3(\cancel{4180})(T_F - 88) = 44(\cancel{4180})(T_F - 8)$$

$$-3T_F + 264 = 44T_F - 352$$

$$\frac{616}{47} = \frac{47T_F}{47}$$

$$\boxed{T_F = 13.1°C}$$

Ex. A 6.6kg pot of molten iron at 687°C is added to a 204kg bucket of water at 15°C. Determine the final temperature of the iron after the system reaches thermal equilibrium.

Power

Power is the rate of change of energy

Units:

Watt (W) $= \frac{J}{s}$ $\left(\frac{kg\,m^2}{s^3}\right)$

This is not work

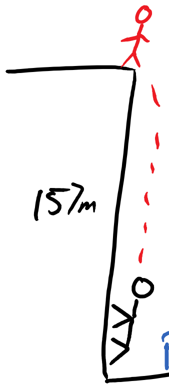
$$\boxed{P = \frac{W}{t} = \frac{\Delta E}{t}}$$

Power, Work

Ex. Cliff McClimber is climbing up a 157m cliff. He is 65kg and takes 5min 3sec to climb the cliff. What is Cliff's power output?

$PE_f = mgh_f$

$t = 5min\ 3sec$
$= 303s$



$m = 65kg$

$PE_i = mgh_i$

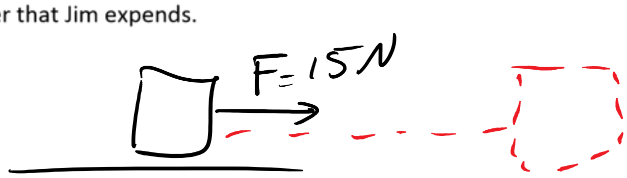
$$P = \frac{\Delta PE}{t} = \frac{PE_f - PE_i}{t}$$

$$= \frac{65(9.8)(157) - \cancel{65(9.8)}(0)}{303s}$$

$$= \frac{100009}{303}$$

$$\boxed{P = 330W}$$

Ex. Jim pushes a box along the floor with a force of 15N for 32 seconds. The box goes 131m in this time. What is the power that Jim expends.



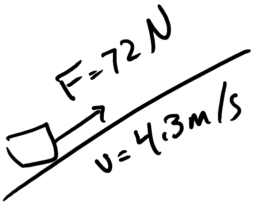
$d = 131m$
$t = 32s$

$$P = \frac{W}{t} = \frac{F \cdot d}{t}$$

$$P = \frac{15(131)}{32}$$

$$\boxed{P = 61.4W}$$

Ex. Joe slides a box up a ramp with a force of 72N. The box slides at a constant velocity of 4.3m/s. What is the power expended by Joe while he is pushing?



$$P = \frac{W}{t} = \frac{F \cdot d}{t}$$

$$V = \frac{d}{t}$$

when there is no acceleration

$$P = F \cdot v = 72 \times 4.3 = \boxed{309.6\,W}$$

when there is no acceleration

Ex. How long will it take a 1000W hotplate to bring a 20°C cup of water (250g) to boiling?

100°C

$$P = \frac{Q}{t} = (m\,c\,\Delta T)$$

$$P = \frac{m c \Delta T}{t}$$

$$t \times 1000 = \frac{0.250(4180)(80)}{\cancel{t}} \times \cancel{t}$$

$$1000\,t = 83600$$

$$\boxed{t = 83.6\,s}$$

Efficiency

There are no perfect machines or objects that do work in the universe. There is always some "loss" of energy into unintended forms of energy (usually thermal) whenever work is done.

- Friction is the primary cause, it changes "useful" work energy into "useless" heat energy

The measure of how much energy input is used appropriately is **efficiency**.

Units: No. Efficiency is a comparison often reported in percentage.

$$\text{eff} = \frac{W_{output}}{W_{input}}$$

$$\text{eff} = \frac{P_{output}}{P_{input}}$$

Outputs: The physical/observable results
→ What actually happens
Changes in:
$\Delta PE \rightarrow \Delta$height
$\Delta KE \rightarrow \Delta$velocity
$Q \rightarrow \Delta$Temperature

Inputs: How hard you try. Energy put into making a change.
→ Applied Forces
→ Ratings of motors/hotplates

Easy Check to all efficiency problems:

Efficiency can never be greater than 100%!!!

Ex. A 4000W crane lifts a 20kg crate up 100m in 22s. How efficient is the crane?

P_{in} (4000W), m (20kg), Δh (100m), t (22s)

$$P_{out} = \frac{\Delta PE}{t} = \frac{mg\Delta h}{t}$$

$$P_{out} = \frac{20(9.8)(100)}{22} = 891\,W$$

$$\text{eff} = \frac{P_{out}}{P_{in}} = \frac{891}{4000} = 0.223$$

$\boxed{\text{The crane was 22.3\% efficient}}$

kg!

Ex. A 74% efficient hot plate has a rating of 1000W. How long will it take heat 250g of water up 5K?

P_{in} (1000W) $\quad m$ (250g) $\quad \Delta T$ (5K)

$$eff = \frac{P_{out}}{P_{in}}$$

$$1000 \times 0.74 = \frac{P_{out}}{1000} \times 1000$$

$$740 = P_{out}$$

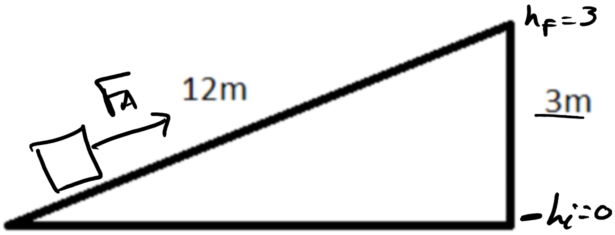
$$P_{out} = \frac{Q}{t} = \frac{mc\Delta T}{t}$$

$$t \times 740 = \frac{0.250(4180)(5)}{\cancel{t}} \times t$$

$$\frac{740t}{740} = \frac{5225}{740}$$

$$\boxed{t = 7.06 s}$$

Ex. A mover pushes a box up a ramp into the truck using a 150N force. The box has a mass of 50kg. Determine the efficiency of the ramp.



$$W_{out} = \Delta PE = mg\Delta h$$
$$= 50(9.8)(3)$$
$$= 1470 J$$

$$W_{in} = F_A \cdot d$$
$$= 150 \times 12$$
$$= 1800 J$$

$$eff = \frac{W_{out}}{W_{in}} = \frac{1470}{1800} = 0.817$$

$$\boxed{81.7\%}$$