

Kinetic Energy

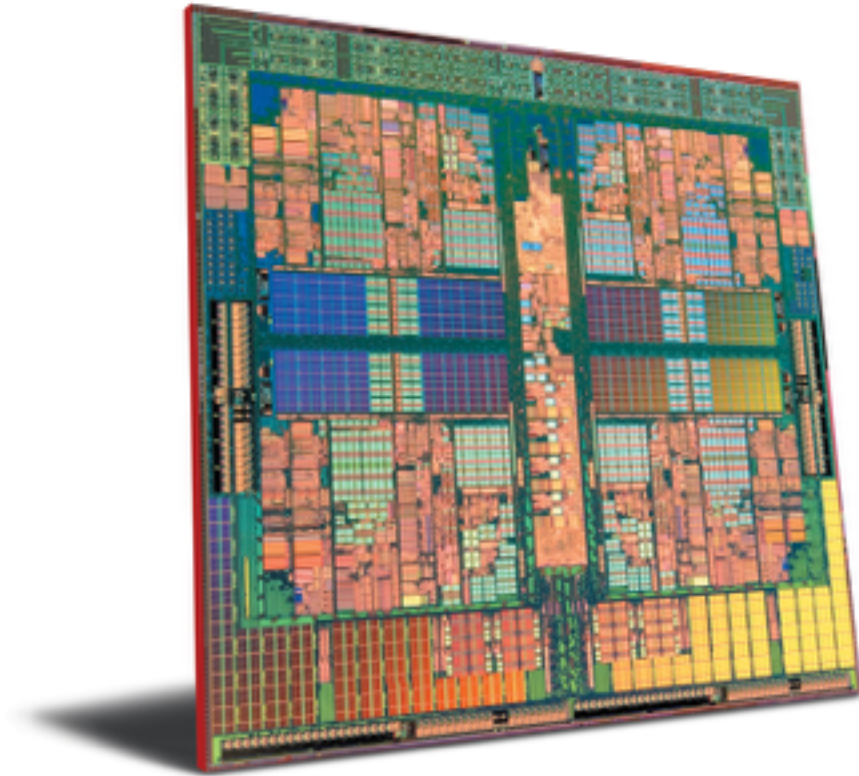
Energy

ITP / NYU / Feddersen

Humans move
things



moving rocks



moving electrons

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

Newton's second law:

$$\mathbf{Force = mass * acceleration}$$

$$\mathbf{(F = ma)}$$

so also

$$\mathbf{acceleration = force / mass}$$

SI Units:

$$1 \text{ Newton force} = 1 \text{ kg mass} * 1 \text{ m/s/s acceleration}$$

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):



$$(1 \text{ kg}) * 1 ((\text{meter} / \text{second}) / \text{second}) = 1 \text{ newton}$$

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:

$$\mathbf{Energy = force * distance}$$

SI Units:

$$1 \text{ **Joule** } \textit{energy} = 1 \text{ Newton } \textit{force} * 1 \text{ Meter } \textit{distance}$$

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

$$1 \text{ joule} = \text{kg} * 1 \text{ m} / \text{s} / \text{s} * 1 \text{ m})$$



$$(1 \text{ newton}) * 1 \text{ meter} = 1 \text{ joule}$$



$$((1 \text{ kg}) * (1 \text{ (m}^2\text{)})) / (1 \text{ (s}^2\text{)}) = 1 \text{ joule}$$

Power is the rate of work.

$$\mathbf{Power = Energy / Time}$$

SI Units:

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

so also

1 Joule = 1 Watt * 1 second



$$(1 \text{ joule}) / (1 \text{ second}) = 1 \text{ watt}$$

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

$$\text{Gravitational Potential Energy} = mgh$$

m = mass

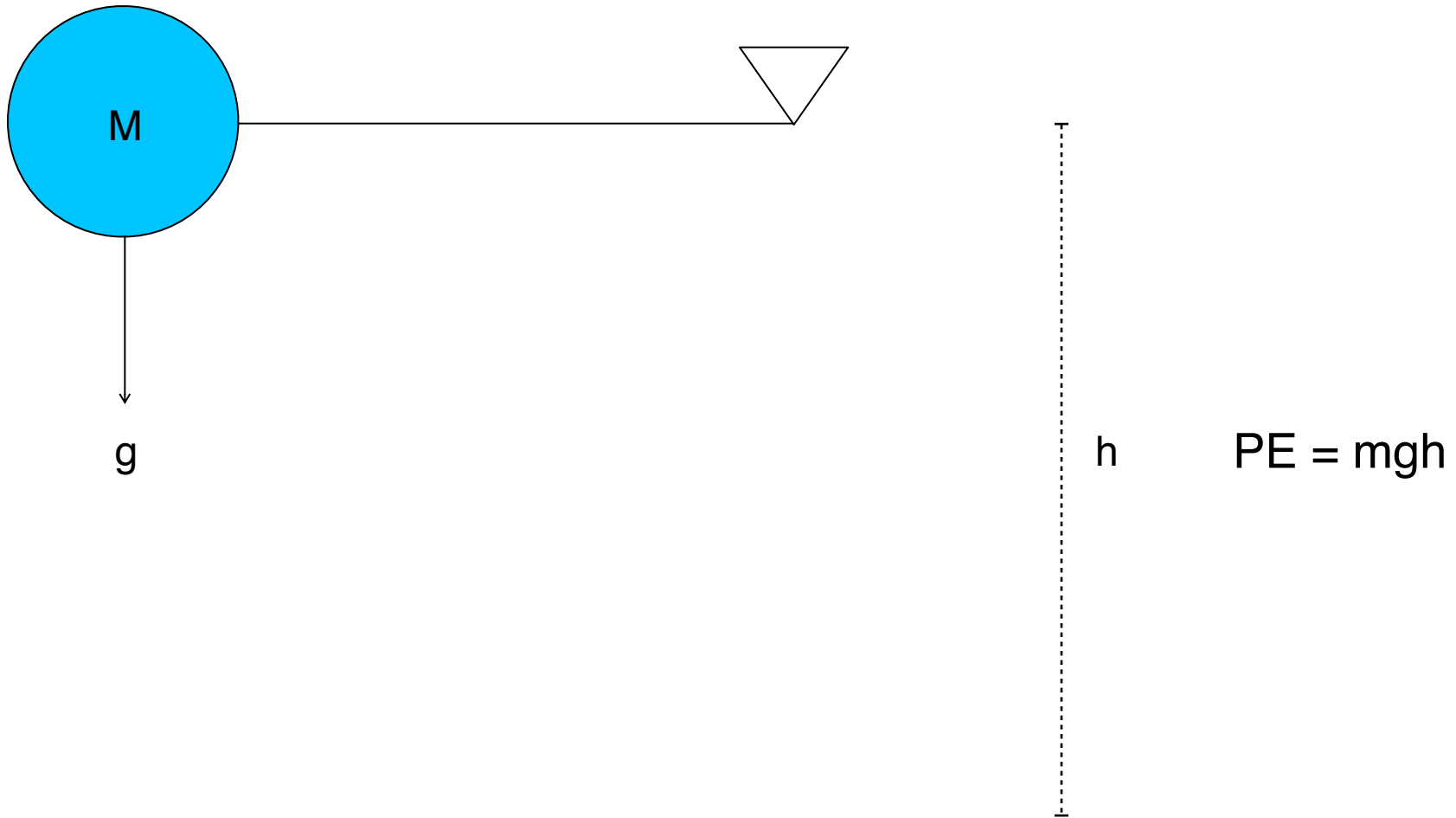
g = gravitational acceleration = 9.8 m/s/s

h = height



$$(1 \text{ kg}) * (9.8 \text{ ((m / s) / s)}) * (1 \text{ meter}) = 9.8 \text{ joules}$$

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



example: $(10 \text{ kg}) * (9.8 \text{ (m / (s^2))}) * (1 \text{ m}) =$
98 joules

Kinetic energy is the energy of objects in motion:

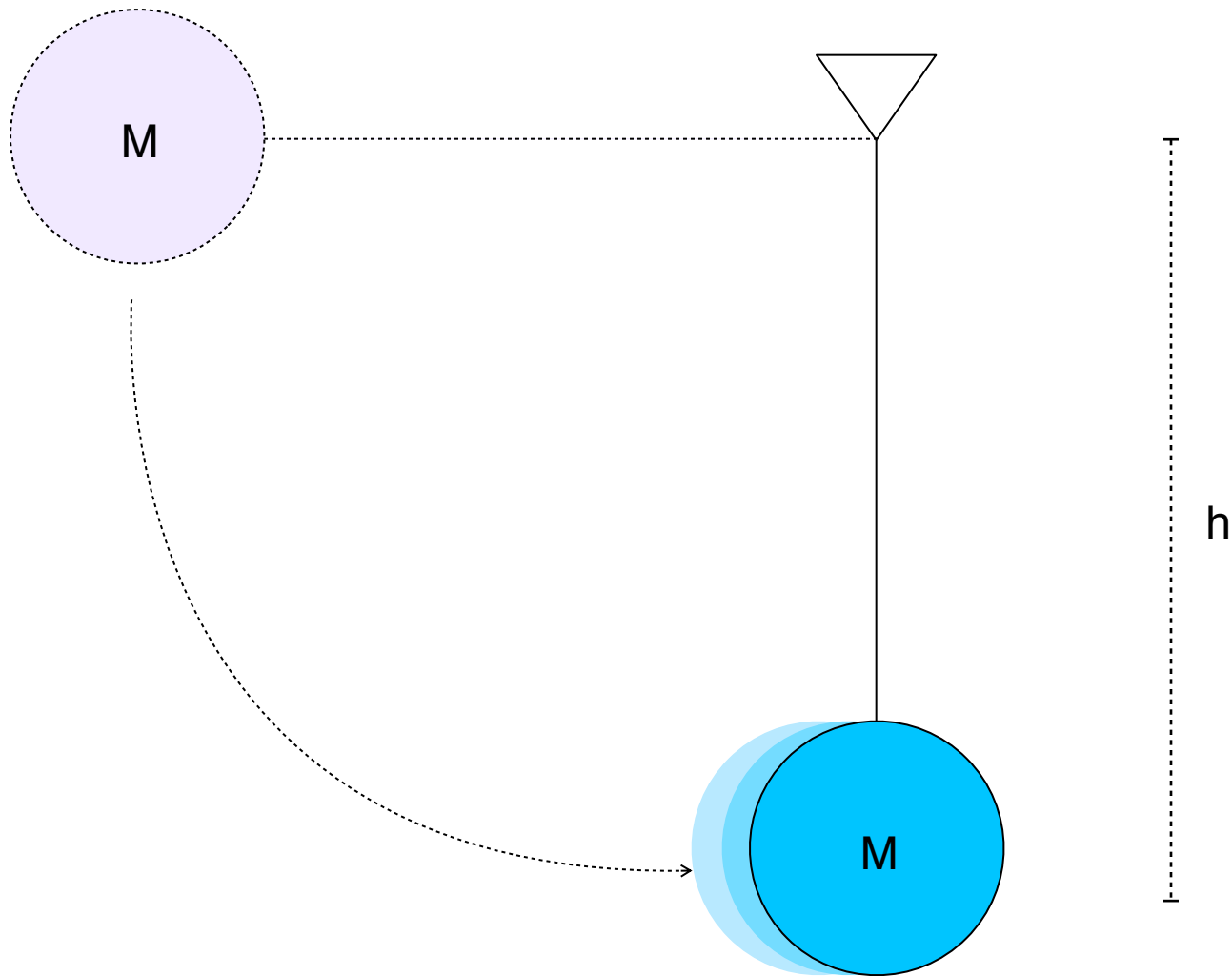
$$\text{Kinetic Energy} = \frac{1}{2} mv^2$$

m = mass in kg

v = velocity in meters/second



$$(1 / 2) * (1 \text{ kg}) * ((1 \text{ (m / s)})^2) = 0.5 \text{ joules}$$

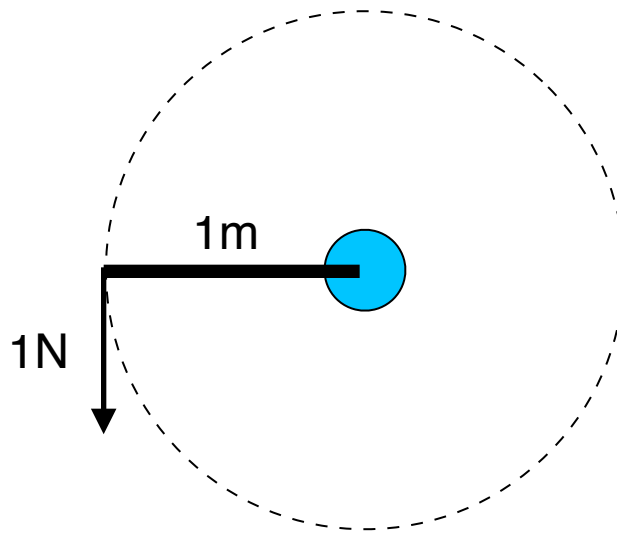


$$KE = \frac{1}{2} mv^2$$

Rotational Work

Same as linear work, but the force is traveling in a circle.

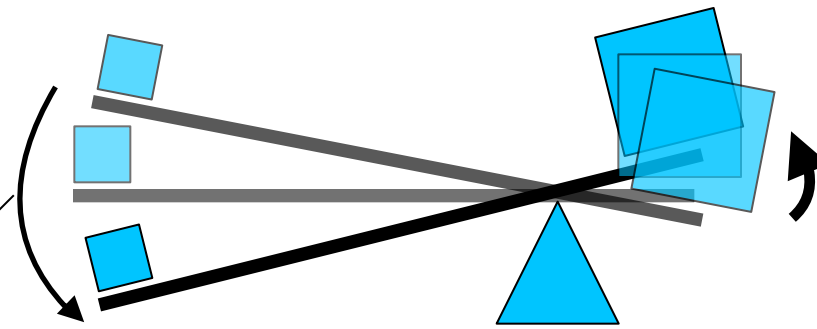
So 1 Newton force applied to a 1 meter lever pushed through 360 degrees = 6.28 Joules work (The force moves through the circumference of the circle = 2 pi meters)



$$(1 \text{ newton}) * 1 \text{ meter} * (360 \text{ degrees}) = 6.28318531 \text{ joules}$$

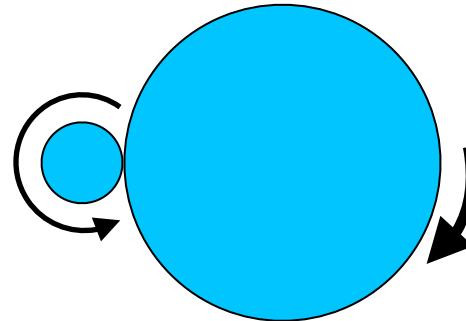
Mechanics

Levers, gears, and other mechanisms let us **trade off distance and force** to best suit an application.



Smaller force through
greater distance/more rotations

Larger force through
smaller distance / less rotations

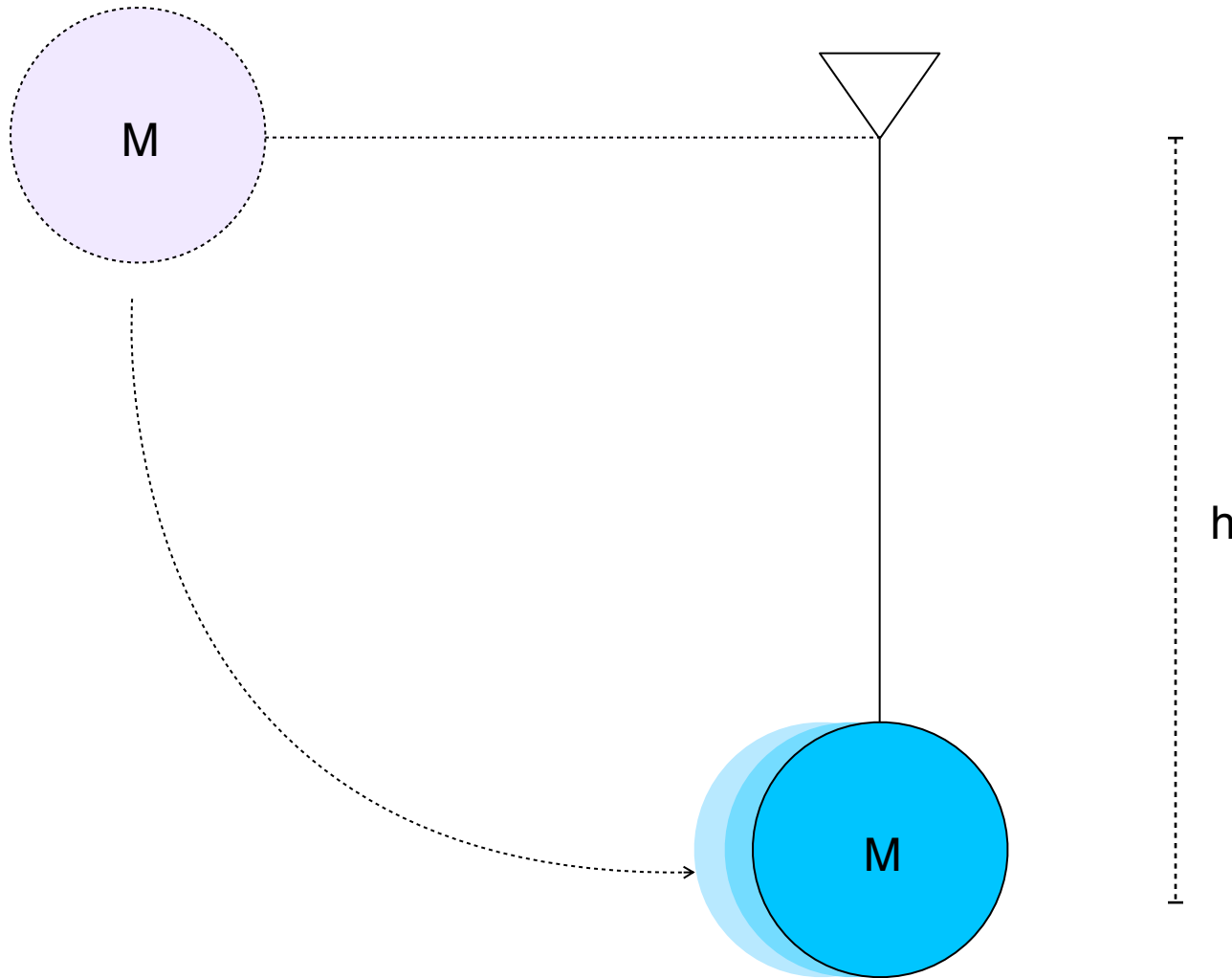


Thermodynamics:

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:

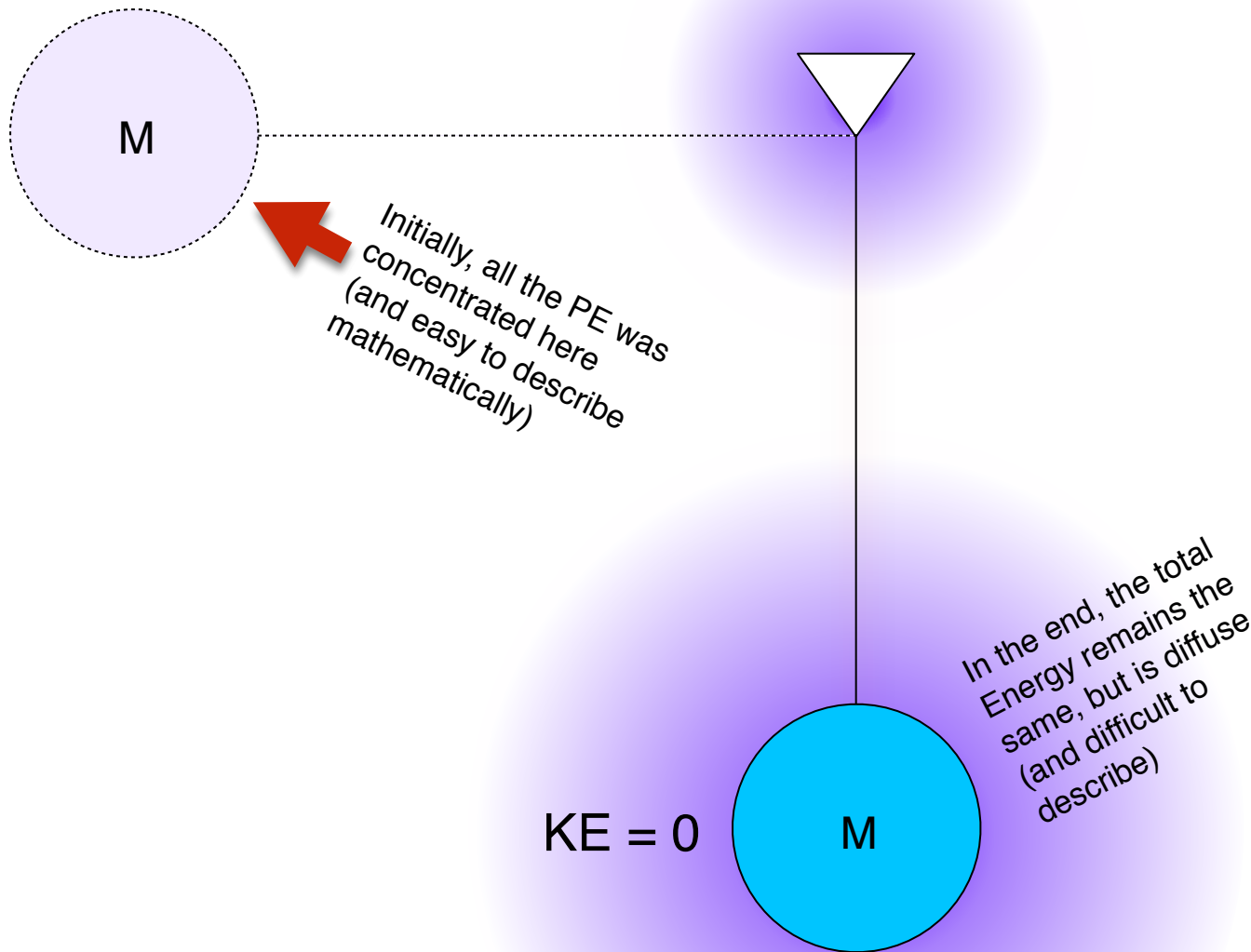
$KE \approx PE$ (energy is conserved)

The 2nd law of thermodynamics:

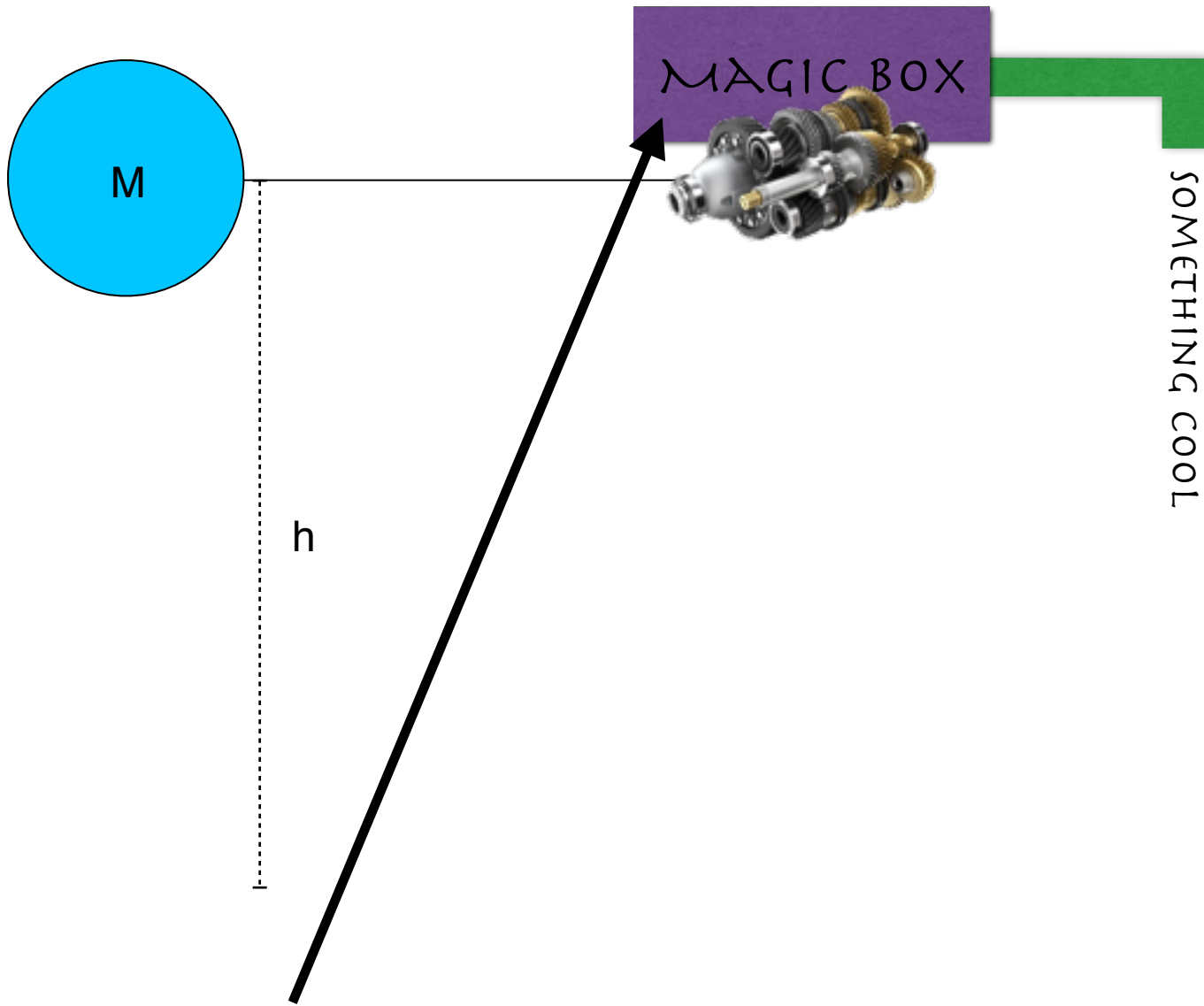
Not all of the energy in a system will be available to do
the work we want.

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 $PE = mgh$).

Always remember:

$$\text{Power (watts)} = \text{Energy (joules)} / \text{time (seconds)}$$

Energy is a quantity. Power is a rate.

Technical take away:

We can make estimates of energy in systems (potential energy, kinetic energy) if we know mass, force, velocity, etc.

We can use these estimates to form maximum outside bounds as to the useful work we could get from a system.