Physics in the classroom

Lecture 3

Force = mass times acceleration

This is probably the most frequently used formula in all of physics and engineering.

In shorthand

$$\mathbf{F = ma}$$

acceleration

We already know all about acceleration.
It is the time rate at which speed changes.
It has units of meters per second per second
or [m/s^2]

mass

Mass is a measure of something's inertia.
Inertia is an objects resistance to change.
For example, one could say that bureaucracies such as large universities have a lot of inertia.
Mass is closely related to weight, but there is a difference. Weight is actually the force of gravity on an object with mass. Since the gravity is about the same everywhere on earth, we typically do not distinguish between mass and weight.
Astronauts have the same mass they had on earth, but they have zero weight; weightless. The unit of mass is kilogram [kg].

Force

Force is a push or a pull.
The unit of force is Newton [N].

Units

$F = m a$

$[N] = [kg][m/s^2]$

So, we see that the unit for force, the Newton, is actually make up of more fundamental units.

$F = ma$

This equation simply says that the more you push something, the more it accelerates depending on it's mass.

Suppose you wanted to accelerate a 1000 kg car from zero to 90m/s in 10 seconds. What force would you need?

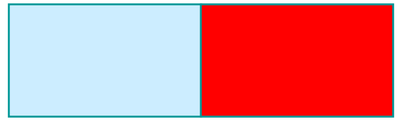
First we calculate the acceleration.
Acceleration = change in speed divided by time.

$$\text{acceleration} = \frac{90 \text{ m/s}}{10 \text{ s}} = 9 \text{ m/s}^2$$

Now, we can calculate the force.
Force = mass times acceleration
Force = (1000 kg) x (9 m/s^2)
F = 9000 kg * m/s^2
F = 9000 N

Now that we have the car in motion, going 90 m/s it will continue to travel at this speed in the same direction, unless another force is applied to slow it down, speed it up, or change its direction.

Does this make common sense?



Finally, suppose the car had an unfortunate head on collision with an identical car going the same speed in the opposite direction.

Don’t worry, everyone was wearing safety belts!

The other car exerts a large force to decelerate (deceleration is just negative acceleration) the first car in a very short time.

The first car exerts the same force on the other car.

We have just given examples of Newton's three laws of motion, which can be stated in the following way.

1. Objects in motion tend to remain in motion with the same speed and direction, unless acted upon by an outside force.

2. $F = ma$

3. For every action force, there is an equal and and opposite reaction force.

Do NOT simply memorize these laws!

You should not simply memorize these laws of motion. You should understand them. It is not very likely that I will ask you to list these laws on the final. It is much more likely that I present you with a problem and you would have to apply the appropriate law to solve the problem.

Simple Machines

Examples:

Lever: Car jack, pry bar, crow bar, bottle opener.

Pulley: bicycle chain, automobile transmission.

Ramp: Ramp, stairs, screw (ramp wrapped around shaft).

Others

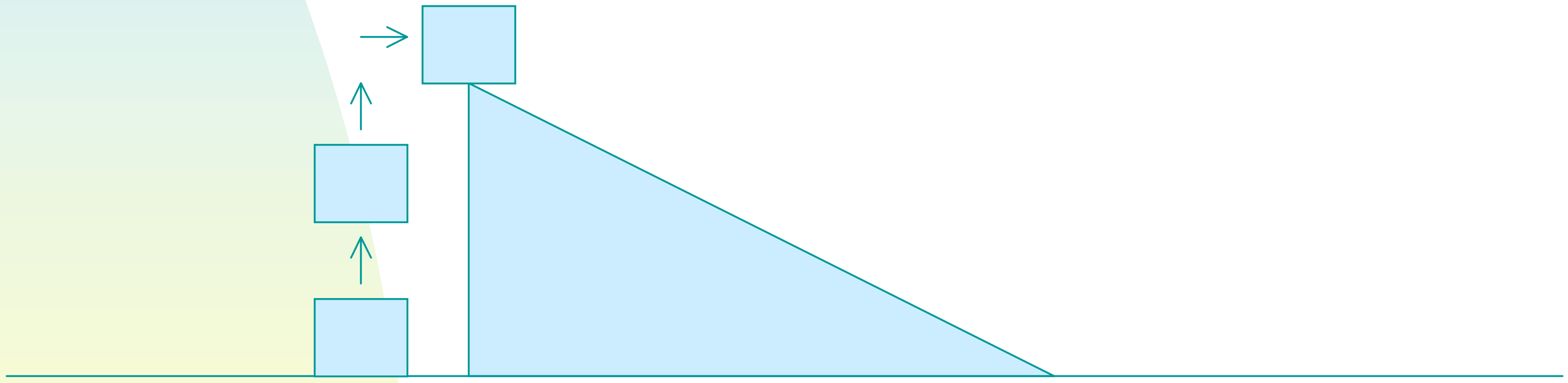
Machines make our lives easier, usually by reducing the forces we have to apply.

"You do not get something for nothing."

The reduced forces usually have to be applied over a greater distance.

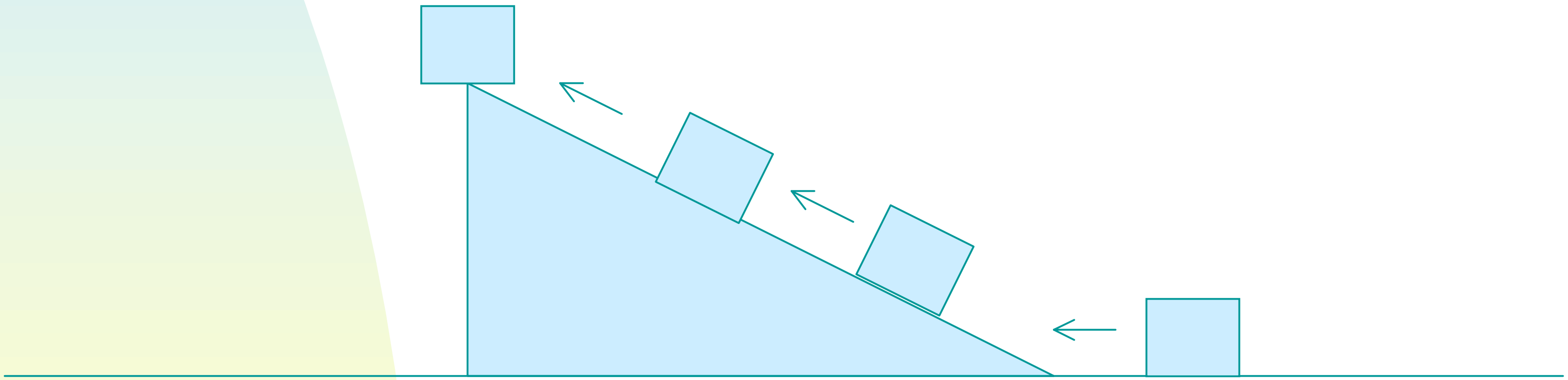
Ramp

Hard way

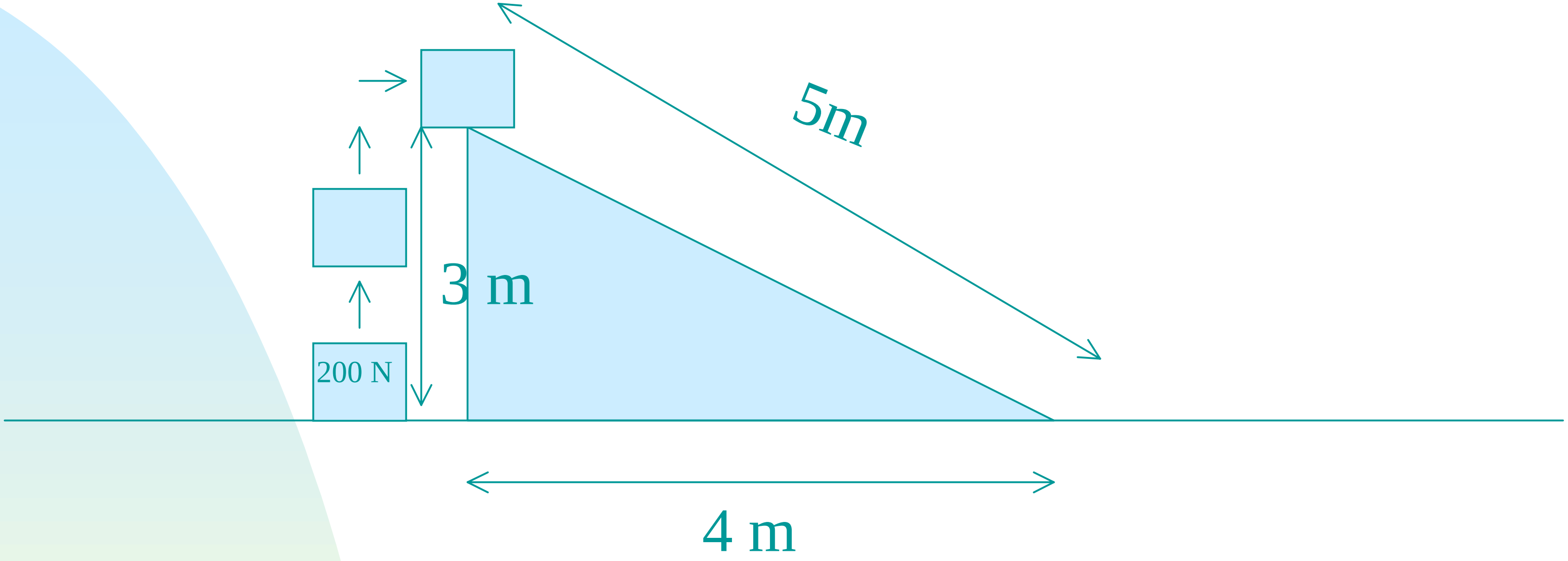


Ramp

Easy way

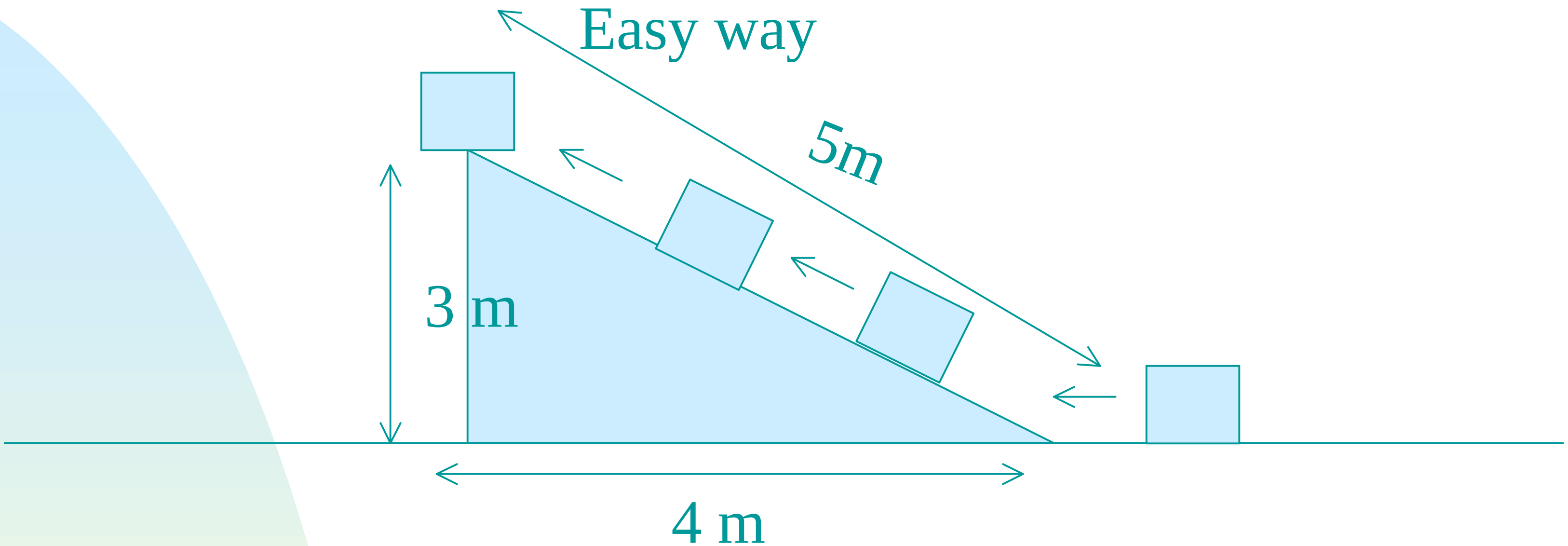


Ramp (Hard way)



(200 N) x (3 m) = 600 N*m

Ramp



Reduced force = 200N * 3/5 = 120 N

But larger distance = 5m

120 N * 5 m = 600 N*m

Compare this number with the hard way.

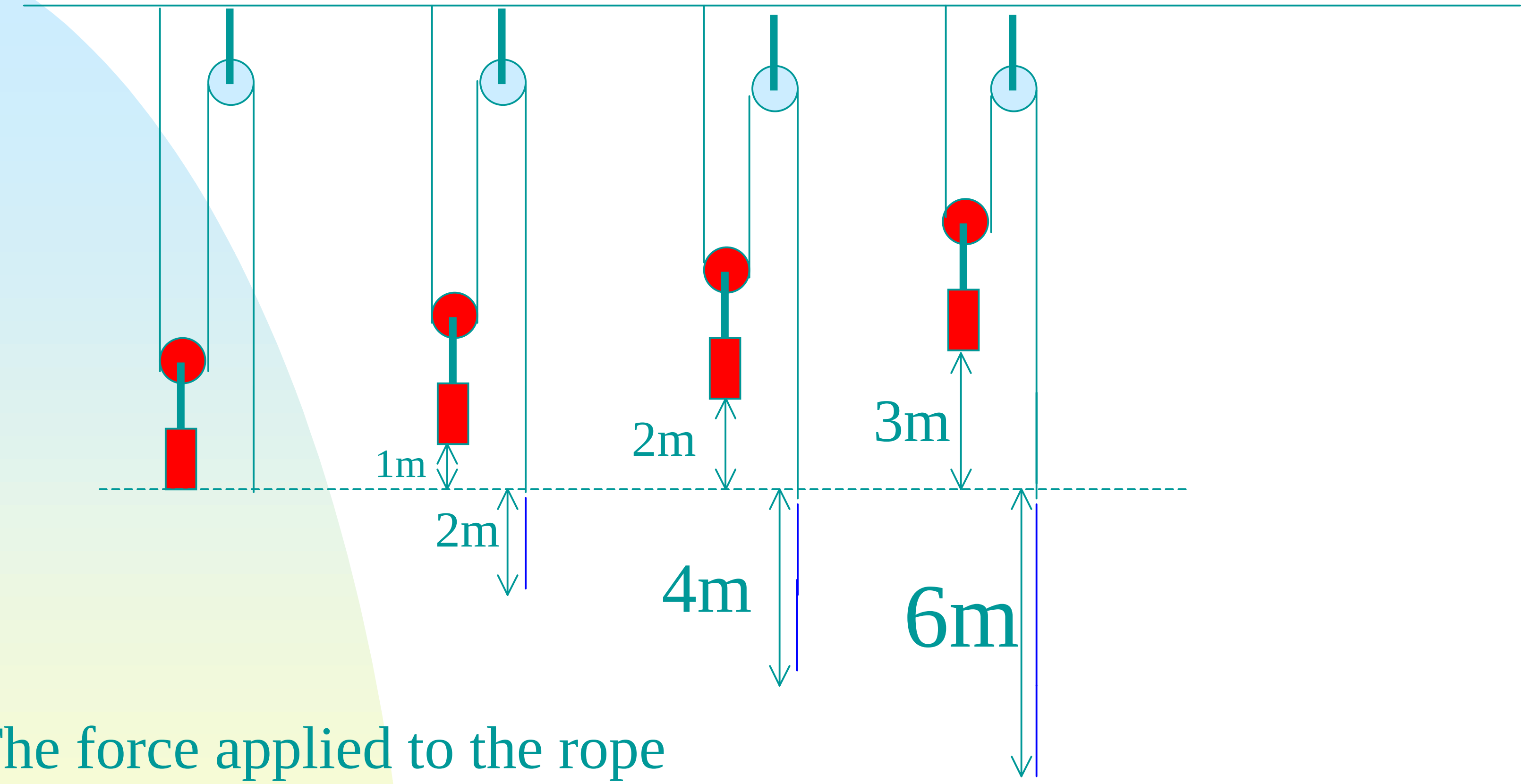
What is this number?

It is the **WORK**

Work = Force times distance

$W = F \times d$

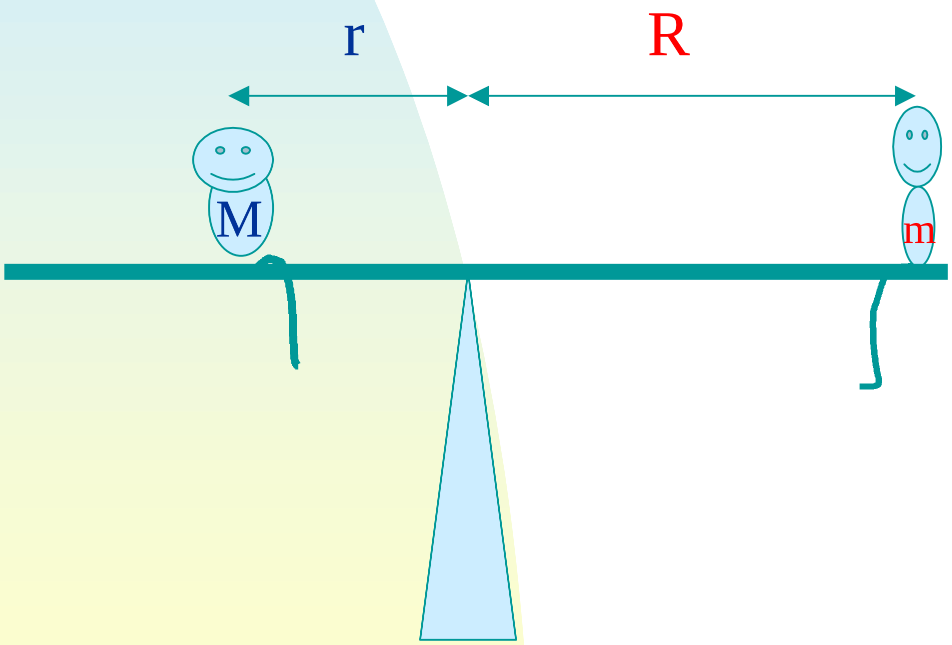
Pulley system



The force applied to the rope
is only half the weight of the mass.
But we have to pull the rope twice
as far as the mass travels.

Balance

See-saw or teeter-totter



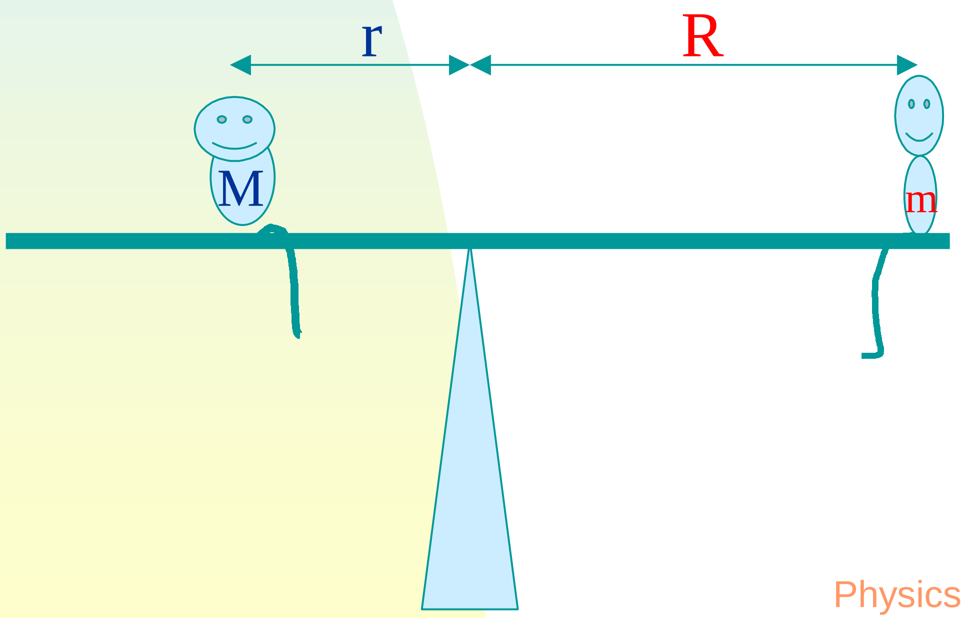
$$Mr = mR$$

$$\frac{Mr}{m} = R$$

$$\frac{M}{m} = \frac{R}{r}$$

Balance (See-saw or teeter-totter)

Suppose big Mac had a mass of 80kg and petite Penney had a mass of 40kg. If Penney sat 2 meters from the center, where would Mac need to sit to make the see-saw balance?



M = 80kg
m = 40 kg
R = 2 m
r = ?

$Mr = mR$

Solving for r;

$$r = \frac{mR}{M}$$

$$r = \frac{40kg * 2\ m}{80kg}$$

$r = 1\ m$