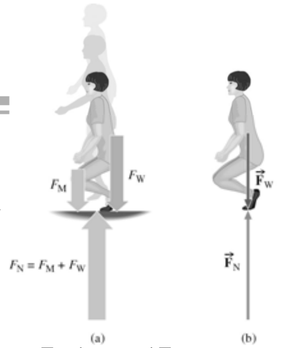
Jumping

- Walking and Running involves pushing on the ground to make the ground push back on you - accelerating you forward (and stopping you)
- To jump up (to accelerate upwards), there must be a net upward force on the person.
- Where does it come from?

Jumping

- Use Newton's third law - if you push down on the floor it will push up on you
- Push hard enough and the upward force will exceed your weight.



Only two forces act *on the jumper* - $\mathbf{F}_W$ down and $\mathbf{F}_N$ up
The harder you push *down* - the bigger net *upward* force on the jumper - the bigger net *upward* acceleration of the jumper

Energy and Work

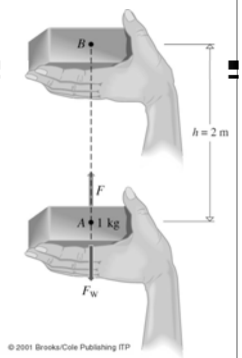
- There is another way to think about jumping - as a change in <u>**Energy**</u>
- Energy derives from the Greek words *en* (meaning *in*) and *ergon* (meaning *work*). *Energy is the capacity to do work.*
- But what does *work* mean?
- In physics, *work is the change in energy resulting from the application of a force to an object as the object moves through a distance*.

$$W = Fd$$

Work

- In lifting an object, your hand is doing work to lift the object "against gravity"
- Say you lift with a constant velocity (i.e. acceleration = 0), then the upward force **F** = weight ($\mathbf{F}_W$) = mg
- The work done by your hand to raise an object a height *h* "against gravity" is

$$W = Fd$$
$$= (mg)h$$



Energy

- The SI unit of work (and energy) is the newton-meter, known as the Joule (J)
- How much energy?
  - Supernova explosion 10^{44} J
  - Earth moving in orbit 10^{33} J
  - Earth's annual sunshine 10^{25} J
  - Severe earthquake 10^{18} J
  - Hiroshima atomic bomb 10^{14} J
  - Running for an hour 10^{6} J
  - Hard-hit cricket ball 10^{3} J
  - Human heartbeat 0.5 J
  - Hopping flea 10^{-7} J
  - Photon of light 10^{-19} J

Kinetic Energy

- Under the influence of a net force, a body accelerates as work is done on it. It increases its speed and gains energy.
- Energy associated with motion is called <u>**Kinetic Energy**</u> (KE)

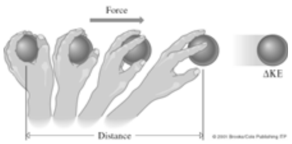
$$KE = \frac{1}{2}mv^2$$

- Example:
  - A Boeing 747 weighing 2.2 million N at take-off cruises at 960 km/h. What is its KE ?
  - Mass ~ 224,000 kg, speed ~ 267 m/s

$$KE = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(224{,}000\ kg)(267\ m/s)^2$$
$$= 8 \times 10^9\ J$$

Kinetic Energy

- Your arm can do work on a cricket ball and increase the ball's KE. It travels some distance and then crashes into the stumps, doing work on them and losing a corresponding amount of KE.
- The ball transports energy in the form of KE from one place to another



Gravitational Potential Energy

- An object lifted against gravity still experiences the downward force of gravity when it is held up, but at rest. When no longer held up, it will obviously fall.
- Energy will appear as KE as it falls, but what's happening while the object is held motionless in the air?
- Apparently it is possible to do work on a system when lifting it and not have it appear as KE.
- Energy is stored, waiting to be let loose.

Gravitational Potential Energy

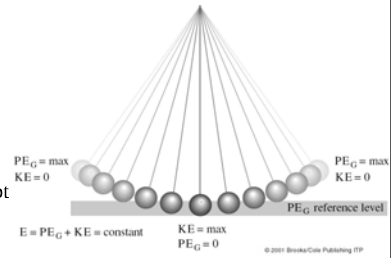
- This retrievable stored energy is called **Gravitational Potential Energy** (PE or sometimes GPE)
- We have already calculated the work done in lifting an object a height h "against gravity" $W = Fd$

$$= (mg)h$$

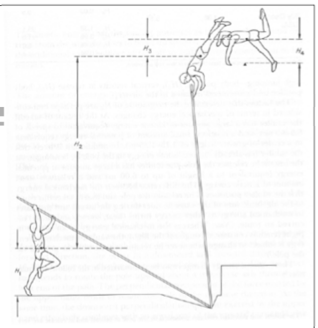
- So Gravitational PE is $GPE = mgh$

Mechanical Energy

- ***Mechanical Energy*** of a system is the sum of KE and gravitational GPE of all its parts.
- If no additional forces (except gravity) are applied to a system, *mechanical energy is conserved*.
- This is a limited case of the more general concept of conservation of all forms of energy.



Jumping



- How can pole vaulters jump so high?
- The pole provides a means of transforming almost all the jumper's initial KE from his run-up, into gravitational PE - i.e. into height.
- Once the jumper is off the ground, his run-up KE is converted into both gravitational PE and elastic PE of the pole. As the pole straightens again it gives up its elastic PE and hurls him even higher.

Summary

- Energy and Work and very closely related concepts.
- Work is a change in energy resulting from the application of a force
- Kinetic Energy (KE) $KE = \frac{1}{2}mv^2$
- Gravitational Potential Energy (GPE) $GPE = mgh$
- If no additional forces are applied to a system, mechanical energy (KE + GPE) is conserved.