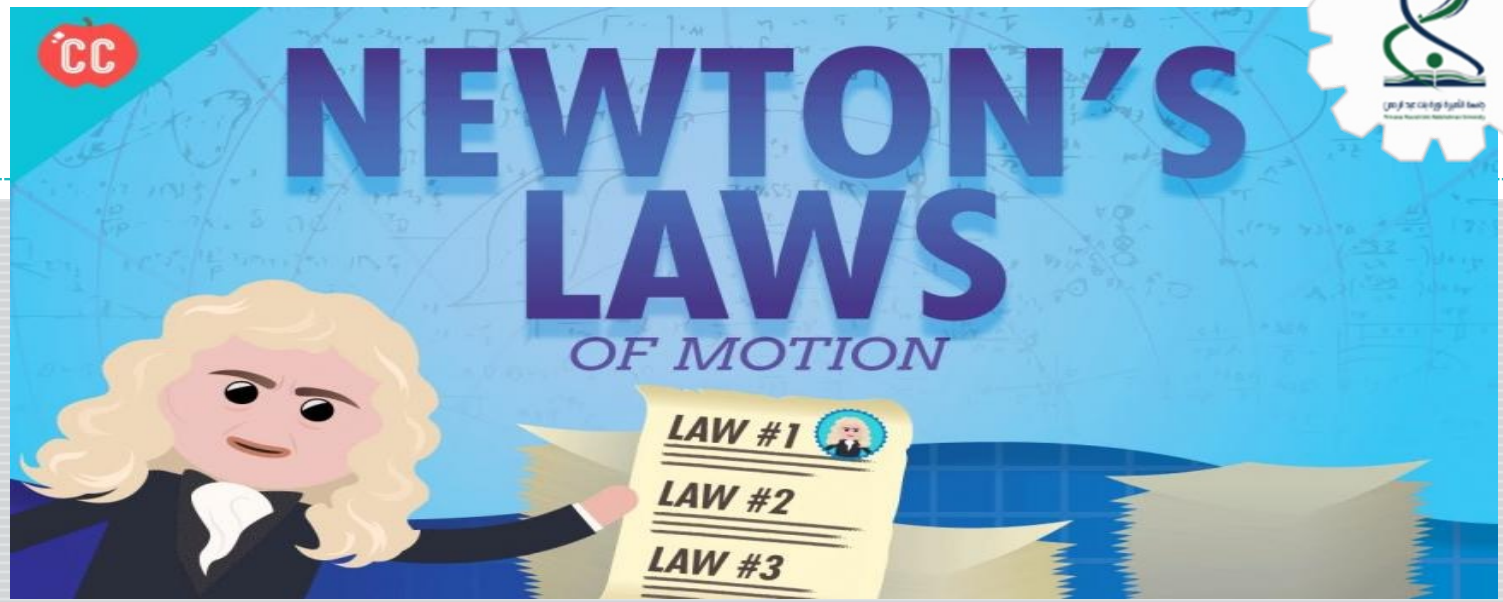
# Lecture 2



# OUTLINE

- The Concept of Force
- Newton’s First Law
- Mass
- Newton’s Second Law
- The Gravitational Force and Weight
- Newton’s Third Law
- Forces of Friction
- Newton's Law of Universal Gravitation.

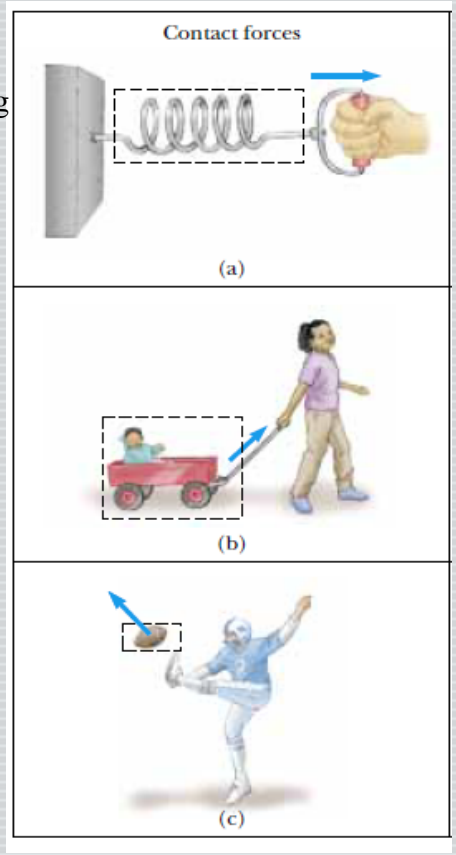
# The Concept of Force

## *contact forces*

a) When a coiled spring is pulled, the spring stretches.

b) When a stationary cart is pulled hard that friction is overcome, the cart moves.

c) When a football is kicked, it is both deformed and set in motion.

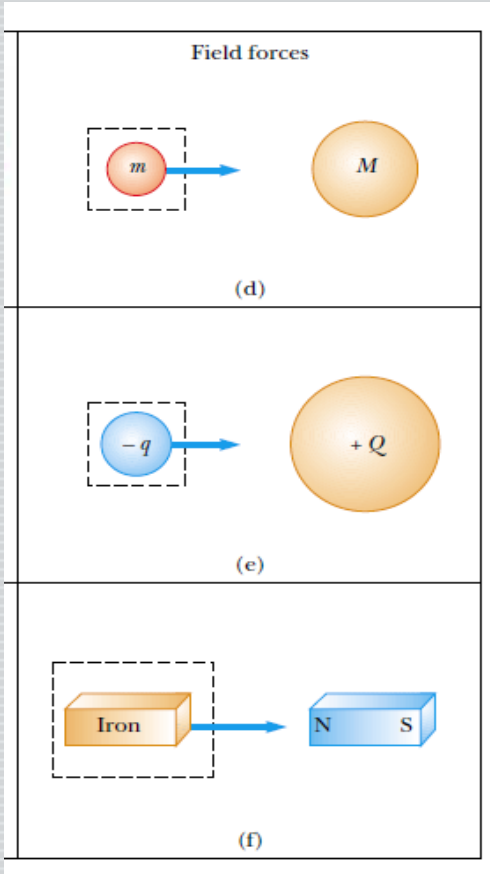



## *field forces*

d) The gravitational force of attraction between two objects.

e) electric force that one electric charge exerts on another; example: charges of the electron and proton that form a hydrogen atom

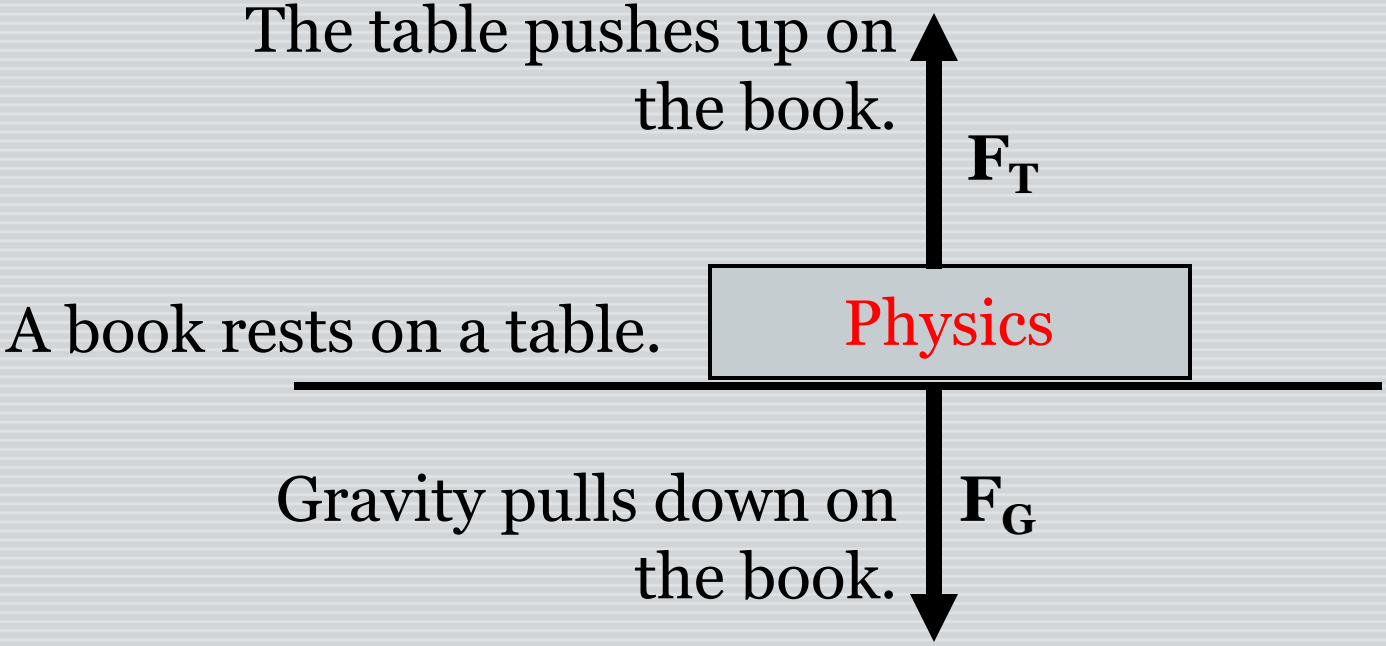
f) Force a bar magnet exerts on a piece of iron.



# The Concept of Force

- The net force (or resultant force ) acting on an object is defined as the vector sum of all forces acting on the object.
- If the net force exerted on an object is zero, the acceleration of the object is zero and its velocity remains constant.
- When the velocity of an object is constant (including when the object is at rest), the object is said to be in equilibrium.

# What is Zero Net Force?




Even though there are forces on the book, they are balanced. Therefore, there is no net force on the book.

$$\Sigma F = 0$$

# *Newton's First Law*

"An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force"

$$\sum F = 0$$

# 1st Law

In another words:

If no **net force** acts on a body, the body's velocity cannot change(velocity=constant) ;
that is, the body cannot accelerate (acceleration on an object is zero)… which means:

- it cannot turn,
- it cannot speed up,
- it cannot slow down.

# According to Newton's first law

## (law of inertia):

Inertia is the  tendency of an object to resist changes in its velocity: whether in motion or motionless.

The inertia of an object is directly proportional to its mass. The greater the mass the greater the inertia and the lower the mass the lower the inertia.

# This law is the same reason why you should always wear your seatbelt.

**Because of inertia, objects (including you) resist changes in their motion. When the car going 80 km/hour is stopped by the brick wall, your body keeps moving at 80 m/hour.**

# 2nd Law

**Newton's second law:** the net force on a body is equal to the product of the body's mass and its acceleration.

$$F_{\text{net external}} = ma$$

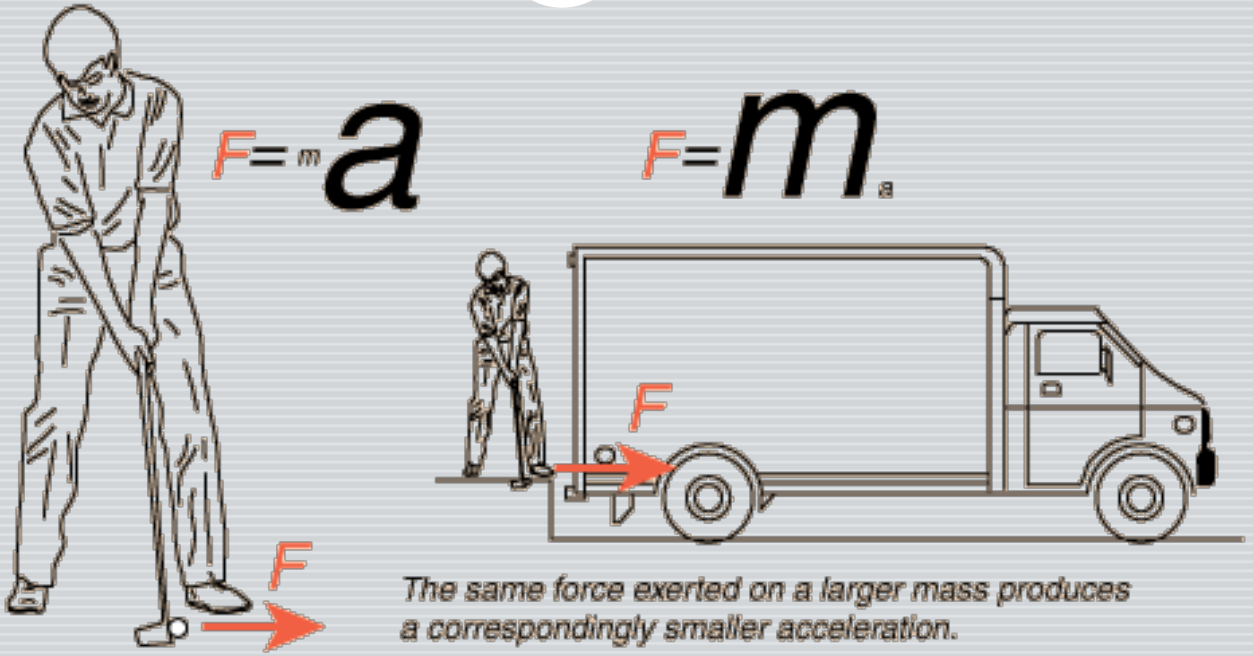
Net force on object = mass of object x acceleration

**Units of force:**

**Newton (in SI system) where; 1 N = 1 kg . m /s²**

**Definition:** **1 N** is the force required to accelerate a **1 kg** mass at a rate of **1 m/s²**

# *For example…*




*The same force exerted on a larger mass produces a correspondingly smaller acceleration.*

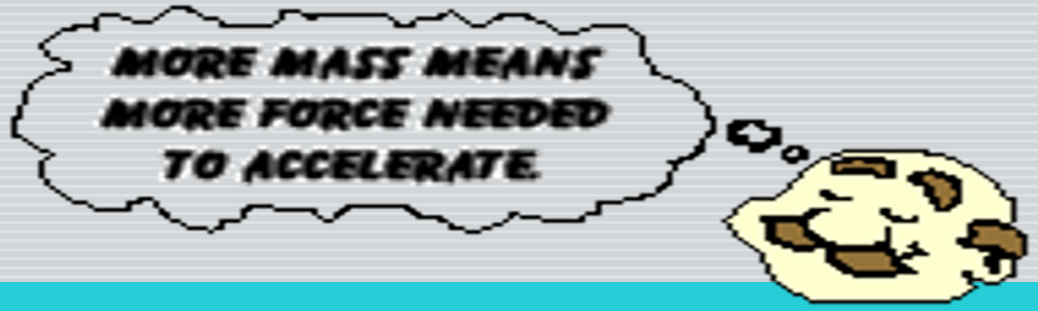
**The acceleration of an object is directly proportional to the force acting on it.**
**The magnitude of the acceleration of an object is inversely proportional to its mass.**

# *According to Newton's second law*

**Acceleration is produced when a force acts on a mass.**

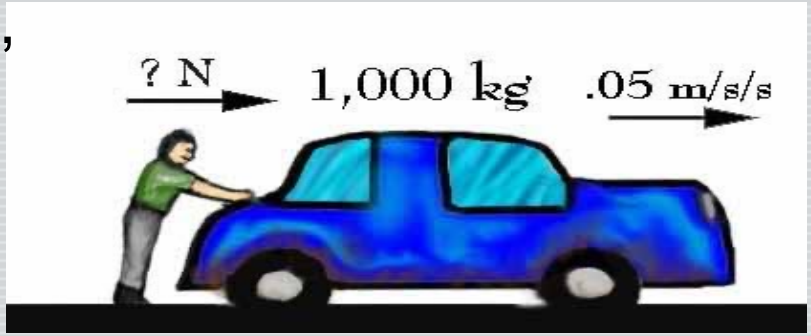
- What does this mean?

  heavier objects require more force to move the same distance as lighter objects.



# This is an example of how Newton's Second Law works:

Mike's car, which weighs **1,000 kg**, is out of gas. Mike is trying to push the car to a gas station, and he makes the car go **0.05 m/s²**. Using Newton's Second Law, you can compute how much force Mike is applying to the car.




## Answer

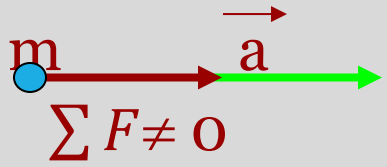
**F=1,000 X 0.05** = 50 Newton

# Analysis Model for Problem Solving

## Particles Under a Net Force

If a particle of mass m experiences a nonzero net force, its acceleration is related to the net force by Newton's second law :

$$\sum \vec{F} = m\vec{a}$$

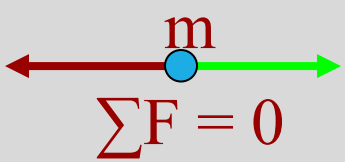



## Particles in Equilibrium

If a particle maintains a constant velocity (so that a= o), which include a velocity of zero, the forces on the particle balance and Newton's first law is applied.

$$\sum \vec{F} = 0$$

$$\vec{a} = 0$$

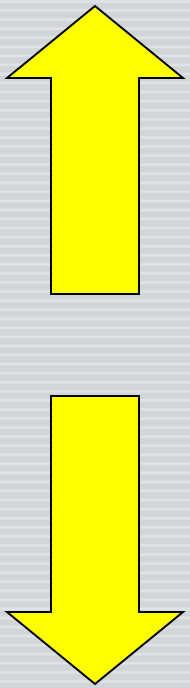


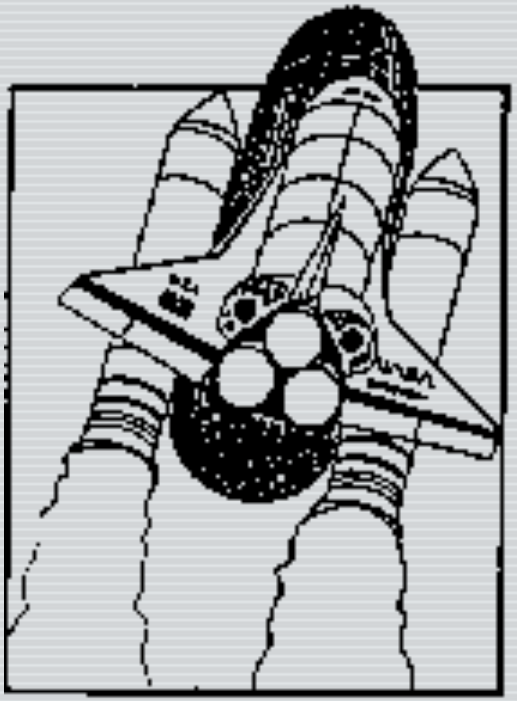
# Newton's 3rd Law

*"For every action, there is an equal and opposite reaction."*

*Reaction*

*Action*





# Newton's 3rd Law

The Newton's Third Law interaction is always between two objects.

**For example :** **A pushes / pulls B.**
**B pushes / pulls A.**

One of these forces is called the action force, and the other one is called the reaction force - it doesn't matter which is which.

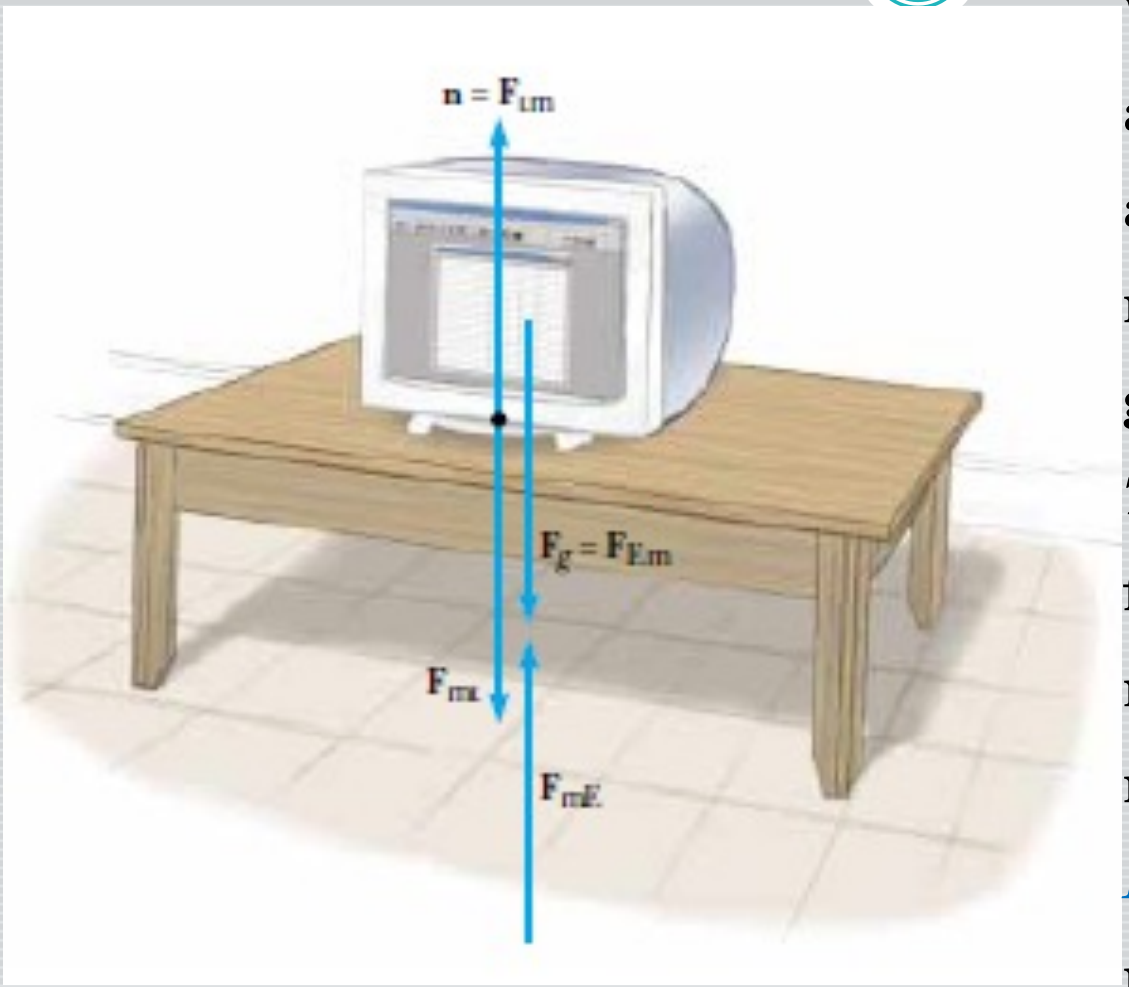
For example, if:

- **You push book. (Action force)**

then Newton's Third Law says that:

- **Book pushes you. (Reaction force)**

# Newton's 3rd Law

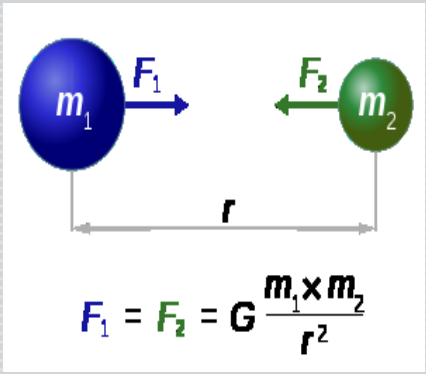



When a computer monitor is at rest on a table, the forces acting on the monitor are **the normal force n and the gravitational force $F_g$ .** ***The reaction to n is the*** **force $F_{mt}$ exerted by the monitor on the table. The reaction to $F_g$ *is the force*** $F_{mE}$ **exerted by the monitor on the Earth.**

# Newton's Law of Universal Gravitation

**Newton's law of universal gravitation**

**states that** a particle attracts every other particle in the universe using a force ($F_g$) that is Directly Proportional to the product of their masses ( m1 , m2 ), and Inversely Proportional to the square of the distance between them ( r ² ).




$$F_g = G\frac{m_1 m_2}{r^2}$$

where *G is a constant, called the universal gravitational constant, that has been measured* experimentally.

Its value in SI units is

$$G = 6.673 \times 10^{-11} \quad N \cdot m^2/kg^2$$

# The Gravitational Force and Weight

- all objects are attracted to the Earth.
- The attractive force exerted by the Earth on an object is called the gravitational force $F_g$.
- *This force is directed* toward the center of the Earth, and its magnitude is called the weight of the object.

# What is the difference between mass and weight?

## Mass

1. Is always constant at any place and time.
2. Is measured in Kilograms in SI unit
3. Can never be zero.
4. Is an intrinsic property of a body and is independent of the body's surroundings and of the method used to measure it.

## Weight

1. Depends on:
   a. gravity at the place,
   b. Mass of the object which is attracting it.
2. Is measured in Newton not in kilograms.
3. Can also be zero.
4. Is measured using scales.

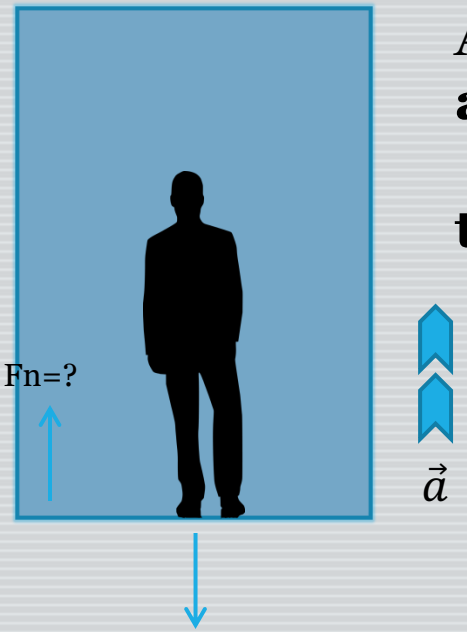
# *Weight & Mass*

$$m = \frac{W}{g}$$

Ex. : Man whose weight is 1000 N on the earth has a mass of :

$$m = \frac{W}{g} = \frac{1\,000\ kg\ \cdot m/s^2}{9.8\ m/s^2} = 102\ kg.$$

# The Gravitational Force and Weight




**An 80 kg man standing on an elevator that is accelerating upwards at 2 m/s² .**
**Calculate the support force $F_n$ exerted by the elevator floor on the man?**

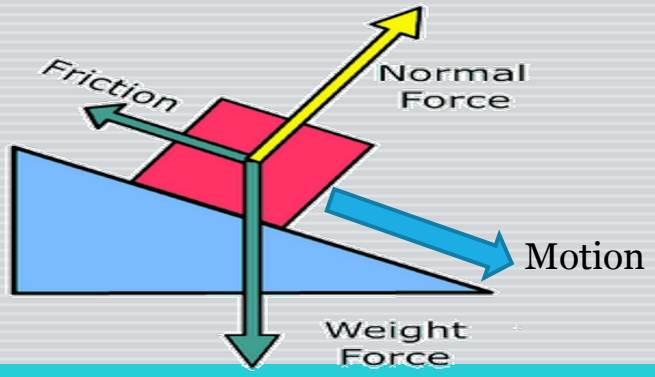
$$\sum F = ma$$

$$F_n - \mathrm{mg} = \mathrm{m}a$$

$$F_n = \mathrm{m}a + \mathrm{mg} = 944\ \mathrm{N}$$

# The Force of Friction

- Friction is a force that is created whenever two surfaces move or try to move across each other.
- Friction acts in a direction parallel to the area of contact.
- Friction always opposes the motion or the tendency to move .



# The Force of Friction

The force of friction depends upon both surfaces in contact ($\mu$) and the normal force ($F_n$).

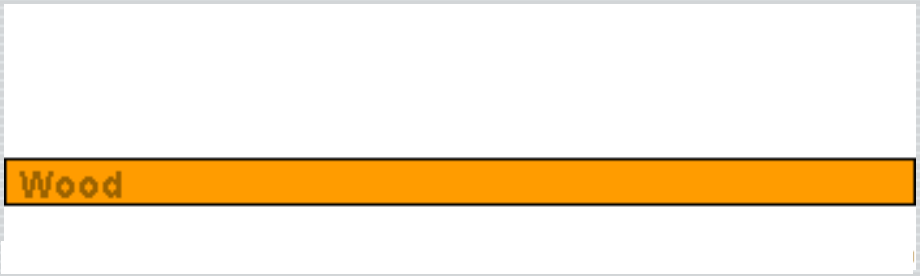
A mathematical relationship can be created here:

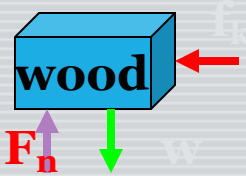
$$F_f = \mu F_n$$ were $\mu$ is the friction coefficient.

** Friction force **does not** depend on the surface area ( contact area).

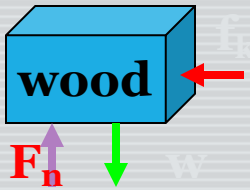
# The Force of Friction

Friction is dependant on the texture of both surfaces



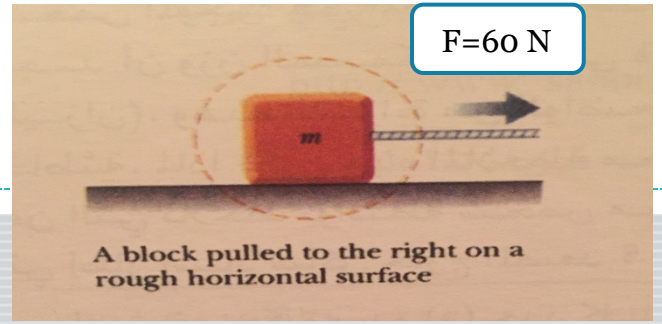




$$\frac{f_k}{F_N} = 0.4$$

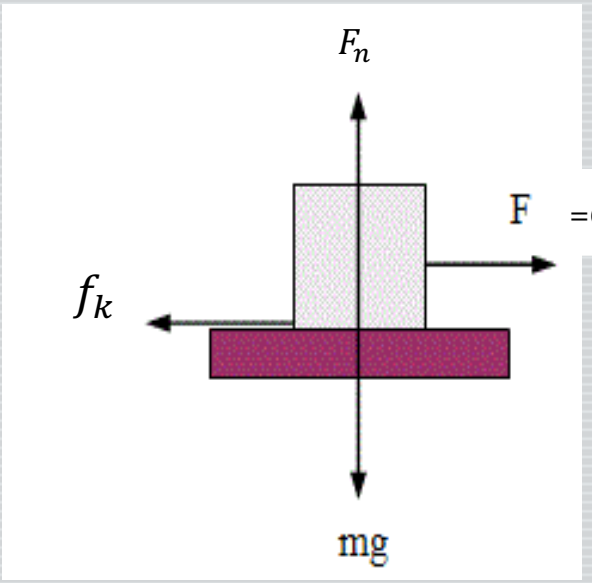




$$\mu_k = 0.6$$

# example




A 16 kg box is on a rough horizontal surface. A constant 60 N pulling force is applied to the box horizontally.
The coefficient of kinetic friction between the box and the surface is 0.3.
what is the acceleration of the box?




$$\sum F = ma$$

$$\sum F_y = 0 \Longrightarrow F_n = \text{mg} = 16 \times 9.8 = 156.8 \text{ N} \qquad (1)$$

$$\sum F_x = \text{m}a \Longrightarrow \quad 60 - f_k = \text{m}a = 16\,a \qquad (2)$$

$$f_k = \mu_k F_n = 0.3 \times 156.8 = 47.04 \text{ N} \qquad (3)$$

By using eq. 3 in eq. 2 we get:

$$60 - 47.04 = 16\,a$$

$$\Longrightarrow a = \frac{12.96}{16} = 0.81\ m/s^2$$

# Home Work

- Q1- A man has a mass of 70.0kg.What is his weight on a)the earth where g=9.81 m/s2 b)the moon where g=1.60 m/s2 c) Jupiter where g= 26.0 m/s2
- Q2- A spaceship weighs 10800N on a planet where g=7.20m/s2.What would it weigh on a smaller planet where g=4.30 m/s2
- Q3- If a car is travelling westward with a constant velocity of 20m/s, what is the net force acting on it?
- Q4- A 5.5 kg watermelon is pushed across a table. If its acceleration is 4.2m/s2,find the net external force exerted on it.
- Q5- A ball pushed with a force of 13.5N accelerates at 6.5m/s2 to the right, what is the mass of the ball?
- Q6- Once the 24kg box is in motion, a horizontal force of 53N keeps it moving, find the co-efficient of kinetic friction.
- Q7- The moon orbits the earth along a path of radius 3.84 x 108 m. The mass of the Moon =7.35 x 1022 kg. The Earth ‘s mass=6.00 x 1024kg. G= 6.67 x 10-11 Nm2/kg2. The gravitational force of attraction between the earth and the Moon keeps the Moon in orbit. Calculate the size of this force.

# Home Work

- 1. What is the **weight** of a 200 kg object?
- 2. A woman exerts a force of 500 N straight up to lift a 35 kg basket. What is the **acceleration** of the basket?
- 3. An elevator of mass 3000 kg is ascending at a steady speed of 2.0 m/s. What is the **force** in the cable supporting the elevator?
- 4. A 49-N block is pulled by a horizontal force of 50.0 N along a rough horizontal surface at a constant acceleration of 6 $m/s^2$. What is the **coefficient of friction**?