Remember 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 and you will accelerate upwards.

Energy and Work

- There is another way to think about jumping - as a change in energy
- 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 (\( F_w = mg \))
- 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’s annual sunshine \( 10^{25} \) J
  - Severe earthquake \( 10^{18} \) J
  - Hiroshima atomic bomb \( 10^{18} \) J
  - Recommended intake/day \( 10^7 \) J
  - Hard-hit cricket ball \( 10^3 \) J
  - Human heartbeat \( 0.5 \) J
  - Hopping flea \( 10^{-7} \) J
  - Photon of light \( 10^{-19} \) J

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 motion 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 ‘visible’
- 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 \( GPE = mgh \)
**Kinetic Energy**

- When you release it, an object falls - accelerates downward.
- 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 **Kinetic Energy** \( KE = \frac{1}{2}mv^2 \).

**Example:**
- A Boeing 747 weighing 2.2 million N at take-off cruises at 960 km/h. What is its KE?
  - Mass \( m = 224,000 \text{ kg} \), speed \( v = 267 \text{ m/s} \)
  - \( KE = \frac{1}{2} \times 224,000 \text{ kg} \times (267 \text{ m/s})^2 \)
  - \( = 8 \times 10^9 \text{ J} \)

**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.

**Energy content of food**

- Food is your day-to-day source of energy, so the energy content is expressed in energy units
  - In Australia - kilojoules (kJ)
  - Elsewhere - kilocalories (kcal) = Calories (very confusing)
    - (1 Calorie = 4.1868 kJ)
- You could determine the total energy content of a product by burning the dried food, but this will be more than the energy than can be extracted by the body - instead use standard conversion tables in kJ/g (an odd mix of units!) - e.g.
  - Fat 37 kJ/g, carbohydrates 17 kJ/g
- Average person’s energy requirements - 8-10 MJ/day

**Summary**

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