ENERGY

14 week course notes:
fddrsn.net/teaching/
energy

Agenda:

30 minutes
- Quick energy recap from last week
- Kinetic energy concepts

30 minutes
- Experimentation

30 minutes
- Reconvene and compare notes

Review

Conclusions:

- Energy (joule or watt-hour) is important, but surprisingly tricky to pin down in everyday terms.
- Power (watt) is the rate of energy conversion *(informally: "consumption")*.
- Power is more familiar from every day life, especially electronics.
- Power = Energy/Time, and
- Energy = Power x Time

Review

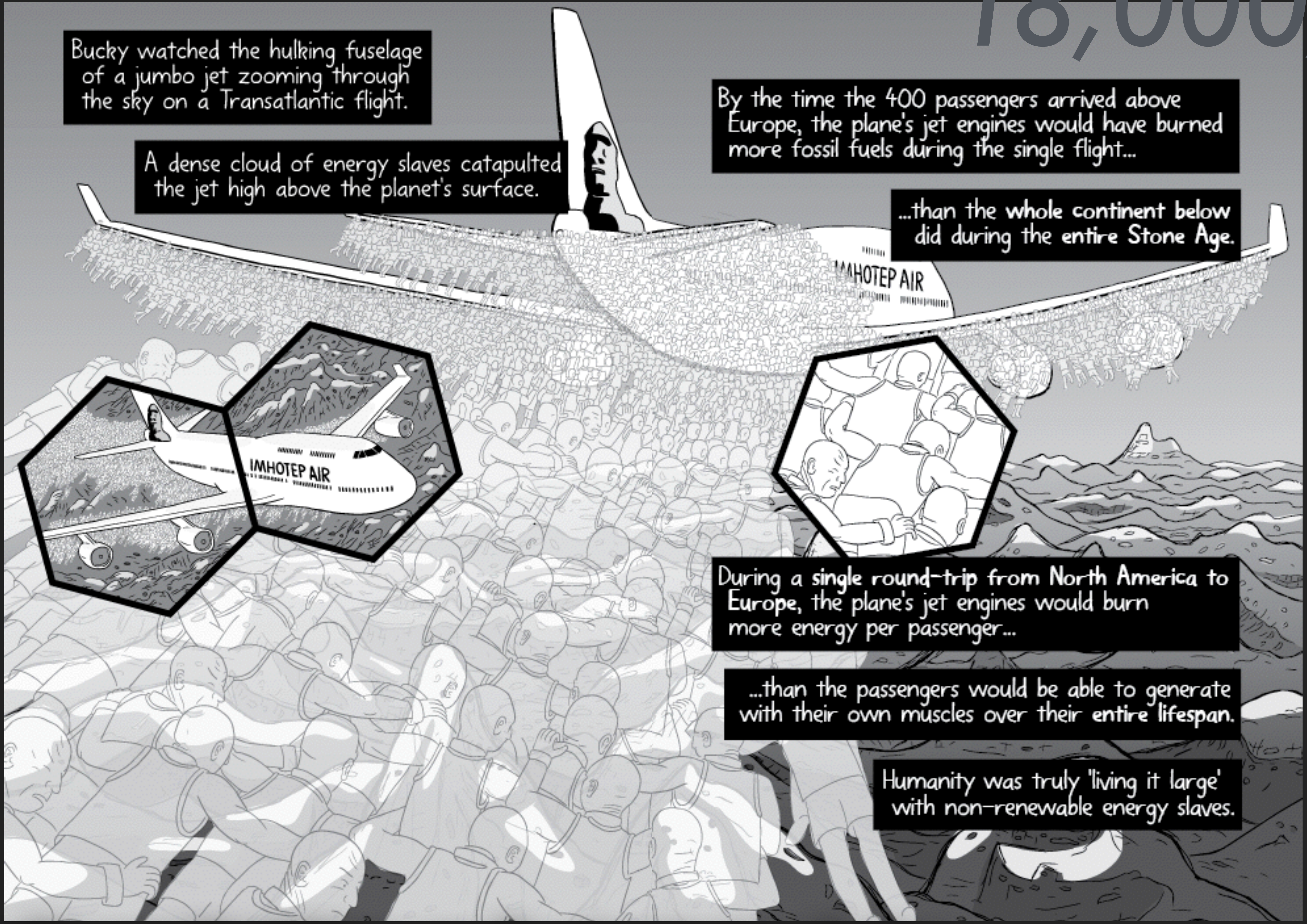
18TW

Source: EIA Total World Primary Energy Production
~550 Quadrillion BTUs / 1 year = 1.8×10^{13} Watts

TW GW MW kW W

18,000,000,000,100

Review



- **Stuart McMillan on Buckminster Fuller**

https://www.stuartmcmillen.com/comic/

Human

2000 kilocalories / 1 day =

~100 Watts

Review

Definitions (from Oxford Dictionary of Physics):

Energy

A measure of a system's ability to do work. Like work itself, it is measured in joules. Energy is conveniently classified into two forms: potential energy is the energy stored in a body or system as a consequence of its position, shape, or state (this includes gravitational energy, electrical energy, nuclear energy, and chemical energy); kinetic energy is energy of motion and is usually defined as the work that will be done by the body possessing the energy when it is brought to rest. For a body of mass m having a speed v, the kinetic energy is mv2/2 (classical) or (m–m0)c2 (relativistic). The rotational kinetic energy of a body having an angular velocity ω is Iω2/2, where I is its moment of inertia.

The internal energy of a body is the sum of the potential energy and the kinetic energy of its component atoms and molecules.

It is a fundamental feature of physics that energy is always conserved in any process. It has occasionally been suggested in various contexts that energy is not conserved, but these suggestions have always turned out to be incorrect.

Work

The work done by a force acting on a body is **the product of the force and the distance moved** by its point of application in the direction of the force. If a force F acts in such a way that the displacement s is in a direction that makes an angle θ with the direction of the force, the work done is given by: W=F.scosθ. Work is the scalar product of the force and displacement vectors. It is measured in joules.

Review

1 Volt * 1 Amp

↕

1 Watt

Rate

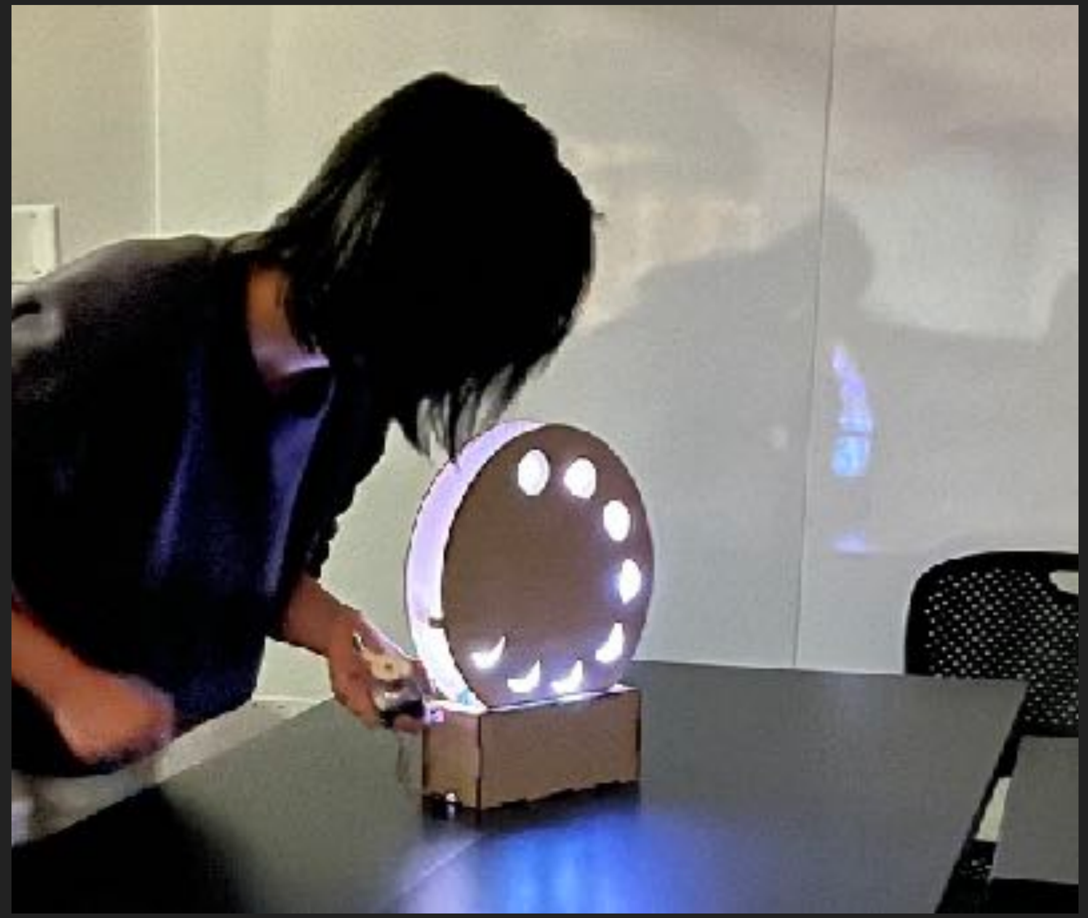
↕

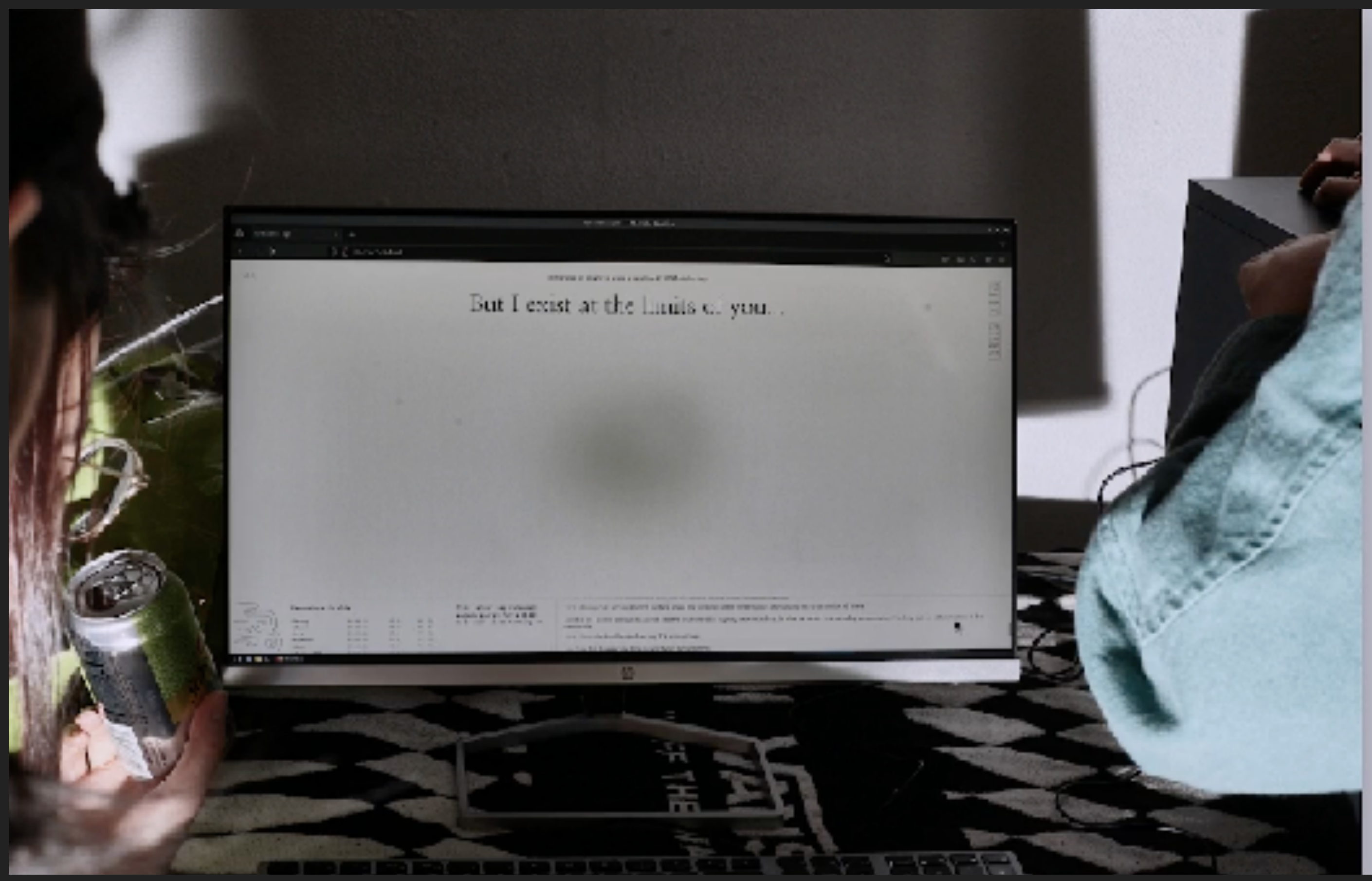
1 Joule / second

SI Energy Unit! Time

What this means: We have a way to measure things with our multimeters that share units with every energy phenomenon in the universe

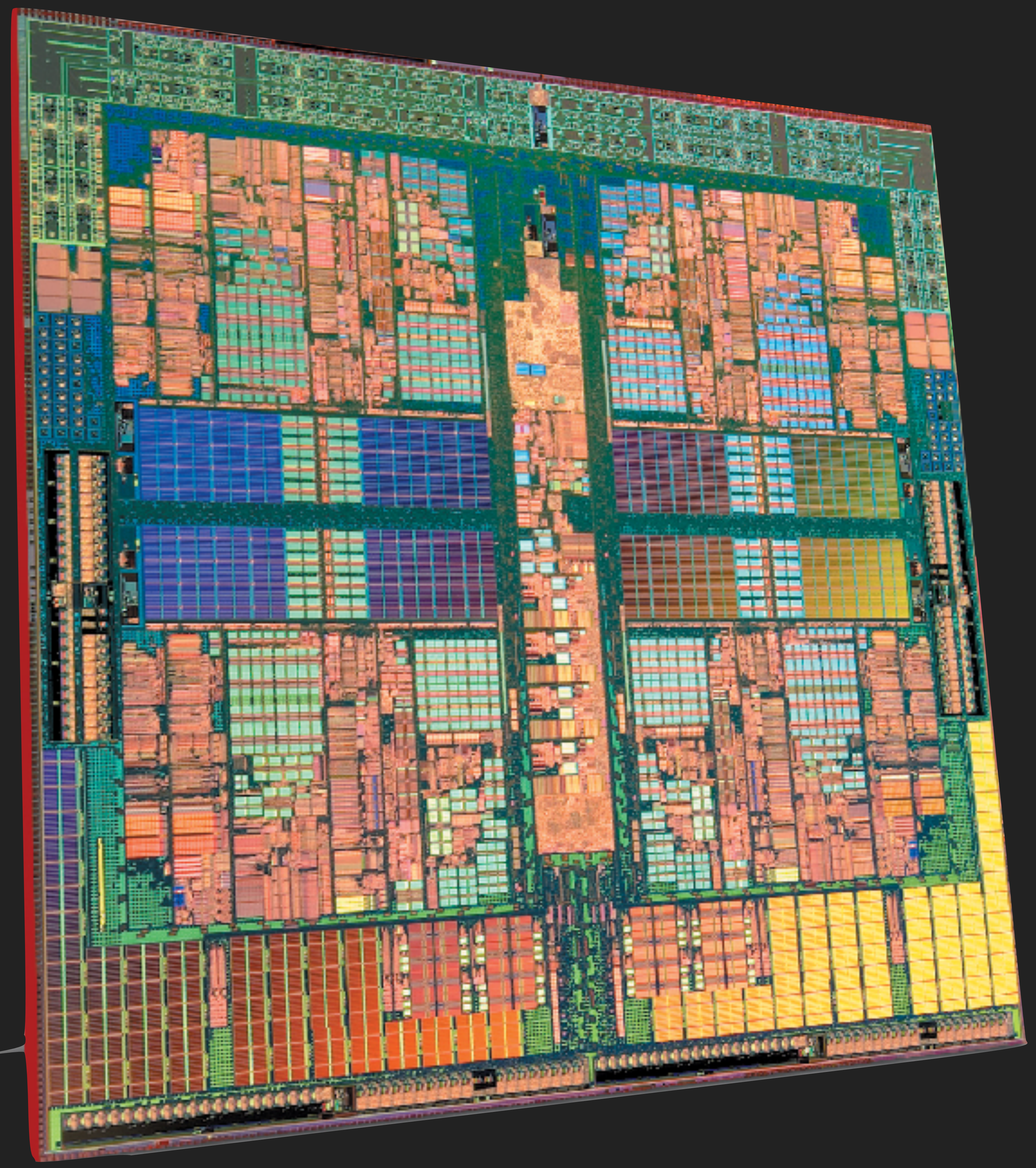
Some recent kinetic assignments





Humans move things

moving rocks



moving electrons

To get anything moving*, we need to exert a force.

Newton's second law:

Force = mass * acceleration

(F = ma)

so also

acceleration = force / mass

SI Units:

1 Newton force = 1 kg mass * 1 m/s/s acceleration

Note:

- "Lbs" or "pounds mass" is mass in English measure
- "Pounds force" is force in English measure

From google (you can type in equations and google handles the units):

(1 kg) * 1 ((meter / second) / second) = 1 newton

This leads to definitions for energy and work in physics:

Work is done when a force is applied through a distance. **Energy** is evidenced by the **capacity for doing work***. So:

Energy = force * distance

SI Units:

1 **Joule** *energy* = 1 Newton *force* * 1 Meter *distance*

(Since a newton is a unit of force, and F=ma, we can reduce this to:

1 joule = kg * 1 m / s / s * 1 m)

(1 newton) * 1 meter = 1 joule

((1 kg) * (1 (m^2))) / (1 (s^2)) = 1 joule

Power is the rate of work.

Power = Energy / Time

SI Units:

1 **Watt** power = 1 Joule energy / 1 second time

so also

1 Joule = 1 Watt * 1 second

(1 joule) / (1 second) = 1 watt

We can perform work against the force of gravity to store energy in the position of objects in a gravitational field.

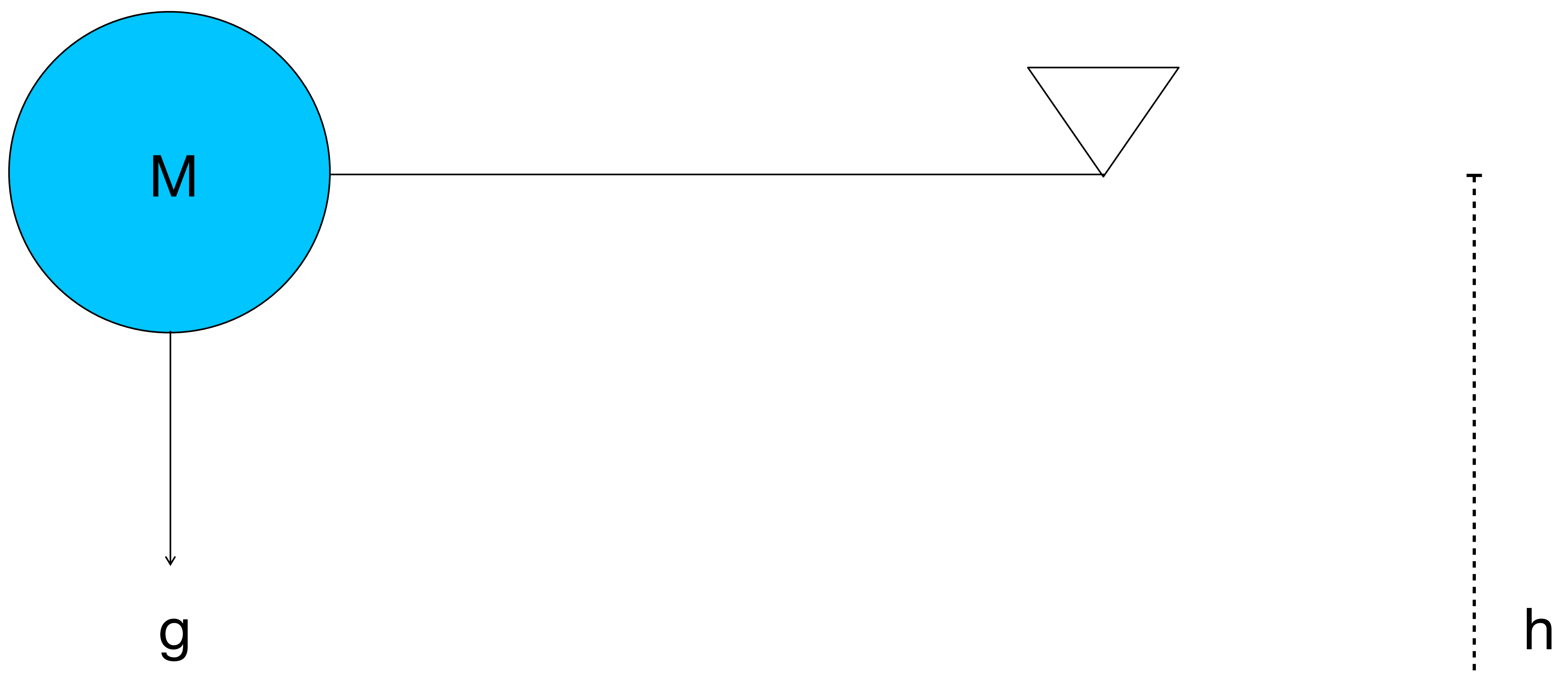
Gravitational Potential Energy = mgh

m = mass
g = gravitational acceleration = 9.8 m/s/s
h = height

Google Calculator handles units!

(1 kg) * (9.8 ((m / s) / s)) * (1 meter) = 9.8 joules

Note: 9.8 is pretty close to 10! Rounding makes the math easy.



$PE = mgh$

(9.8 is pretty close to 10...)

example: (10 kg) * (9.8 (m / (s^2))) * (1 m) =

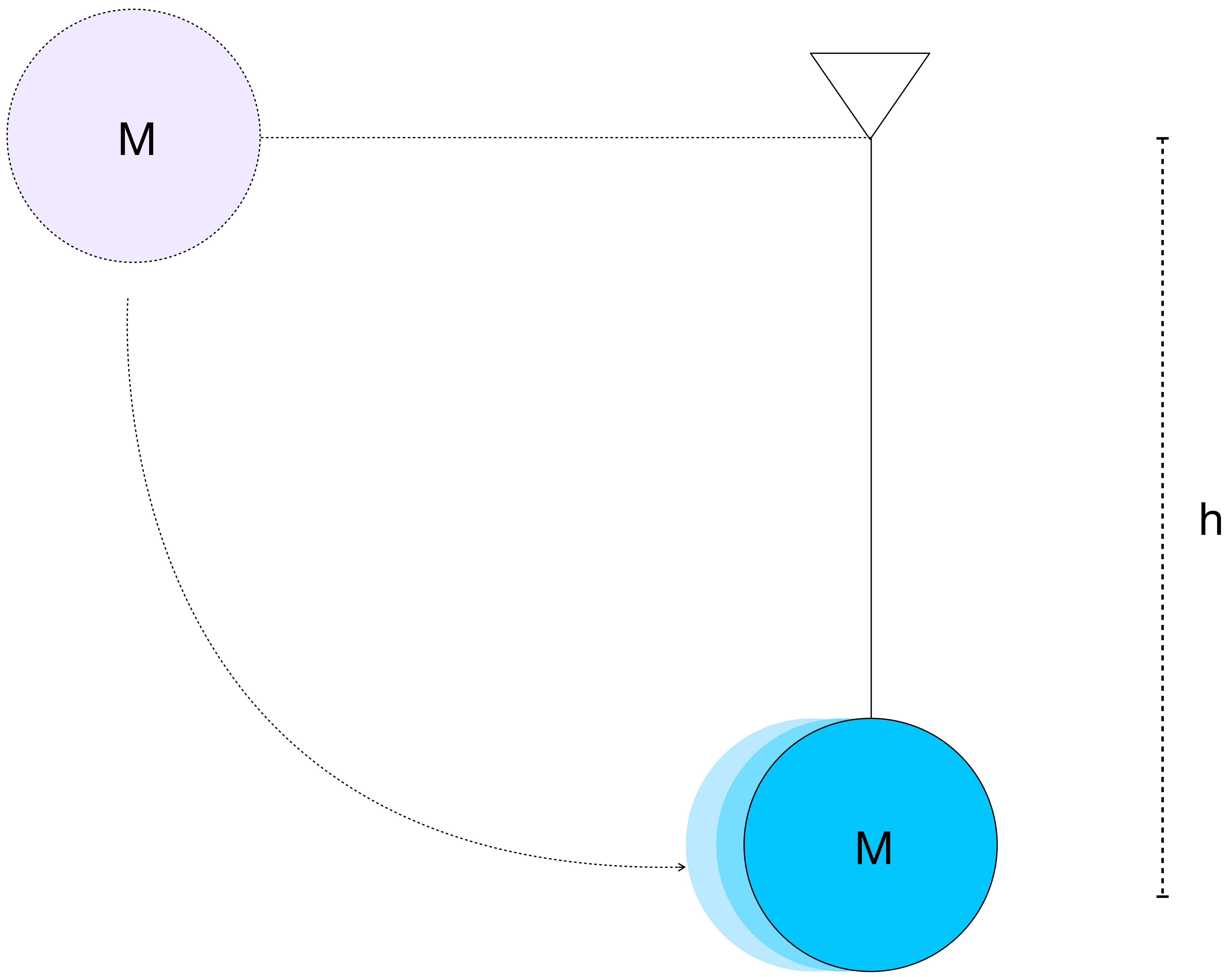
98 joules

Kinetic energy is the energy of objects in motion:

$$\text{Kinetic Energy} = \frac{1}{2} m v^2$$

m = mass in kg
v = velocity in meters/second

(1 / 2) * (1 kg) * ((1 (m / s))^2) = 0.5 joules



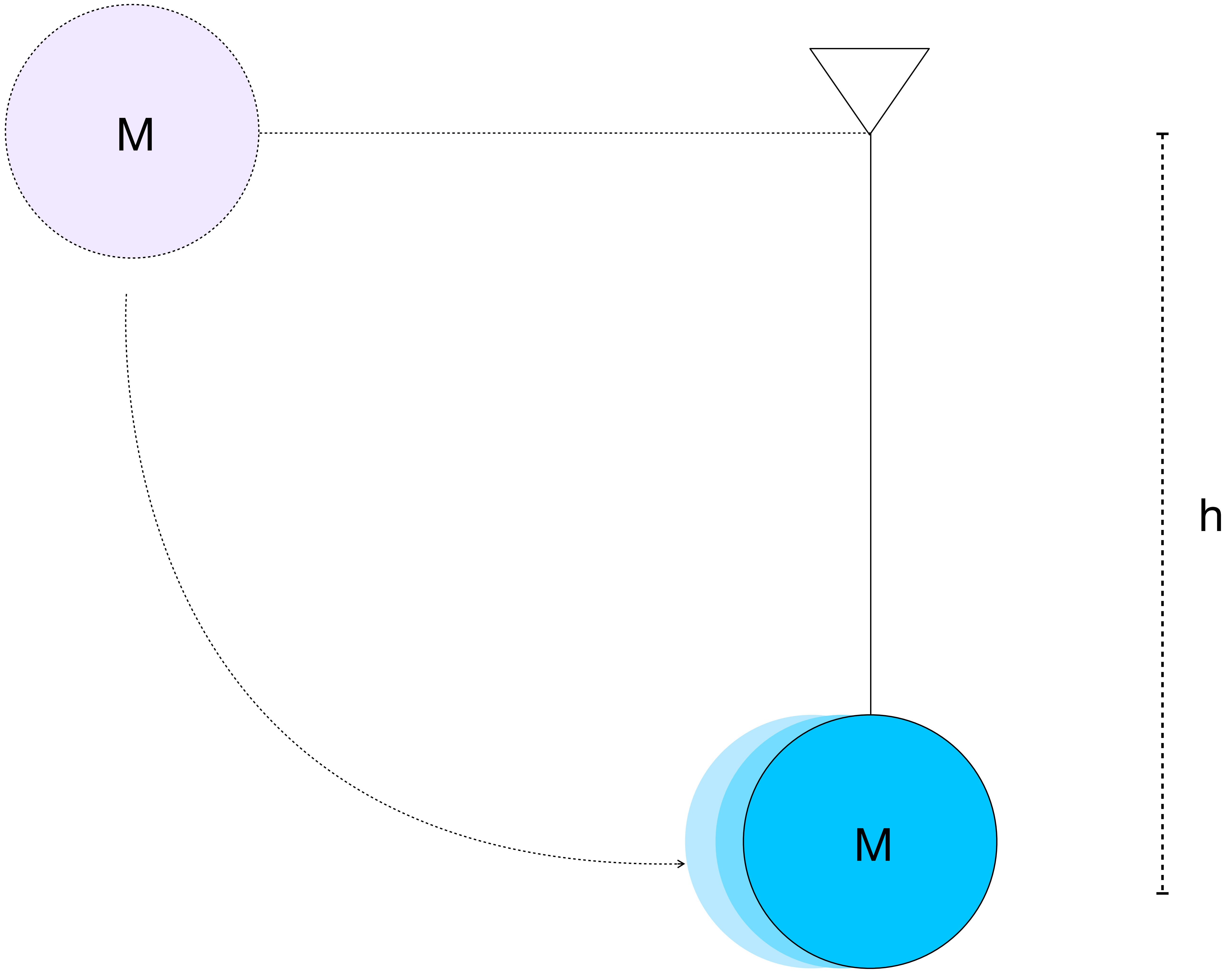
$$KE = \frac{1}{2} mv^2$$

Thermodynamics:

We can’t get work out of a system that isn’t in the system in the first place.

aka 1st law, “*Conservation of energy*”

aka “You can’t win”



On first swing, from 1st Law we can guess that:

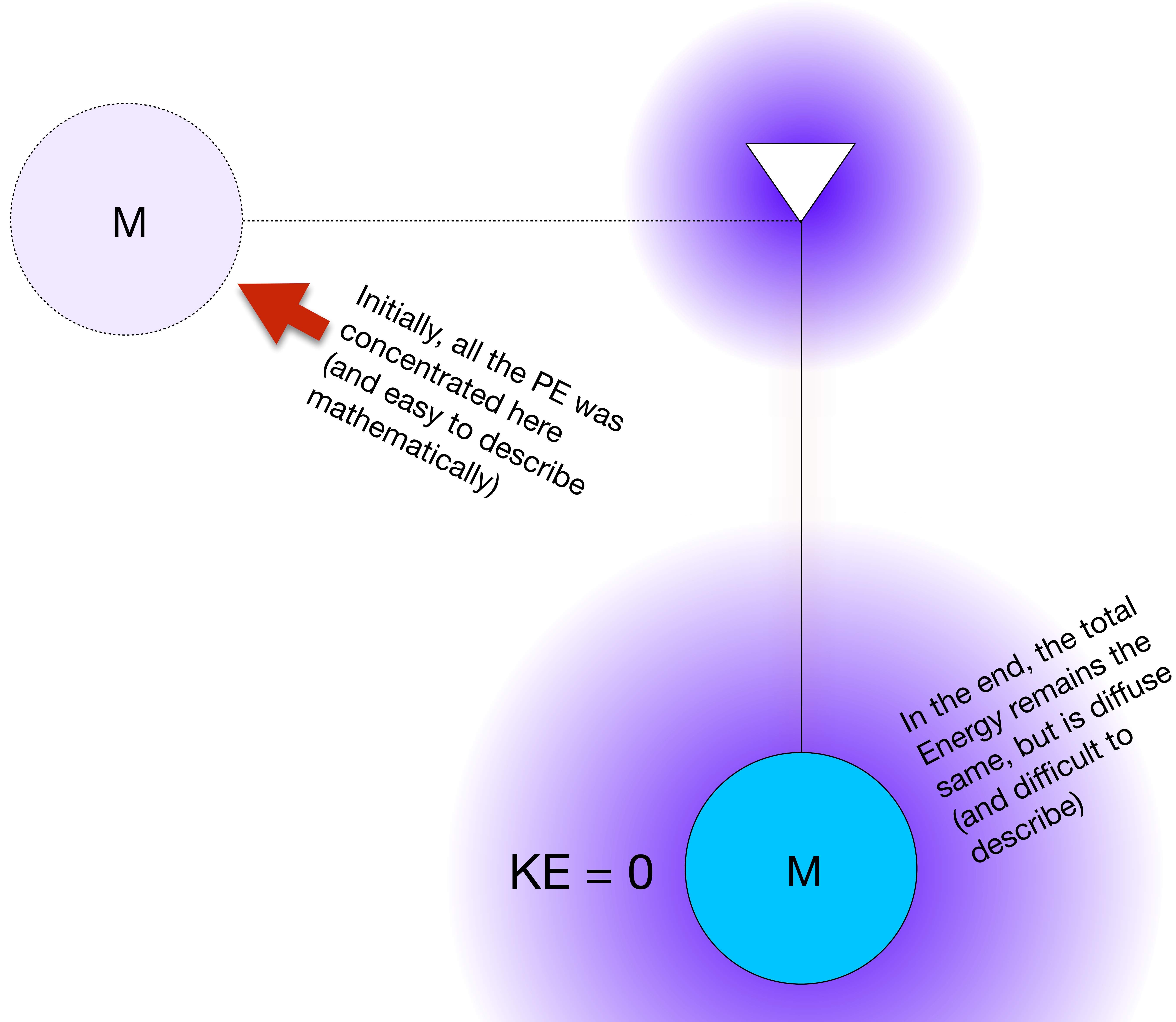
KE ~= PE (energy is conserved)

The 2nd law of thermodynamics:

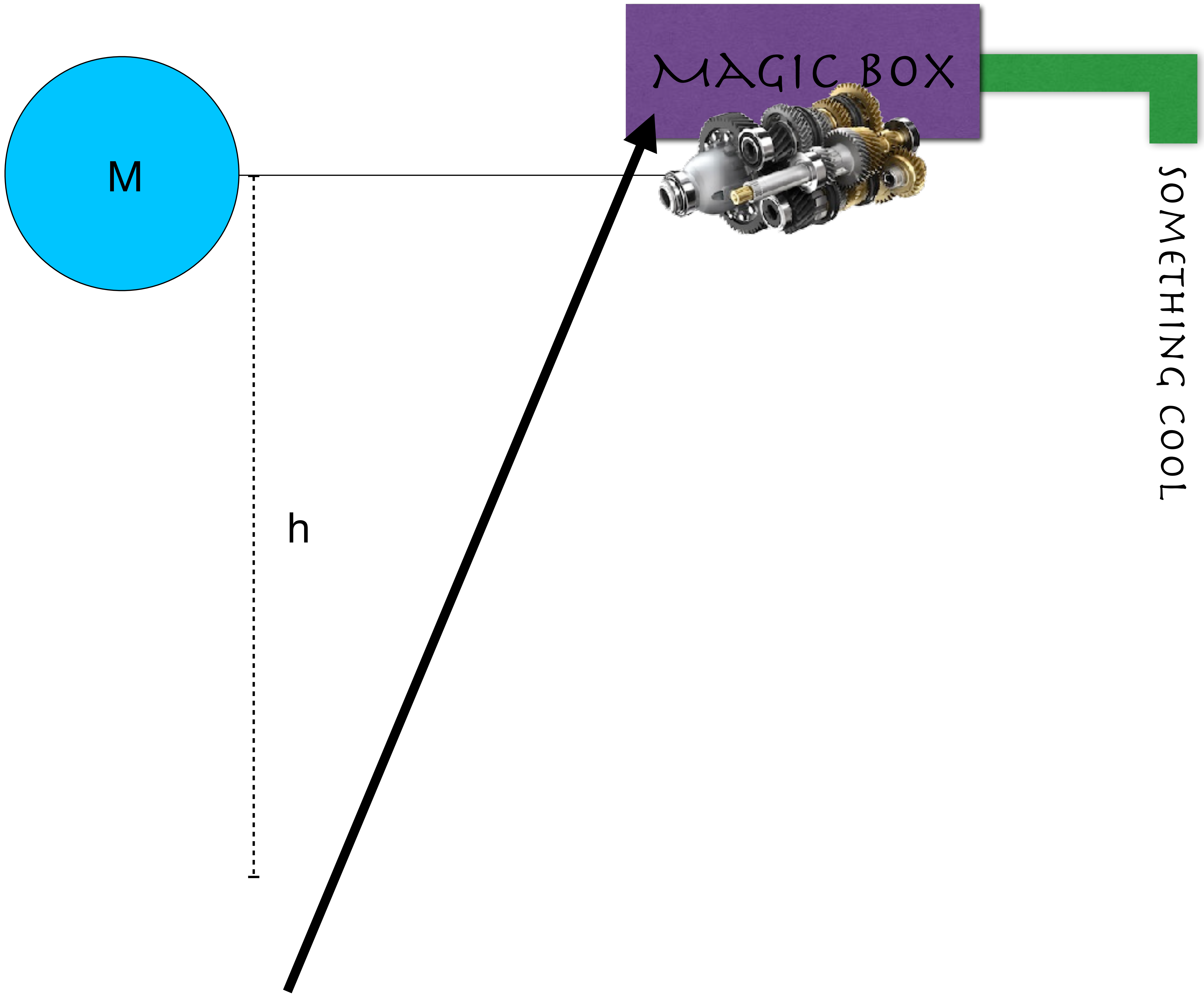
Not all of the energy in a system will be available to do the work we want.

aka 2nd law, “*Entropy increases over time*”

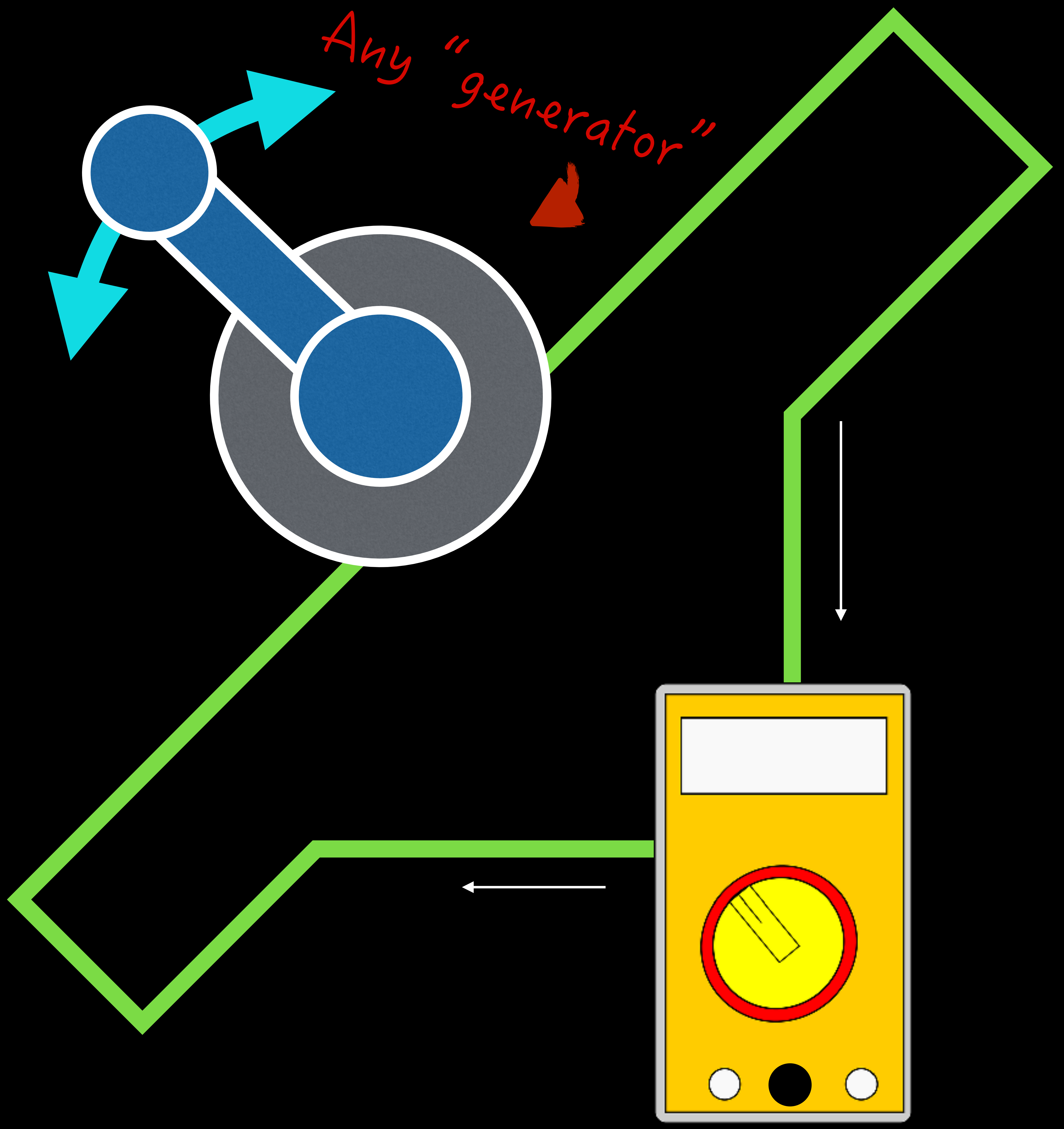
aka “You can’t break even”



At end, we note 1st and 2nd laws. All of the original PE is *somewhere* (heat, noise, etc.), but is *more diffuse and less useful* to us.



This machine can’t get do more work than initial energy input to the system (in this case, bound by PE = mgh).



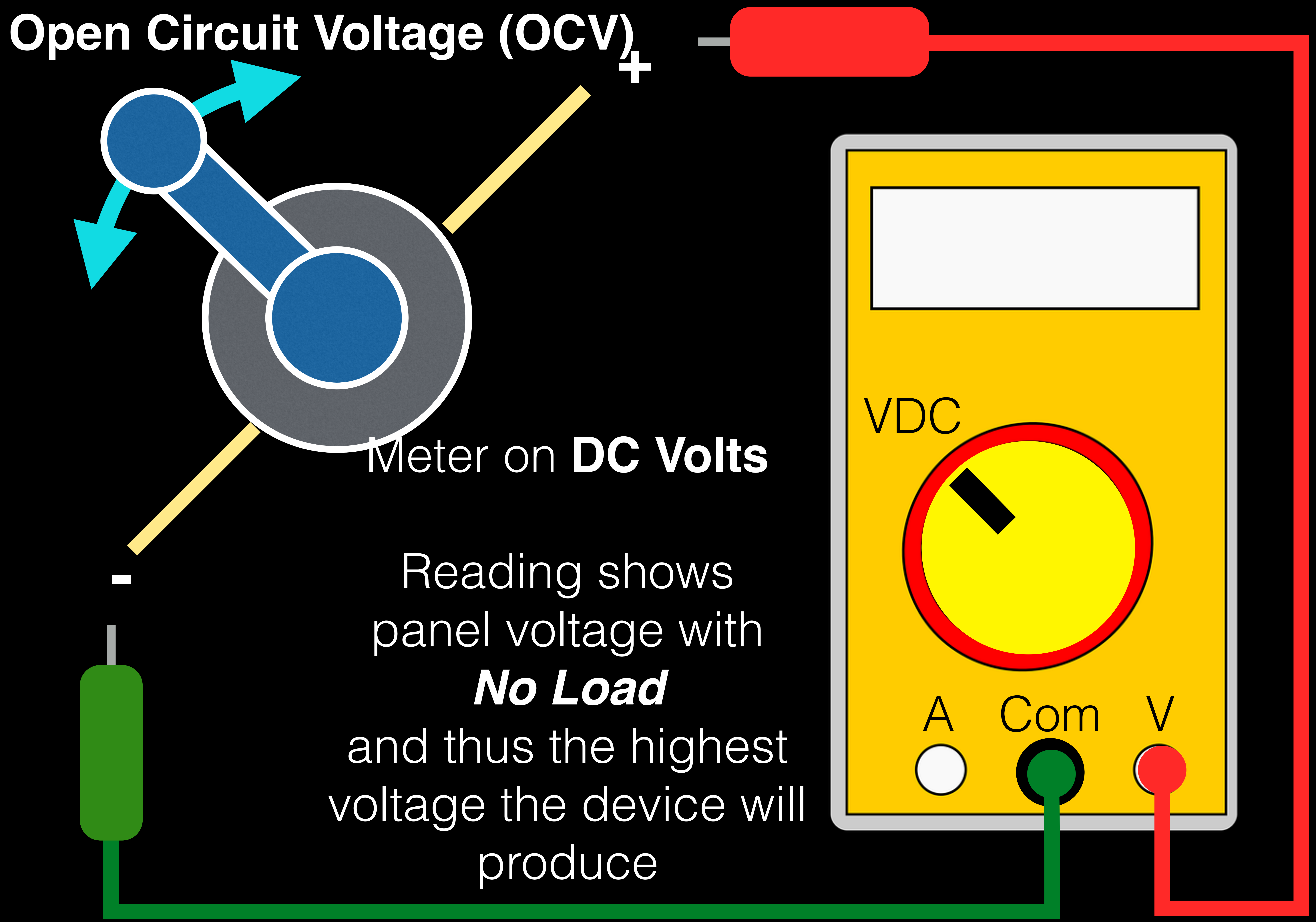
1W (electric) =
1V * 1A

We can measure

Open Circuit Voltage

and

Short Circuit Current


Open Circuit Voltage (OCV)
+
-
Meter on DC Volts
Reading shows panel voltage with
No Load
and thus the highest voltage the device will produce
VDC
A
Com
V

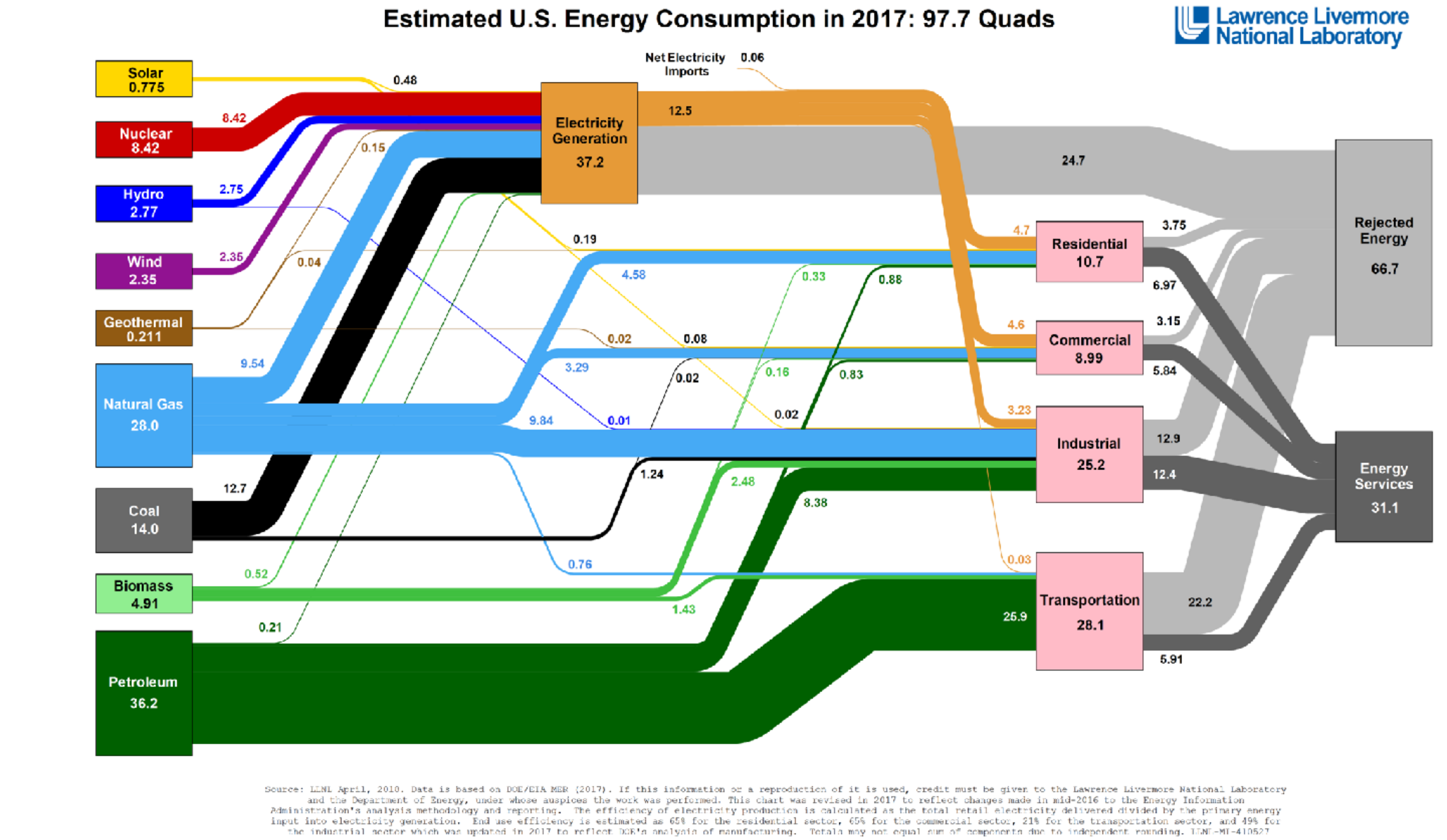

Short Circuit Current (SCC)
+
-
Meter on DC Amps
Reading shows current through no resistance (short circuit) and thus the highest current the device will produce
ADC
A
Com
V

Hands-on activity: Find magnets and coils and try to measure OCV and SCC. Then try lighting LEDs.

If small DC motor: Challenge is spinning fast enough, long enough, to measure. Improvise a mechanism (e.g. pull-cord wound around motor shaft), try using scope for voltage measurements.

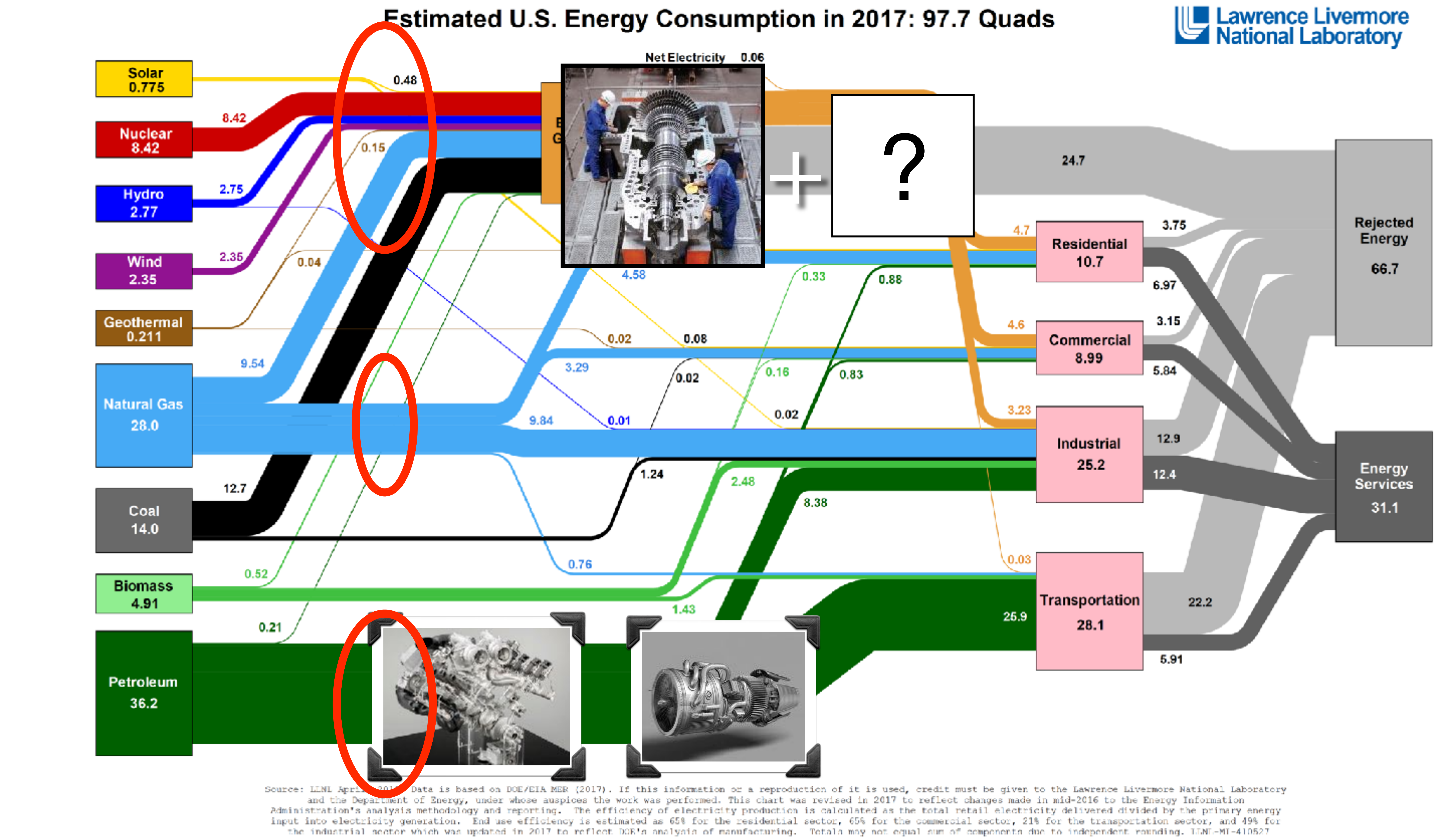
If DC gearmotor: Gearbox solves issue above, so this is the easiest. Create handle for shaft

If stepper motor: Output is AC. Find coil pairs. Measure with Meter set to AC Volts and AC current if it has that, or use scope to see voltage waveform.

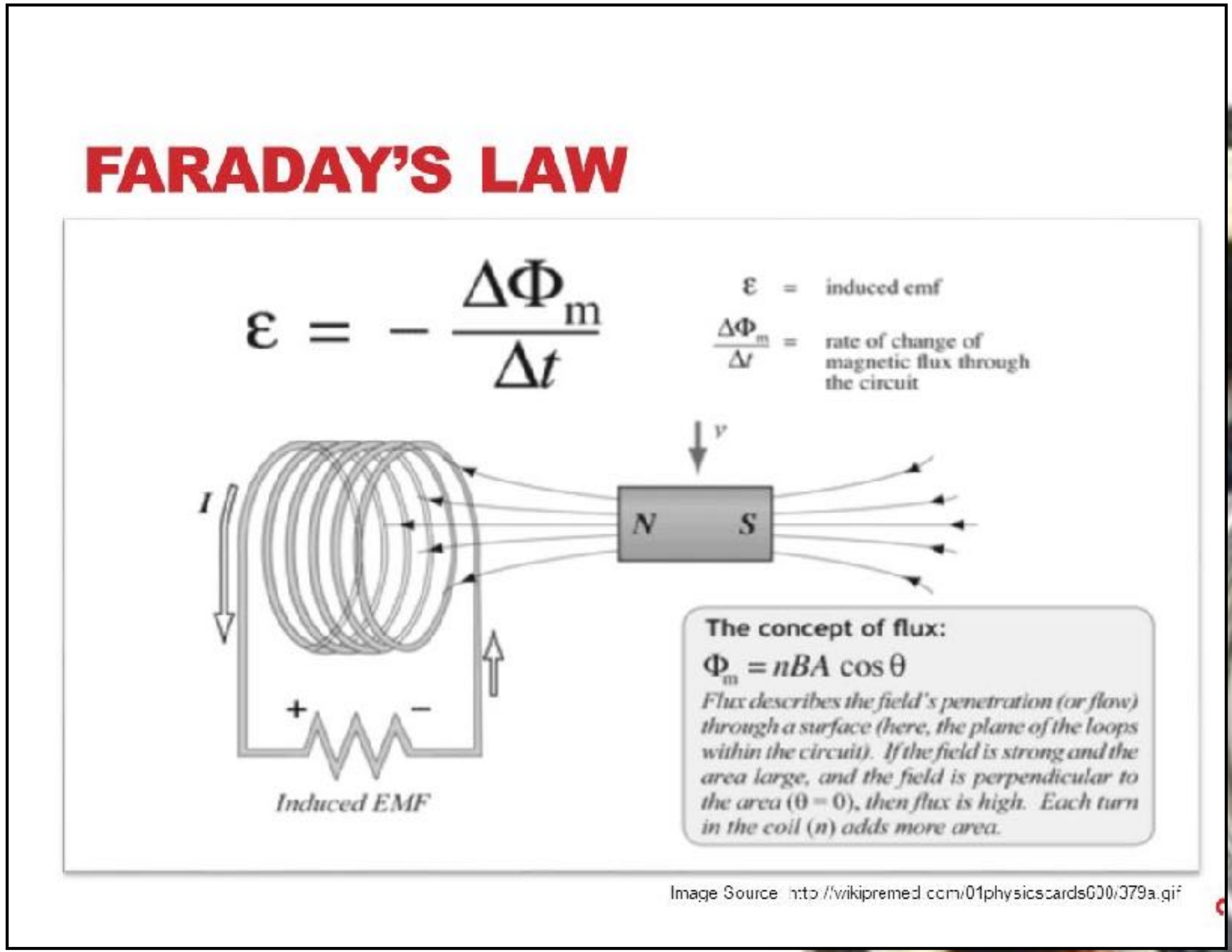


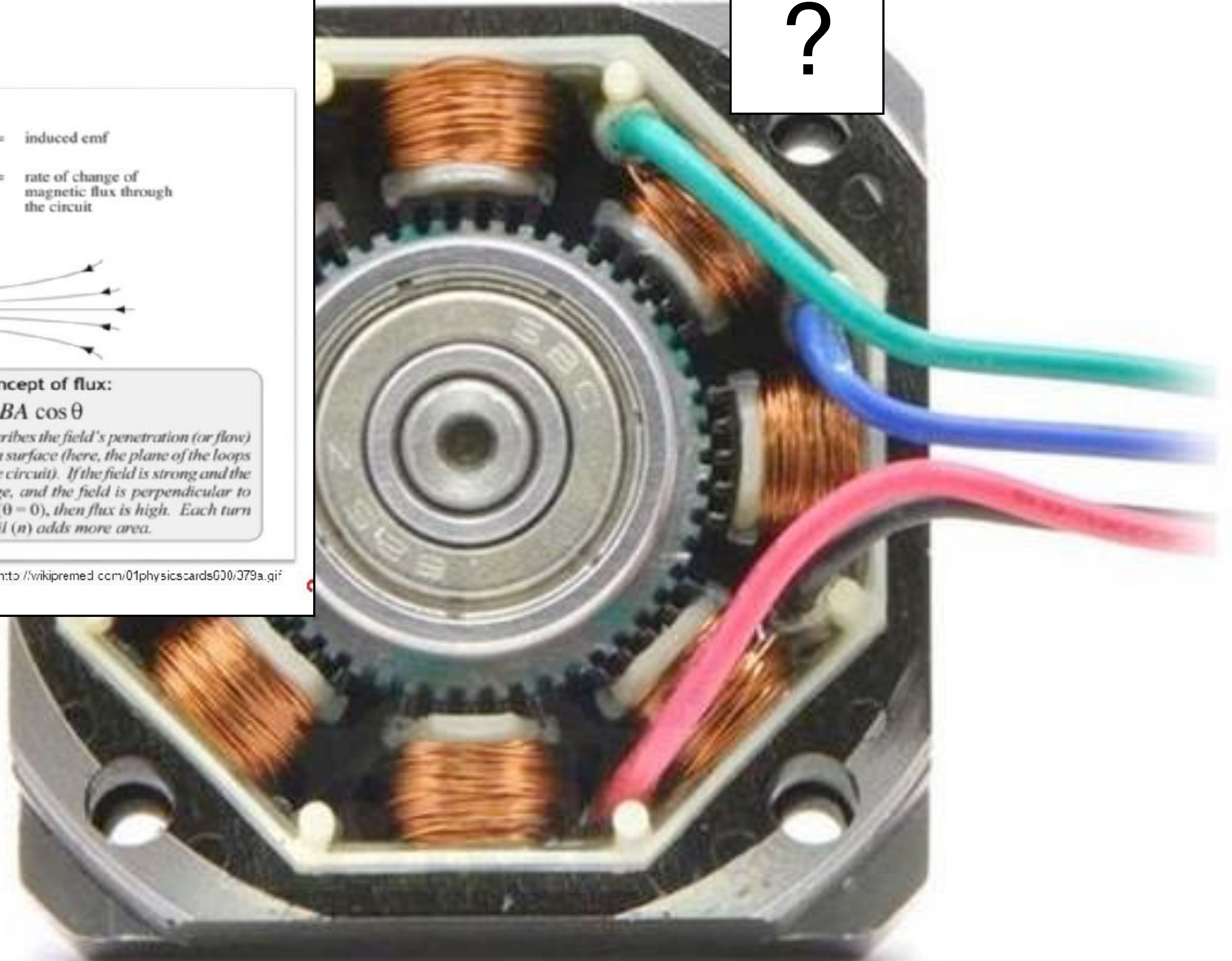
*for more on Rejected Energy, see

**for more on comparing energy quantities, see and



https://flowcharts.llnl.gov/archive.html





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http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/indcur.html