PHYS 1441 – Section 002
Lecture #12

Monday, Mar. 3, 2008

Dr. Jaehoon Yu

- Types of Forces
- The Gravitational Force
  - Newton's Law of Universal Gravitation
  - Weight
- The Normal Force
- Static and Kinetic Frictional Forces
- The Tension Force
- Equilibrium Applications of Newton's Laws of Motion

Today's homework is homework #6, due 9pm, Monday, Mar. 10!!

Announcements

- Term exam
  - Problem #18 was graded incorrectly
  - All will receive credit for this problem
  - Need all your exams back so that I can correct this and keep them
- There will be a quiz this Wednesday
  - Covers CH4.1 up to where ever we finish today
- Term exam #2
  - Wednesday, March 26, in class
  - Will cover CH4.1 – whatever we finish Monday, Mar. 24

Types of Forces

- Fundamental Forces: Truly unique forces that cannot be derived from any other forces
  - Total of three fundamental forces
    - Gravitational Force
    - Electro-Weak Force
    - Strong Nuclear Force
- Non-fundamental forces: Forces that can be derived from fundamental forces
  - Friction
  - Tension in a rope
  - Normal or support forces

Newton's Law of Universal Gravitation

People have been very curious about the stars in the sky, making observations for a long time. The data people collected, however, have not been explained until Newton has discovered the law of gravitation.

Every particle in the Universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

How would you write this law mathematically?

$$F_g \propto \frac{m_1 m_2}{r_{12}^2} \quad \xrightarrow{\text{With } G} \quad F_g = G\frac{m_1 m_2}{r_{12}^2}$$

G is the universal gravitational constant, and its value is

$$G = 6.673 \times 10^{-11}$$

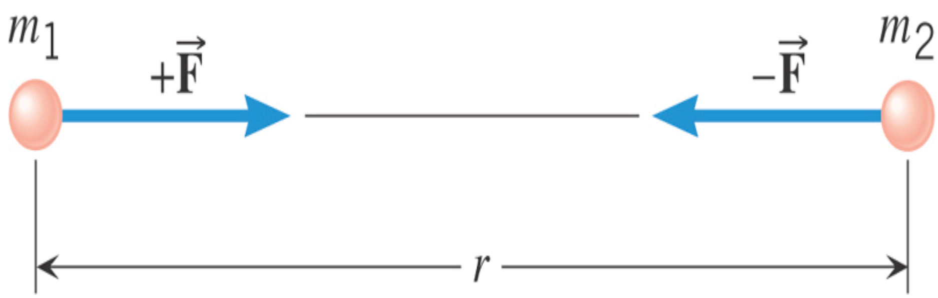
Unit? $N \cdot m^2 / kg^2$

This constant is not given by the theory but must be measured by experiments.

This form of forces is known as the inverse-square law, because the magnitude of the force is inversely proportional to the square of the distances between the objects.

Ex. 5. Gravitational Attraction

What is the magnitude of the gravitational force that acts on each particle in the figure, assuming m_1=12kg, m_2=25kg, and r=1.2m?

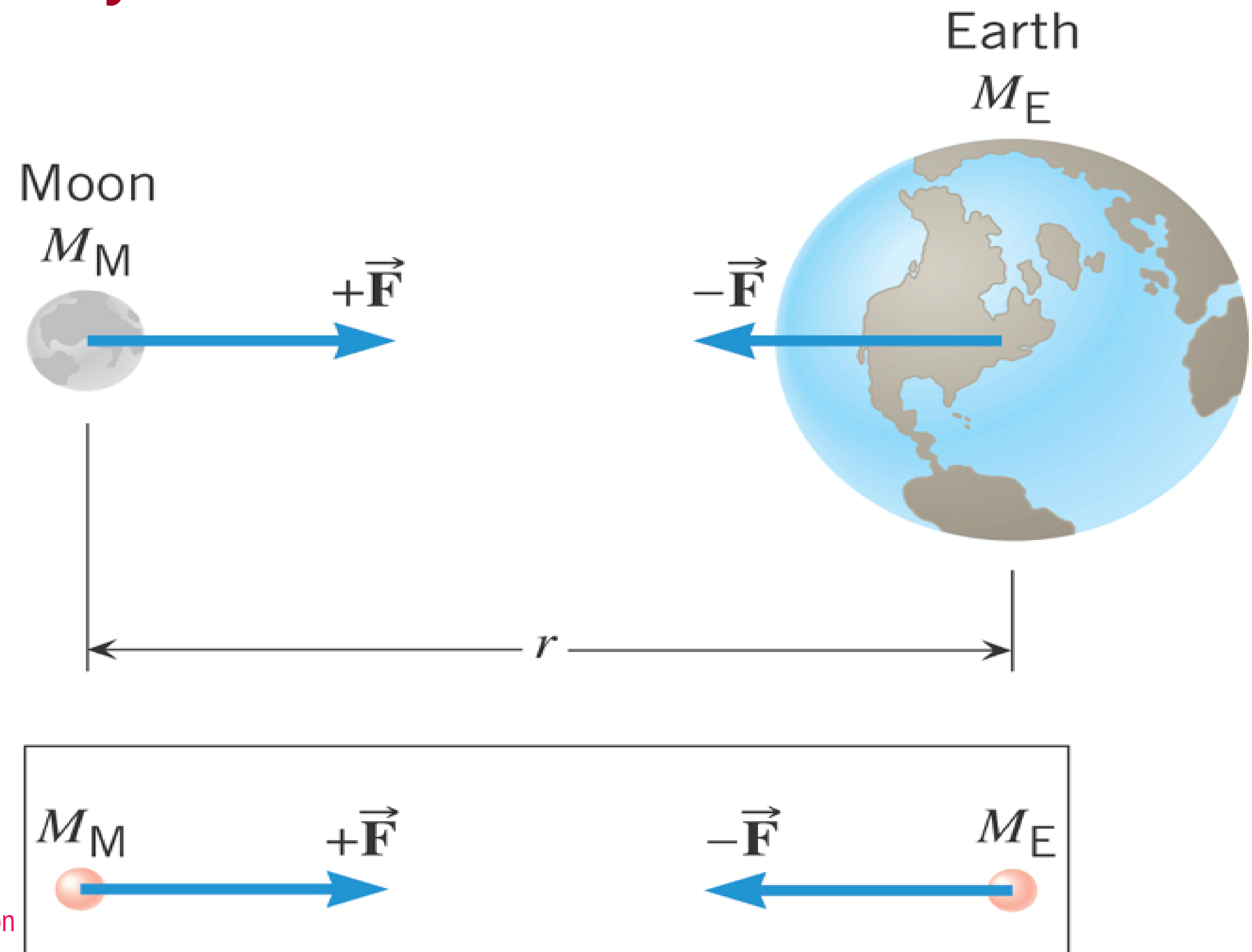


$$F = G\frac{m_1 m_2}{r^2}$$

$$= \left(6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}\right)\frac{(12\ \mathrm{kg})(25\ \mathrm{kg})}{(1.2\ \mathrm{m})^2}$$

$$= 1.4\times10^{-8}\ \mathrm{N}$$

Why does the Moon orbit the Earth?



Gravitational Force and Weight

Gravitational Force, $\mathcal{F}_g$

The attractive force exerted on an object by the Earth

$$\vec{F}_G = m\vec{a} = m\vec{g}$$

Weight of an object with mass M is

$$W = \left|\vec{F}_G\right| = M\left|\vec{g}\right| = Mg$$

What is the SI unit of weight?

$\boxed{\mathrm{N}}$

*Since weight depends on the magnitude of gravitational acceleration, **g**, it varies depending on geographical location.*

By measuring the forces one can determine masses. This is why you can measure mass using the spring scale.

Gravitational Acceleration

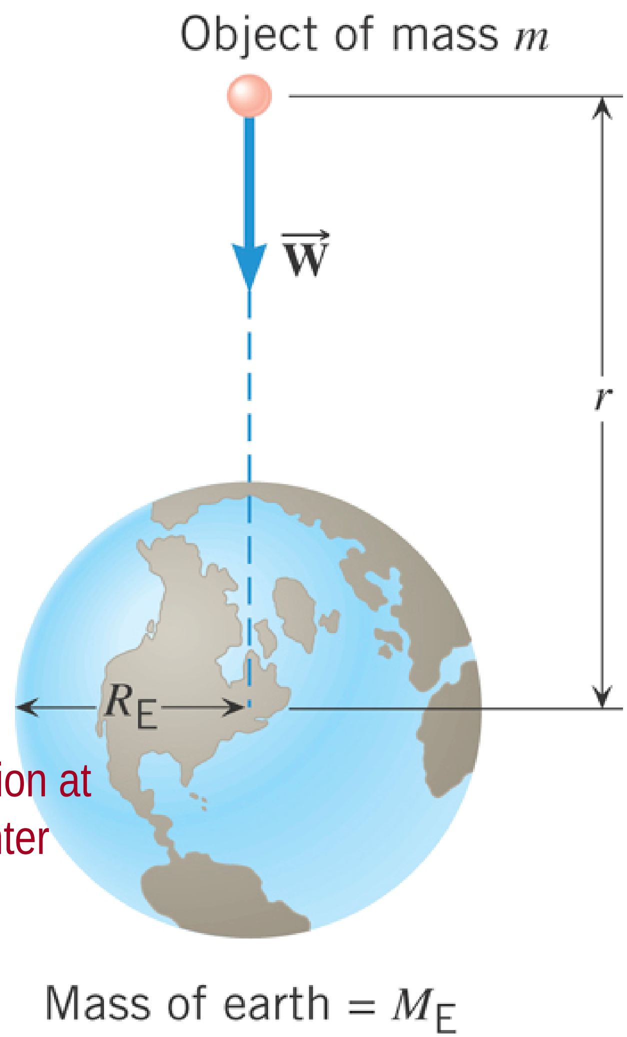
$$W = G\frac{M_E m}{r^2}$$

$$W = mg$$

$$\cancel{m}g = G\frac{M_E \cancel{m}}{r^2}$$

$$g = G\frac{M_E}{r^2}$$

Gravitational acceleration at distance r from the center of the earth!



What is the SI unit of g? $\boxed{m/s^2}$

Magnitude of the gravitational acceleration on the surface of the Earth

Gravitational force on the surface of the earth:

$$F_G = G\frac{M_E m}{r^2} = G\frac{M_E \cancel{m}}{R_E^2} = \cancel{m}g$$

$$g = G\frac{M_E}{R_E^2}$$

$G = 6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}$

$M_E = 5.98\times10^{24}\ \mathrm{kg};\quad R_E = 6.38\times10^{6}\ m$

$$= \left(6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}\right)\frac{\left(5.98\times10^{24}\ \mathrm{kg}\right)}{\left(6.38\times10^{6}\ \mathrm{m}\right)^2}$$

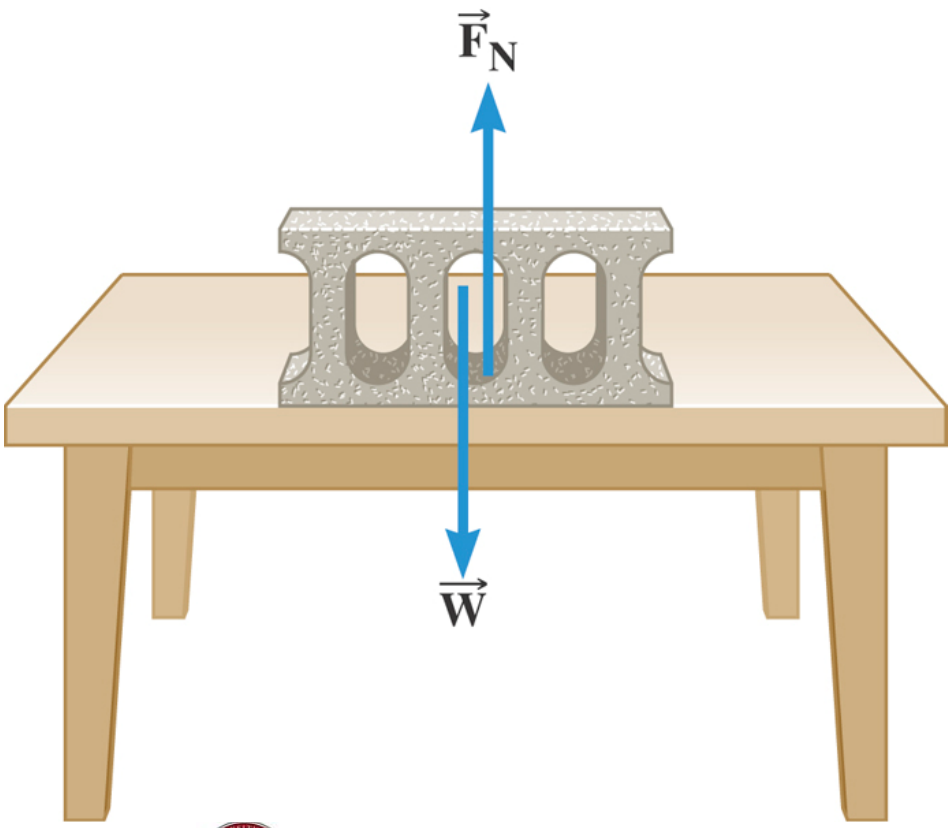
$$= 9.80\ \mathrm{m/s^2}$$

Special Project

- Using the fact that $g=9.80m/s^2$ on the Earth's surface, find the average density of the Earth.
- 20 point extra credit
- Due: Wednesday, Mar. 12
- You must show your OWN, detailed work to obtain any credit!!

The Normal Force

The normal force is one component of the force that a surface exerts on an object with which it is in contact – namely, the component that is perpendicular to the surface.

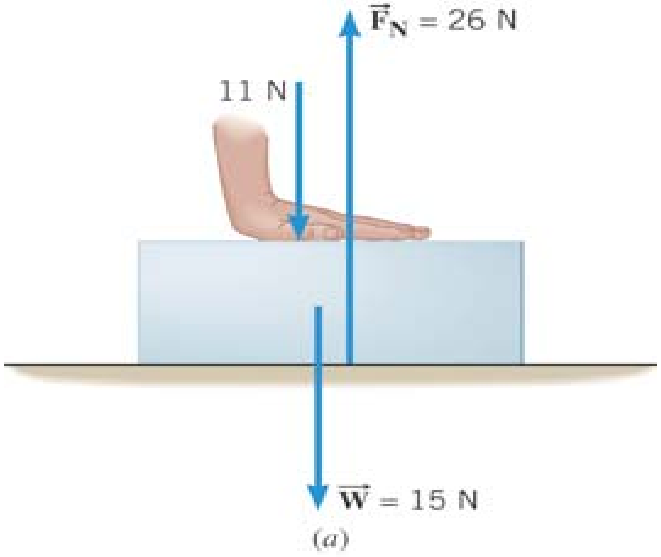


Some normal force exercises

Case 1: Hand pushing down on the book

$$F_N - 11\ \text{N} - 15\ \text{N} = 0$$

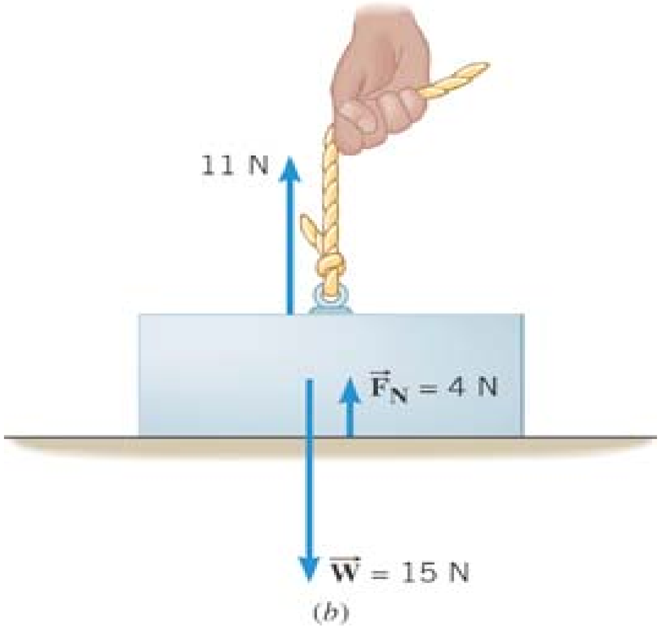
$$F_N = 26\ \text{N}$$



Case 2: Hand pulling up the book

$$F_N + 11\ \text{N} - 15\ \text{N} = 0$$

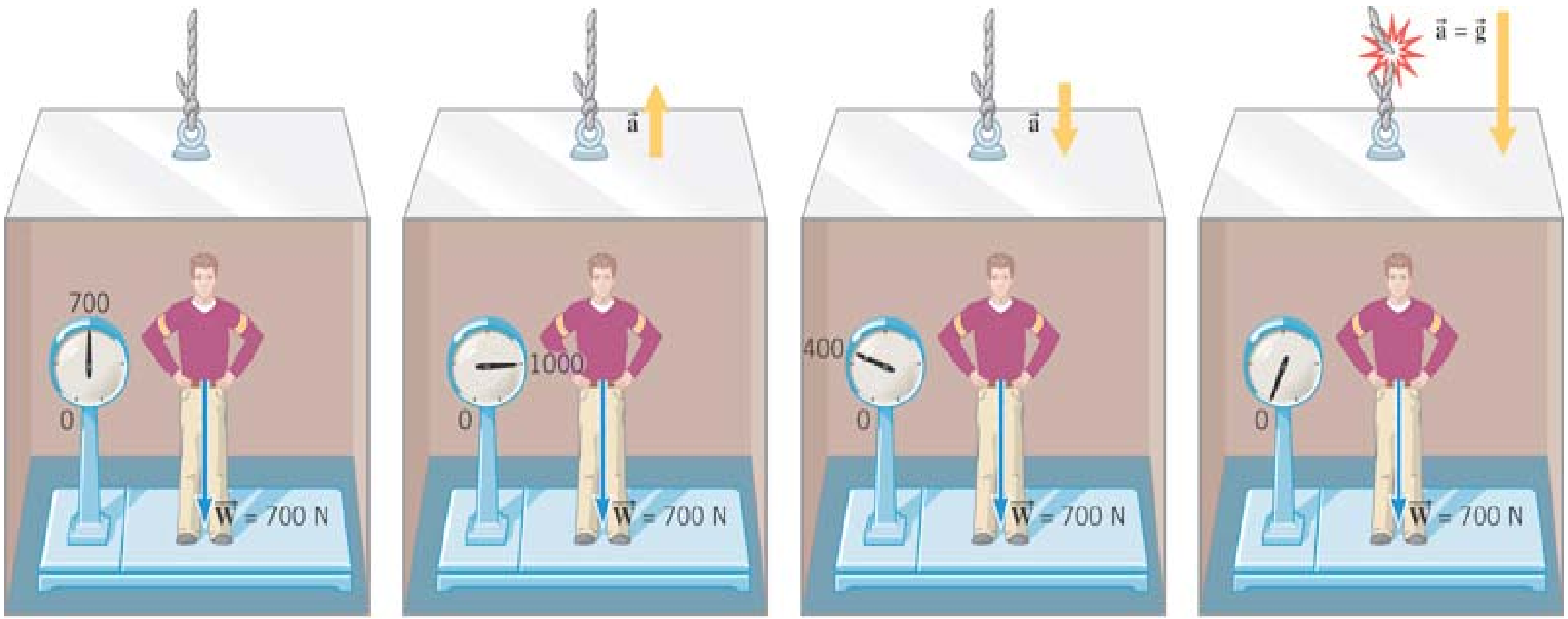
$$F_N = 4\ \text{N}$$



Apparent Weight

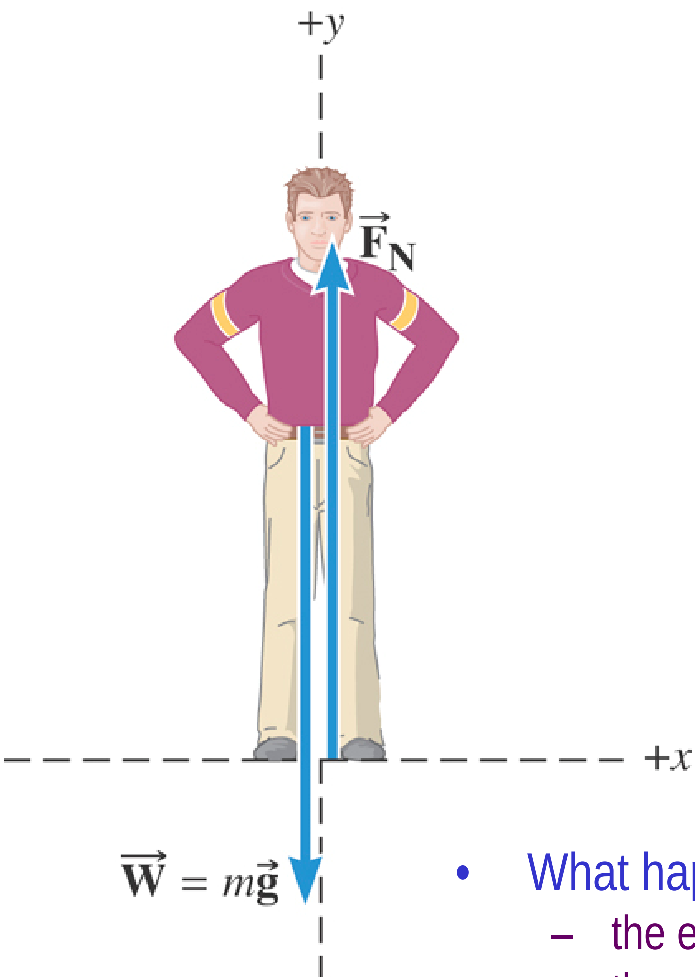
The apparent weight of an object is the reading of the scale.

It is equal to the normal force the man exerts on the scale.



(*a*) No acceleration ($\vec{v}$ = constant) (*b*) Upward acceleration (*c*) Downward acceleration (*d*) Free-fall

Apparent Weight



$$\sum F_y = +F_N - mg = ma$$

$$F_N = mg + ma$$

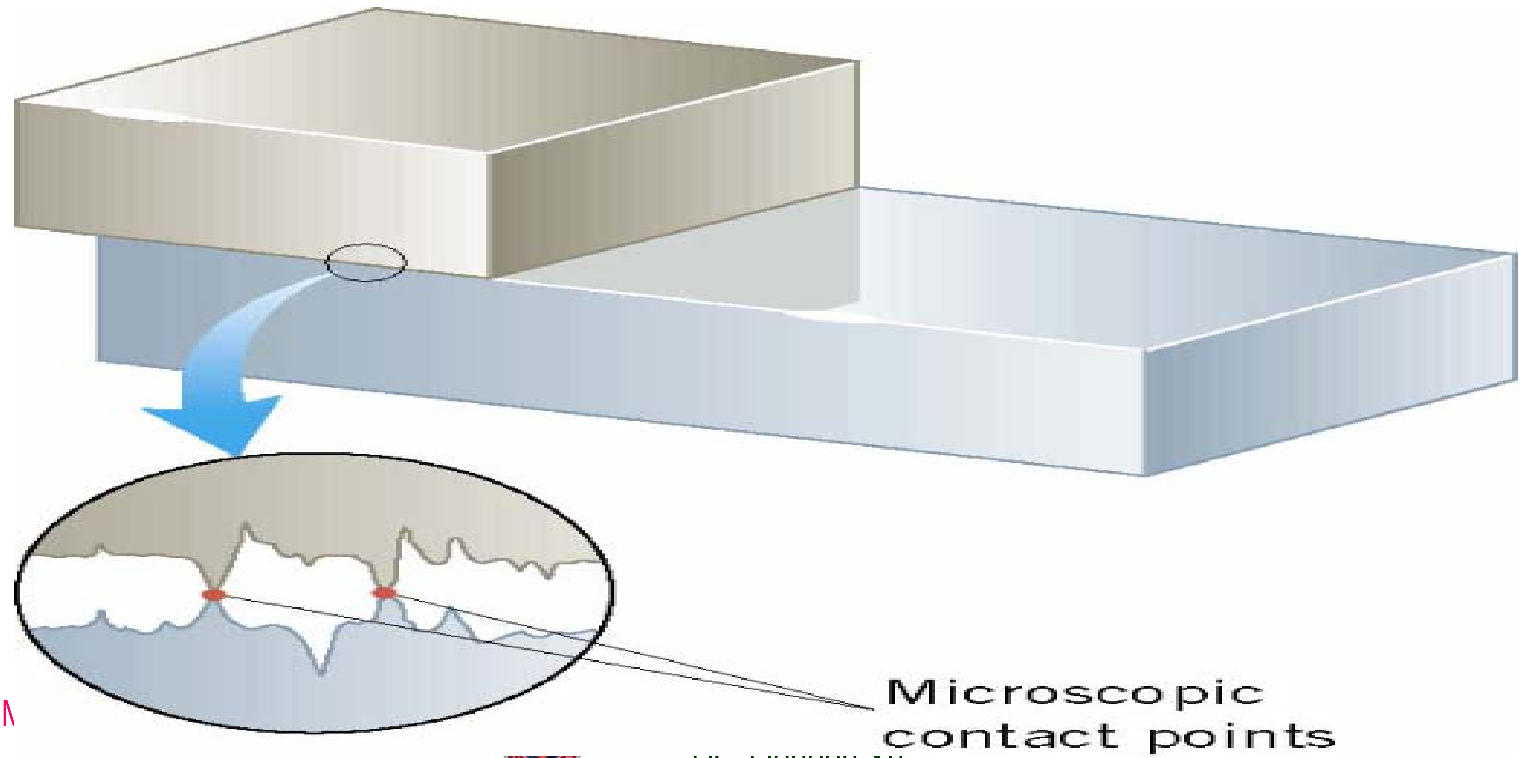
apparent weight

True weight

- What happens to the apparent weight when
  - the elevator is not moving — The same as true weight
  - the elevator is moving at a constant velocity — The same as true weight
  - the elevator is falling since its cables broke — 0

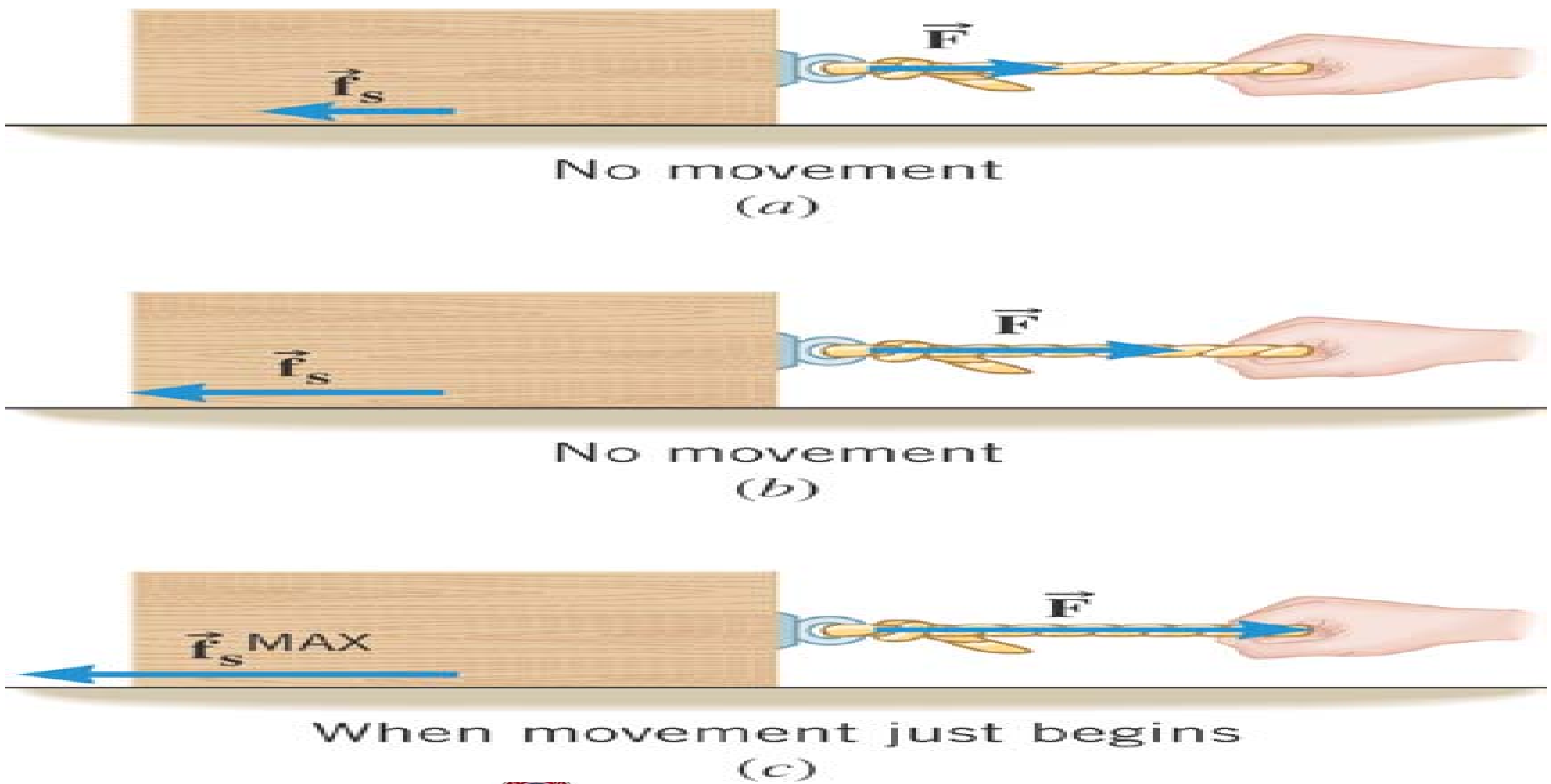
Frictional Forces

When an object is in contact with a surface there is a force acting on that object. The component of this force that is parallel to the surface is called the ***frictional force***. *Resistive force exerted on a moving object due to viscosity or other types frictional property of the medium in or surface on which the object moves. Always opposite to the movement!!*



Static Friction

When the two surfaces are not sliding across one another the friction is called *static friction*. ***The resistive force exerted on the object up to the time just before the object starts moving.***



Magnitude of Static Friction

The magnitude of the static frictional force can have any value from zero up to a maximum value.

$$f_s \le f_s^{MAX}$$

$$f_s^{MAX} = \mu_s F_N$$

$0 < \mu_s < 1$ is called the coefficient of static friction.

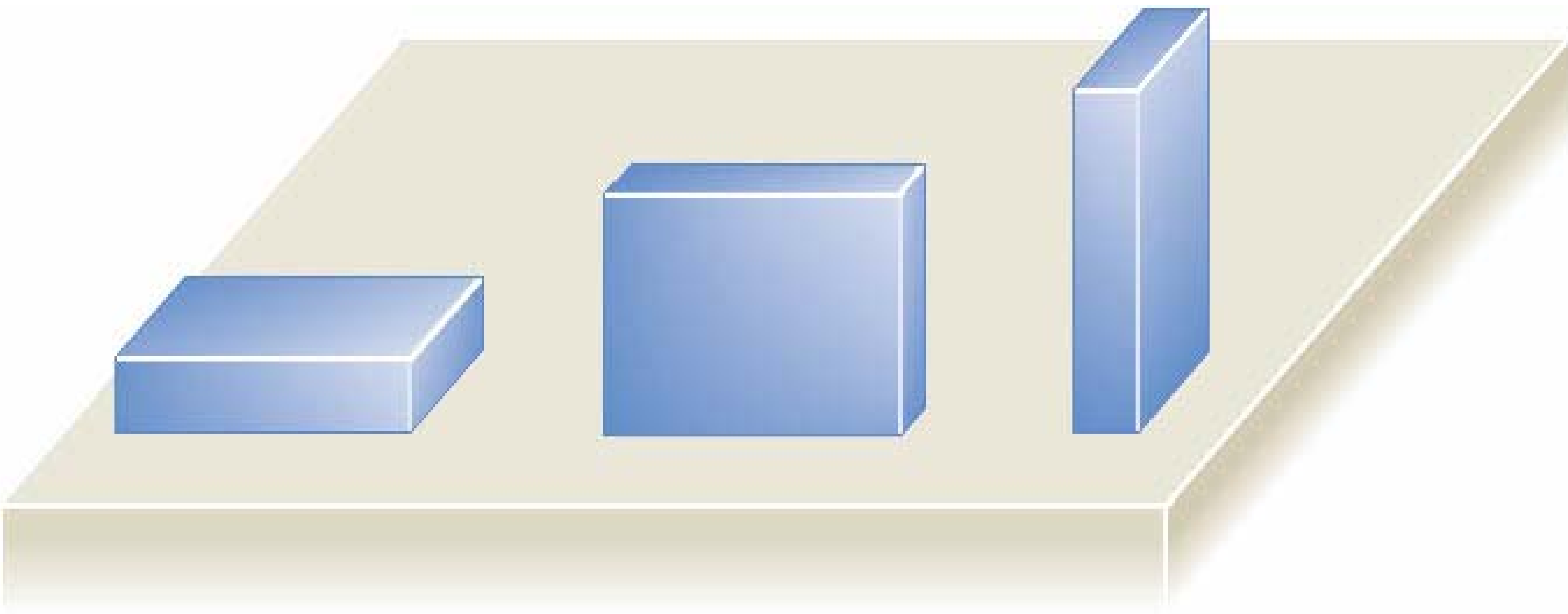
What is the unit? None

Once the object starts moving, there is NO MORE static friction!!

Kinetic friction applies during the move!!

Note that the magnitude of the frictional force <u>does not depend on the contact area of the surfaces</u>.

$$f_s^{MAX} = \mu_s F_N$$



Kinetic Friction

Static friction opposes the *impending* relative motion between two objects.

Kinetic friction opposes the relative sliding motion motions that actually does occur. ***The resistive force exerted on the object during its movement.***

$$f_k = \mu_k F_N$$

$$0 < \mu_s < 1$$ is called the coefficient of kinetic friction.

What is the direction of frictional forces? opposite to the movement

Coefficient of Friction

Table 4.2 **Approximate Values of the Coefficients of Friction for Various Surfaces***

Materials	Coefficient of Static Friction, μ_s	Coefficient of Kinetic Friction, μ_k
Glass on glass (dry)	0.94	0.4
Ice on ice (clean, 0 °C)	0.1	0.02
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Steel on ice	0.1	0.05
Steel on steel (dry hard steel)	0.78	0.42
Teflon on Teflon	0.04	0.04
Wood on wood	0.35	0.3

*The last column gives the coefficients of kinetic friction, a concept that will be discussed shortly.