Chapter 9

Work and energy

Work

- What is work?
- To a scientist work is done when changing motion
- Work is force applied multiplied by the distance the force acts
- W = Force x Distance
- W = F x d
- Only if the force and the direction are the same

Work

- When an Olympic weight lifter presses a barbell over his head
- He is doing work
- he must hold it there until the judges say he can put it down
- He is not doing work
- Big force but no distance

Units of work

- W = F x d
- Netwons x meters = N·m
- Or kg·m/s
- Or Joules = J
- An apple weighs about 1 N
- Lift it one meter
- That is 1 N·m of work or 1 J of work

Calculating Work

- Use the equation W = F x d
- How much work does it take to lift a 200 N weight 2 m off the floor?
- How much work does it take to hold a 200 N weight 2 m off the floor?
- How much work is done if you drop a 2.5 N book 3 meters?
- What does the work?

Power

- Running up stairs is harder than walking up stairs
- Why? They both do the same amount of work.
- Running does the same work more quickly
- Power is the rate at which work is done.
- $\text{Power} = \frac{\text{Work}}{\text{Time}}$

Power

- Measured in units called watts (W)
- 1 watt is the power to do 1 J of work in 1 s
- $W = \frac{J.}{s}$
- A student lifts a 12 N textbook 1.5m of the floor in 1.5 s. How much work did he do?
- How much power did he use?

Power

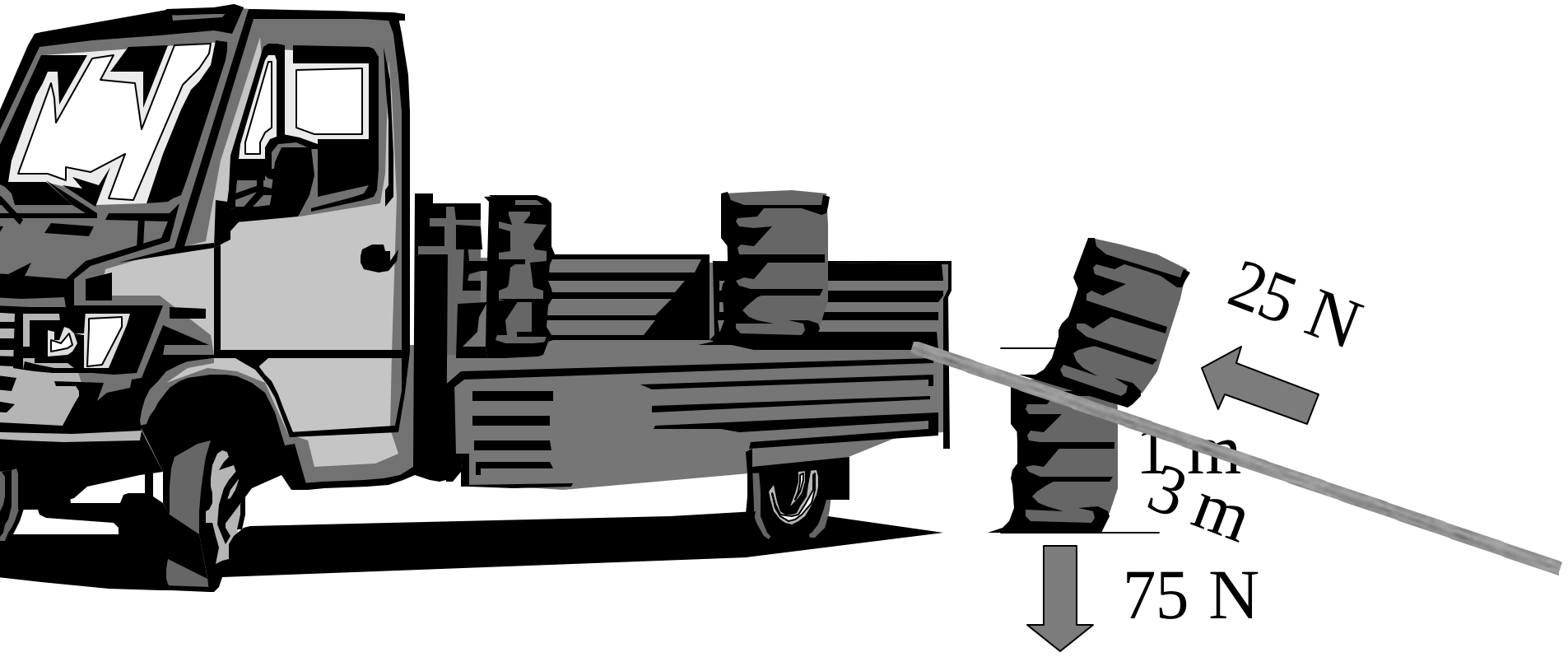
- A 43 N force is exerted through 2.0 m distance for 3.0 s. How much work was done?
- How much power was used?

Machine

- Machines make work easier.
- They multiply force or change its direction
- They multiply force by using a small force to go a long distance
- Things like ramps, levers, etc.

$$W = 75\ N \times 1\ m = 75\ J$$

$$W = 25\ N \times 3\ m = 75\ J$$



Mechanical Advantage

- How many time a machine multiplies the input force
- Mechanical Advantage = $\frac{\text{output force}}{\text{input force}}$
- Mechanical Advantage = $\frac{\text{input distance}}{\text{output distance}}$
- Mechanical advantage greater than 1 multiples force
- Less than 1 it multiples distance, less force

Energy

- Energy is the ability to do work
- Whenever you do work you transfer energy from one thing to another
- It can only be observed when it is transferred
- Measured in the same units as work- joules

Potential energy

- Stored energy
- Energy of position
- Stretched rubber band
- Gravitational potential energy – any time gravity supplies the force
- Most often because it is raised off the ground.

Gravitational Potential Energy

- Depends on mass and height
- PE = m x g x h
- m is mass in kilograms
- g is acceleration caused by gravity
- h is distance it can fall in meters.
- Remember mg is weight in N so mgh is force times distance.

Calculating PE

- A 100 kg boulder is on the edge of the cliff 10 m off the ground. How much energy does it have?
- A 0.5 kg ball is thrown 15 m into the air How much potential energy does it have at its highest point?

Kinetic Energy

- The energy of motion
- Depends on two things
- Mass and velocity
- Twice the mass, twice the kinetic energy
- Twice the velocity four times the kinetic energy
- $KE = \frac{1}{2} mv^2$

Calculating Kinetic Energy

- $KE = \frac{1}{2} mv^2$
- What is the kinetic energy of a 100 kg man moving 5 m/s?
- What is the kinetic energy of 0.5 kg ball moving at 30 m/s?

Mechanical Energy

- The sum of the potential and kinetic energy.
- Before an apple falls it has all potential energy
- Just before it hits the ground it has all kinetic energy
- In between it has some potential energy, and some kinetic energy

Other forms of energy

- Chemical energy – stored in the bonds between atoms
- Reactions release or absorb energy
- Temperature – measures the kinetic energy of the particles
- Heat – the total kinetic energy of the particles of a substance

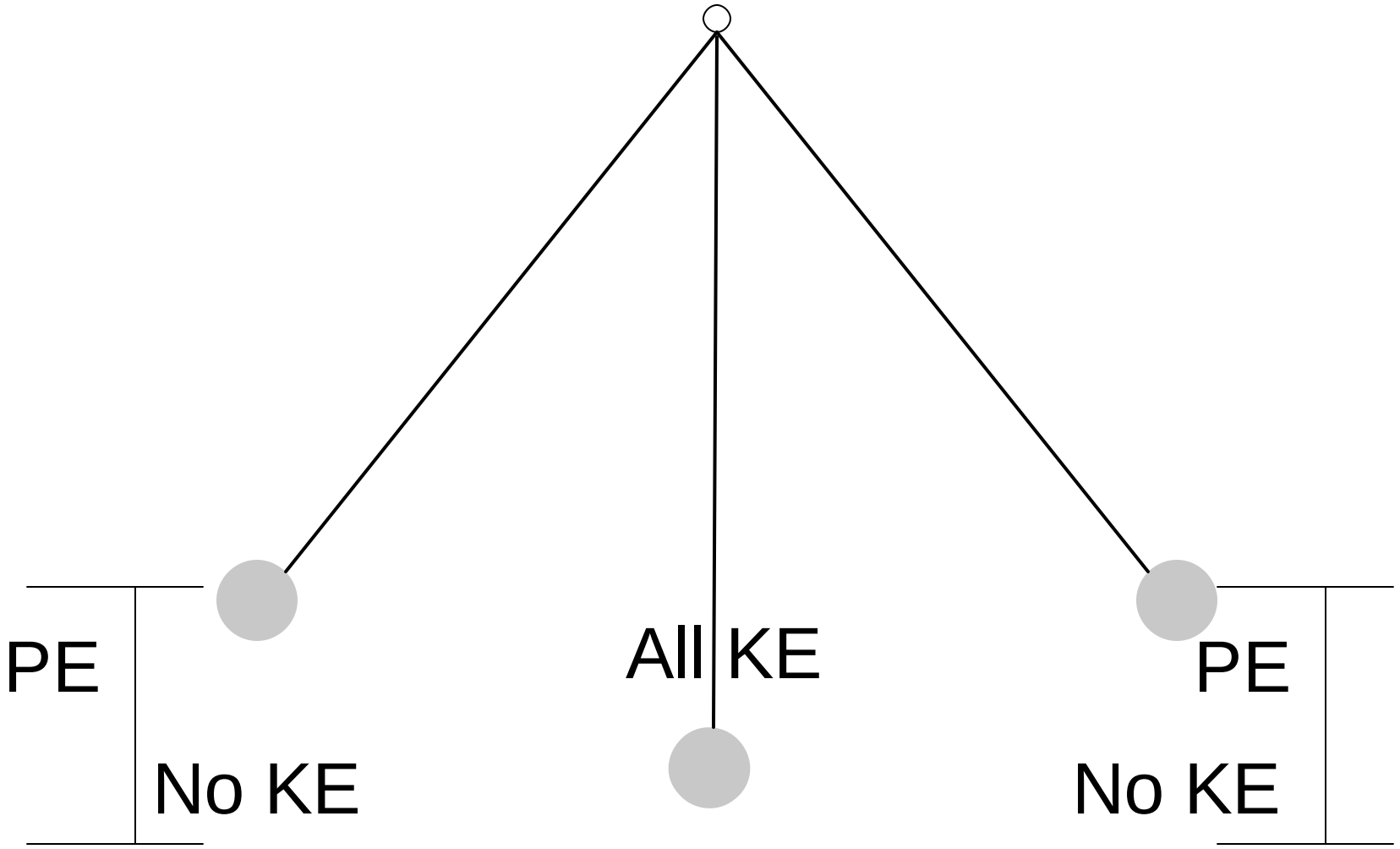
Other forms of energy

- Nuclear energy- energy from changing the nucleus of atoms
- The sun's energy comes from fusion – putting two hydrogen atoms to make helium atoms
- $E = mc^2$ mass is converted to energy
- Electricity- the energy of charged particles
- Light- energy that can travel through empty space in electromagnetic waves

Conservation of energy

- Energy can’t be created or destroyed
- The total energy remains constant
- It just changes form

A Pendulum



Energy is transformed

- Potential to kinetic
- But the pendulum will stop eventually.
- Where does the energy go
- Into moving the air
- Some energy is always changed into a form you don’t want
- Friction turns motion to heat.
- Electric cords get hot

Energy is Conserved

- All the energy can be accounted for
- It can be hard
- Two types of systems
- Closed system does not let energy in or out
- Used by scientists to limit variables
- Open system does let energy in or out
- Much more common

Efficiency

- Not all the work done is useful work
- Some gets turned into other forms
- Often heat
- Efficiency = $\frac{\text{Useful work}}{\text{Work input}}$
- Or % Efficiency = $\frac{\text{Useful work}}{\text{Work input}} \times 100\%$
- Always less than 100% efficient

Perpetual Motion Machines

- Machines that would run forever without energy input
- Or machines that put out more energy than you put in.
- They don’t exist.
- Would require a complete absence of friction.
- Or they would break the law of conservation of energy