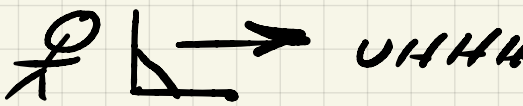
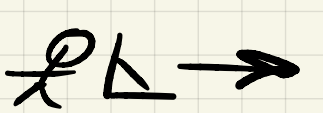
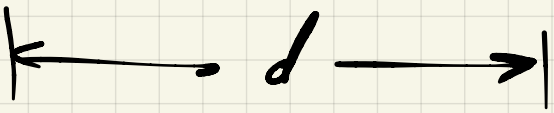
Energy and Power

Energy can be used to do work. A good example of work is shoving a tackling dummy down a football field







A force F is applied over a distance d. The energy is $F \cdot d$.

The units are the units of force (which is mass times acceleration) times distance:

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

This combination comes up so often in the MKS units system it gets its own name, the Joule:

$$1 J = 1 \; kg \frac{m^2}{s^2}$$

$E = mc^2$

Einstein's most famous formula comes from the theory of Special Relativity. The c in the formula is the speed of light. The m is the mass being converted to energy (through fission in a nuclear reactor or an A-bomb — through fusion in the Sun or an H-bomb).

Let's check the units. mc^2 has units

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

So in the MKS system when mass is converted to energy, Einstein's formula comes out in Joules.

Example: 1 mg of matter becomes...

$$1\,mg \cdot \left(3\times10^8\,\frac{m}{s}\right)^2 = 10^{-6}\,kg \times 9\times10^{16}\,\frac{m^2}{s^2}$$

$$= 9\times10^{10}\,J = 90 \text{ trillion Joules.}$$

Power

Power is just a rate of doing work

$$P \equiv \frac{E}{t}$$

(triple equals means this is a definition)

We can rearrange the definition to get a formula that was used in several problems:

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

That formula is used to answer the question

"If you have E of Energy and you use it at a rate P of Power, how long will your energy source last?"

Units of Power

$P = \frac{E}{t}$ so the units of power are $\frac{J}{s}$

Joules per second comes up so often in the MKS system, it gets its own name:

$$1\ \frac{J}{s} = 1\ W$$

the Watt. Rearranging this, you can also see that $1\ J = 1\ W \cdot s$

So if you use 1 W for 1 second you have used 1 J.

Example, how many Joules in a kWh

↑ kilowatt-hour

↖ costs about 10¢ on your electric bill

$1\ kWh = 1000\ W \times 3600\ s$

$= 3{,}600{,}000\ W \cdot s$

$= 3.6$ million Joules

Luminosity and Intensity

The Power of a star is a common thing to contemplate. It is often called "luminosity," and written L instead of P.

Power per area is a common thing to contemplate. It is called "intensity."

$$I \equiv \frac{P}{A} \quad \text{units are } \frac{W}{m^2}$$

Example Light with intensity $I = 1100 \frac{W}{m^2}$ falls on a $0.5m \times 1.0m$ solar panel. What is the Power of the light?

$$P = I \cdot A = 1100 \frac{W}{m^2} \cdot 0.5m \times 1.0m$$

$$= 550\ W$$

Solar Panels are only about 10% efficient so it would actually only produce about 50W of power.