

LECTURE VII

Force and Motion (cont.)

VII.1. Newton's 3rd Law

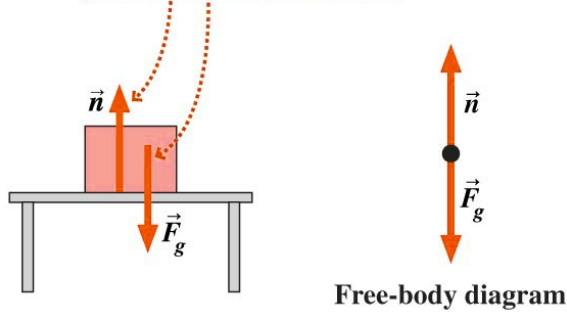
Newton's 3rd law is often called "action-reaction" law. It means that if an object A exerts a force \vec{F}_{AB} on an object B, then the object B also exerts a force, say \vec{F}_{BA} , on the object A, and that $\vec{F}_{AB} = -\vec{F}_{BA}$. It is extremely important to realize that \vec{F}_{AB} and \vec{F}_{BA} act on different objects, namely object B and object A respectively. [If the two forces acted on a single object, the result will be zero net force! If this were true in general, then there would be never any net force acting on any object.] Also, the two forces \vec{F}_{AB} and \vec{F}_{BA} , often referred to as "interaction force pair" or "3rd-law pair", must have the same nature. For instance, a gravitational force and an electro-magnetic force cannot form a 3rd-law pair.

7.1. DEFINITION. Normal Force

Normal force refers to the repulsive force that acts between two bodies in contact. The direction of the force is always normal to the surface of contact, and hence the name. This force is electromagnetic in nature.

7.2. NOTE. Normal force and gravitational force acting on the same body are not Newton's 3rd law pair forces! There are at least three reasons why they are not Newton's 3rd law pair forces. (1) Normal force, an electro-magnetic force, and gravitational force, have different natures. (2) If they act on the same body, then they cannot be 3rd law pair. (3) Normal force and gravitational force do not cancel each other if the body is put on a slope.

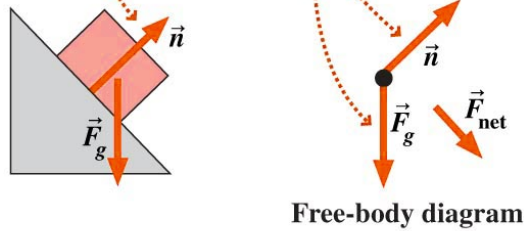
The upward normal force from the table and the downward force due to gravity are not an action/reaction pair of Newton's third law.



(a)

The normal force acts perpendicular to the surface.

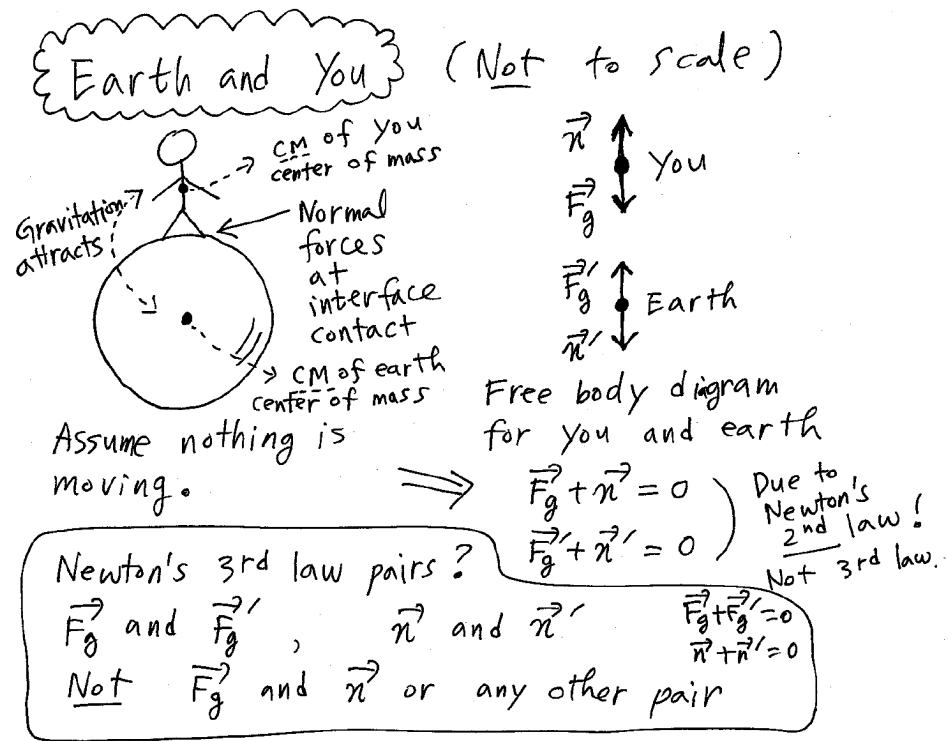
The normal force and gravitational force do not balance, so the block slides down the slope.



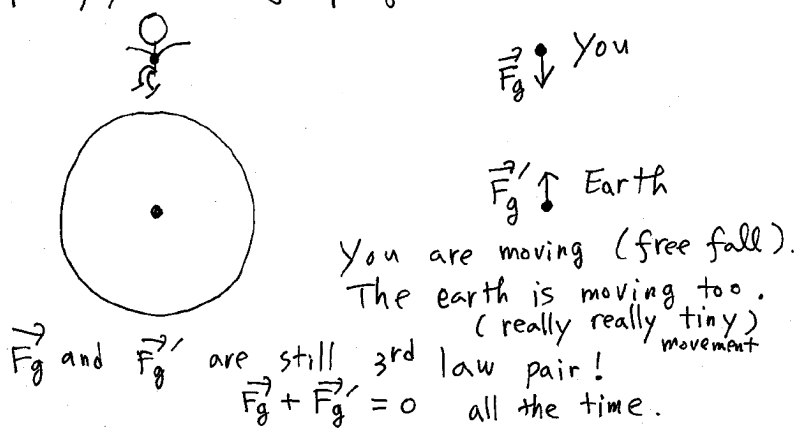
(b)

Copyright © 2007 Pearson Education, Inc., publishing as Pearson Addison-Wesley.

7.3. EXAMPLE. The following diagram should be studied very carefully.

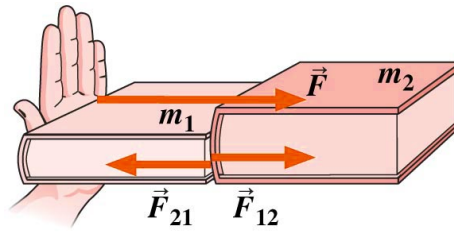


Now, you are jumping. \vec{n} and \vec{n}' disappear.

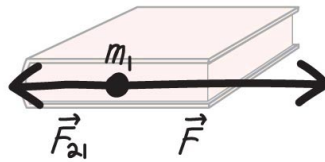


7.4. EXAMPLE. Pushing books [Example 4.4 of textbook]

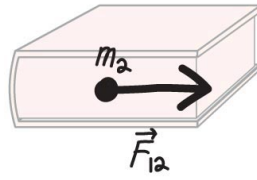
Pushing two books in contact with force \vec{F} . m_1 and m_2 . What is the force that the 2nd book exerts on the 1st book? Ans: $\vec{F} = (m_1 + m_2)\vec{a}$. (1) Using the 3rd law: For the book 2, $\vec{F}_{12} = m_2\vec{a} = \frac{m_2}{m_1+m_2}\vec{F}$. $\vec{F}_{21} = -\vec{F}_{12}$ (3rd law), and so $\vec{F}_{21} = -\frac{m_2}{m_1+m_2}\vec{F}$. (2) Without using the 3rd law: For the book 1, $\vec{F} + \vec{F}_{21} = m_1\vec{a}$. So, $\vec{F}/(m_1 + m_2) = (\vec{F} + \vec{F}_{21})/m_1$. $\vec{F}_{21} = (\frac{m_1}{m_1+m_2} - 1)\vec{F} = -\frac{m_2}{m_1+m_2}\vec{F}$.



(a)



(b)



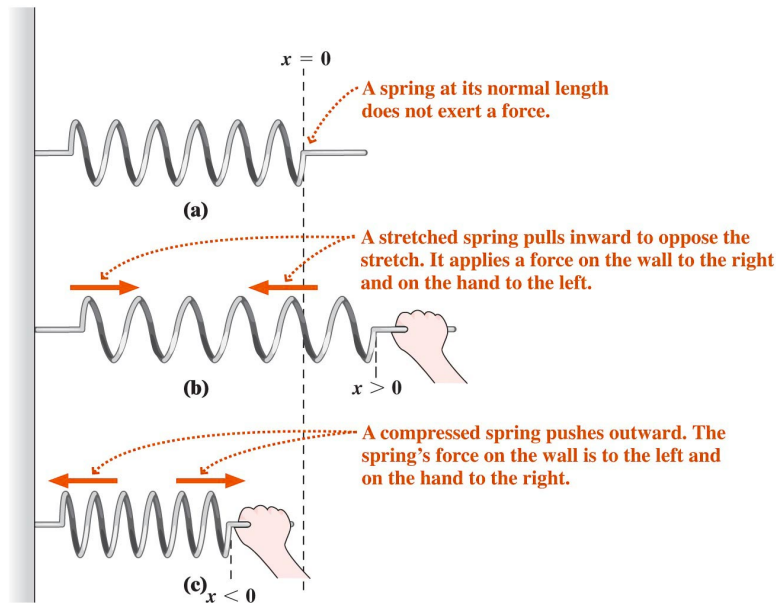
(c)

Copyright © 2007 Pearson Education, Inc., publishing as Pearson Addison-Wesley.

7.5. LAW. Hooke's Law

For an ideal spring, the spring force $F_{sp} = -kx$

k =spring constant, x =the difference of the length of the spring and its equilibrium length. F_{sp} is the force of the spring that acts on the object connected to the spring. The meaning of the minus sign in the above equation is this: F_{sp} opposes the change of length, x . Thus, the actual direction of F_{sp} **depends on** which end of the spring we consider.



Copyright © 2007 Pearson Education, Inc., publishing as Pearson Addison-Wesley.

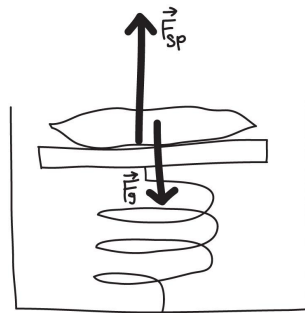
By using Hooke's law, we can build a scale to measure the weight. However, the true weight must be measured in an inertial frame. In an accelerating frame, the spring scale does not give you the correct weight (it gives you only an apparent weight).

7.6. EXAMPLE. Weighing in a helicopter [Example 4.5 of textbook]

[Try to understand this problem in terms of your experience in an elevator.] Helicopter rises vertically. 35 kg bag on a spring scale. $k = 3.4 \text{ kN/m}$. How much does the spring compress (a) when the copter is at rest, (b) when it's accelerating upward at 1.9 m/s^2 ?

Ans: (a) $x = 35 \text{ kg} \times 9.8 \text{ m/s}^2 / k = \frac{35 \times 9.8}{3.4 \times 10^3} \text{ m} = 0.10 \text{ m} = 10 \text{ cm}$ (2 sig-fig's). (b) In this case, there is a net acceleration of the bag, so the net force must be equal ma . As the following diagram shows, $F_{sp} > F_g = mg$ and $F_{sp} - mg = ma$. So, $F_{sp} = mg + ma$.

$$x = \frac{m(g+a)}{k} = \frac{35 \times (9.8+1.9)}{3.4 \times 10^3} \text{ m} = 0.12 \text{ m} = 12 \text{ cm}.$$



Forces on the concrete

Copyright © 2007 Pearson Education, Inc., publishing as Pearson Addison-Wesley



Free-body diagram