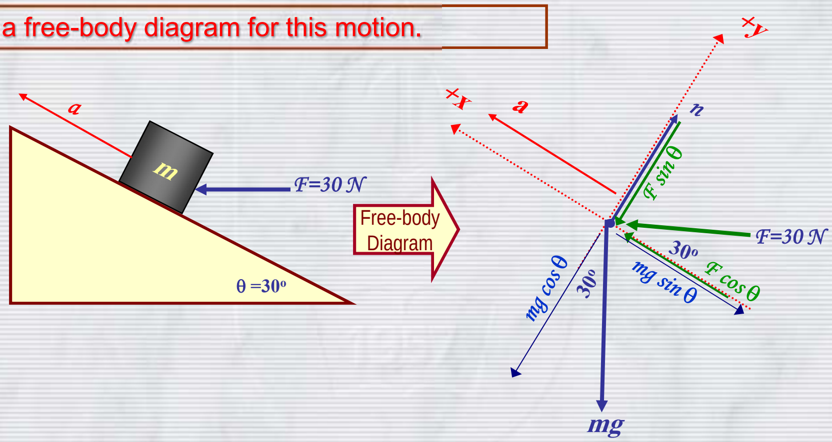
Example;

A 5 kg block is placed on a frictionless inclined plane of angle 30º and <u>pushed up the plane</u> with a horizontal force of magnitude 30 N.

Draw a free-body diagram for this motion.



What are the direction and magnitude of block's acceleration?

x comp.

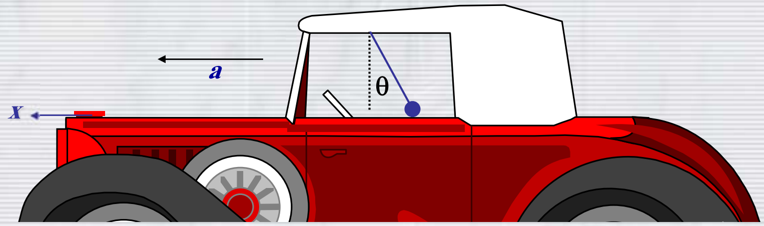
$$\sum F_x = ma$$

$$F\cos\theta - mg\sin\theta = ma$$

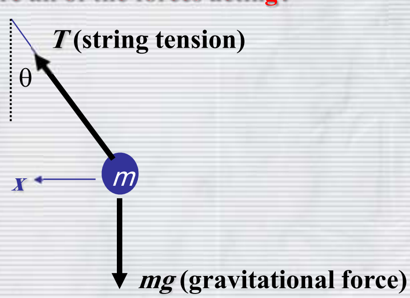
$$\therefore \quad a = \frac{F\cos\theta - mg\sin\theta}{m} = 0.3 \ m/s^2$$

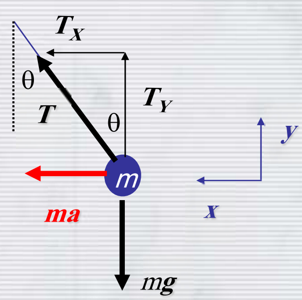
Example: Accelerometer

A weight of mass m is hung from the ceiling of a car with a massless string. The car travels on a horizontal road, and has an acceleration a in the x direction. The string makes an angle θ with respect to the vertical (y) axis. Solve for θ in terms of a and g.



Draw a free body diagram for the mass:
What are all of the forces acting?





- **Using components**

x: $F_X = T_X = T \sin\theta = ma$

y: $F_Y = T_Y - mg$

$= T \cos\theta - mg = 0$

- **Eliminate T:** ➡

$$\frac{T\sin\theta}{T\cos\theta} = \frac{ma}{mg}$$

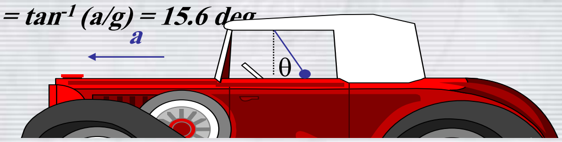
$$\tan\theta = \frac{a}{g}$$

Accelerometer

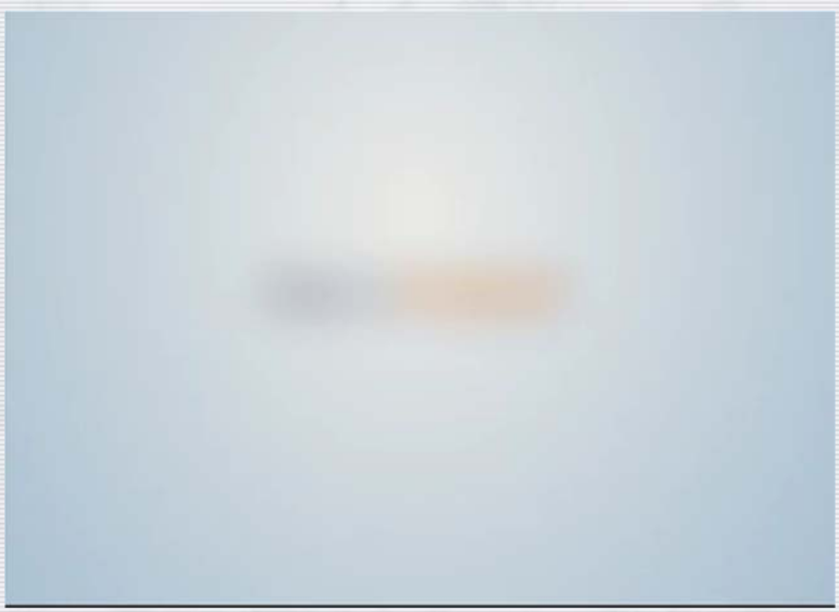
$$\tan\theta = \frac{a}{g}$$

- **Let's put in some numbers:**

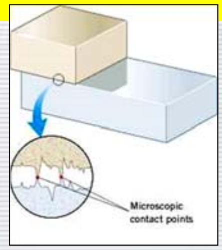
- **Say the car goes from 0 to 60 mph in 10 seconds:**
  - ***60 mph = 60 × 0.45 m/s = 27 m/s.***
  - **Acceleration** $a = \Delta v/\Delta t = 2.7\ m/s^2$.
  - **So** $a/g = 2.7 / 9.8 = 0.28$.
  - $\theta = \tan^{-1}(a/g) = 15.6$ deg



READ EXAMPLES 5.5 to 5.10

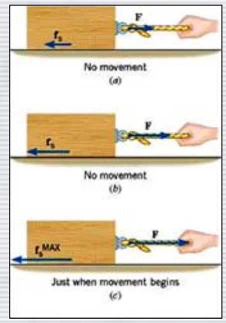


5.8 The Frictional Force:



The frictional force is also one component of the force that a surface exerts on an object with which it is in contact, namely, the component PARALLEL to the surface.

- The magnitude of the frictional force is related to the Normal force (how hard two objects push against one another).
- The magnitude of the frictional force also depends on whether or not the object is already in motion. It is more difficult to accelerate a stationary object than it is to accelerate an object already in motion when there is friction.



$$\text{Magnitude of "static" frictional force} = f_s^{MAX} = \mu_s F_N$$

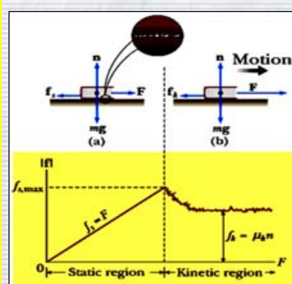
$$\text{Magnitude of "kinetic" frictional force} = f_k = \mu_k F_N$$

The following *empirical* laws hold true about friction:

- Friction force, f, is proportional to normal force, n.

$$f_s \le \mu_s n \qquad f_k = \mu_k n$$

- μ_s and μ_k: coefficients of static and kinetic friction, respectively
- Direction of frictional force is opposite to direction of relative motion
- Values of μ_s and μ_k depend on nature of surface.
- μ_s and μ_k don't depend on the area of contact
- μ_s and μ_k don't depend on speed.



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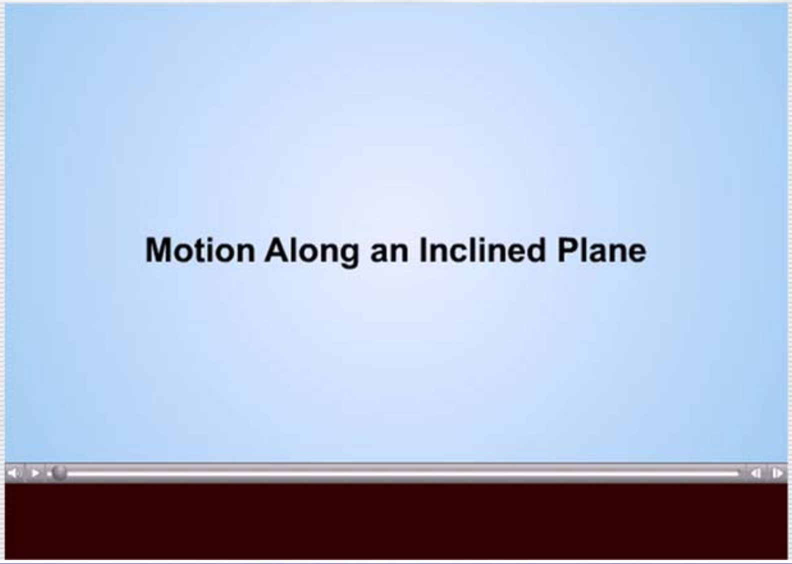
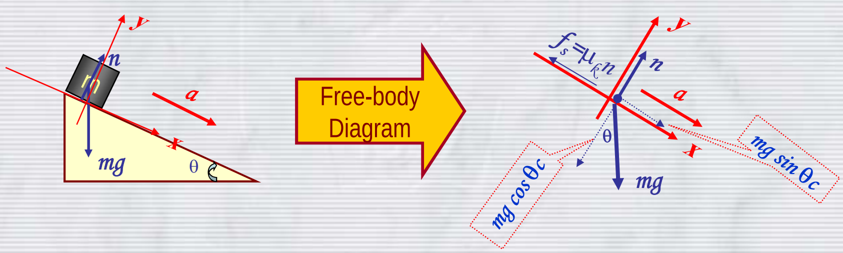


Example 5.12

Suppose a block is placed on a rough surface inclined relative to the horizontal. The inclination angle is increased till the block just starts to move. Show that by measuring this critical angle, θ_c, one can determine coefficient of static friction, μ_s.



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

x component $\sum F_x = mg \sin \theta_c - f_s = 0 \quad (1)$ Just to start or move with constant velocity

y component. $\sum F_y = n - mg \cos \theta_c = 0 \;\Rightarrow\; n = mg \cos \theta_c \quad (2)$

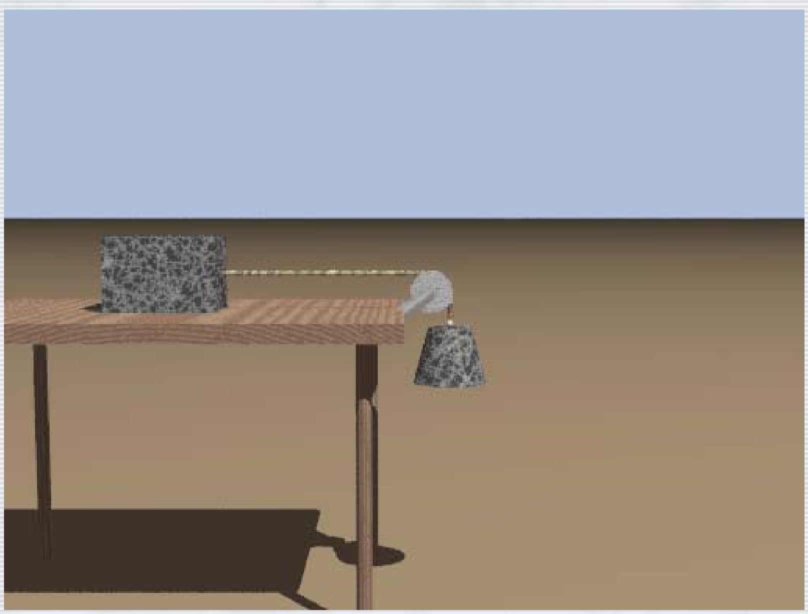
$\because \; f_s = \mu_s n$

Eq. (1) becomes;

$$mg \sin \theta_c - \mu_s mg \cos \theta_c = 0$$

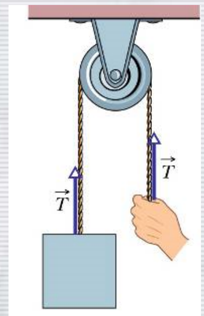
$$\mu_s = \frac{mg \sin \theta_c}{mg \cos \theta_c} = \tan \theta_c$$

READ EXAMPLES 5.13 and 5.14



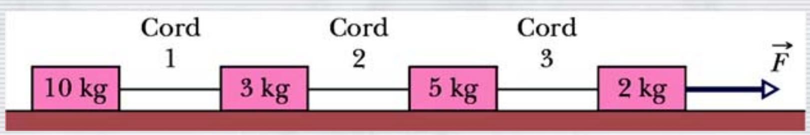
More questions

The body that is suspended by a rope in the figure has a weight of 75N.
Is *T* equal to, greater than or less than 75N when the body is moving downward at...



(a) increasing speed
1. less than
2. equal to
3. greater than

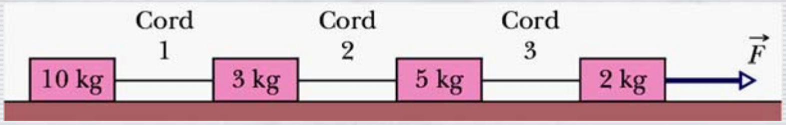
(b) decreasing speed
1. less than
2. greater than
3. equal to



The figure shows a train of four block being pulled across a frictionless floor by force *F*. What total mass is accelerated to the right by...

(a) Force *F*
1. 20
2. 2
3. 7
4. 10

(b) cord 3
1. 8
2. 20
3. 3
4. 18



cord 1
1. 20
2. 13
3. 18
4. 10

(d) Rank the blocks according to their accelerations, greatest first.
1. all tie
2. 1,2,3,4
3. 1,3,2,4
4. 4,3,2,1

(e) Rank the cords according to their tensions, greatest first.
1. all tie
2. 3,2,1
3. 1,3,2
4. 1,2,3

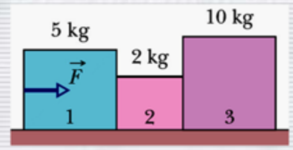
The figure shows a group of three blocks being pushed across a frictionless floor by a horizontal force *F.* What total mass is accelerated to the right ...

(a) by force *F*
1. 17
2. 5
3. 12
4. 7

(b) by force F_{21} on block 2 from block 1
1. 5
2. 2
3. 7
4. 12

(c) by force F_{32} on block 3 from block 2

1. 17
2. 12
3. 2
4. 10



(d) Rank the blocks according to the magnitude of their accelerations, greatest first.

1. 3,2,1
2. 1,2,3
3. all tie
4. 2,1,3

(e) Rank forces F, F_{21} and F_{32} according to their magnitude, greatest first.

1. all tie
2. F_{32}, F_{21}, F
3. F_{21}, F, F_{32}
4. F, F_{21}, F_{32}

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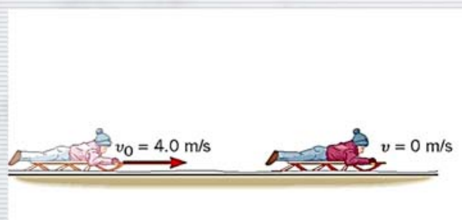
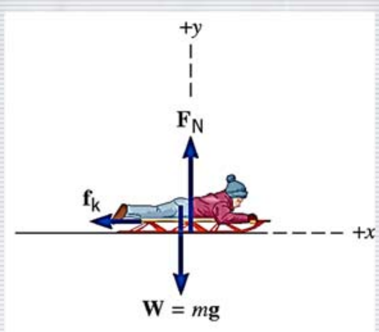
How far will the sled go before stopping?

If the initial velocity is 4 m/s and $\mu_k = 0.05$

What are the forces acting on the sled?





Net force in y-direction is zero!

Net force in x-direction:

$$F_x = \mu_k \times F_N$$

$$F_x = \mu_k \times m \times (-a_{grav})$$

$$F_x = (0.0500)(9.8 m/s^2)(m)$$

Frictional force is in the negative x-direction!

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$$F_x = \mu_k \times F_N$$

$$F_x = \mu_k \times m \times (-a_{grav})$$

$$F_x = (0.0500)(9.8\ m/s^2)(m)$$

Frictional force is in the negative x-direction!

$$a_x = \frac{F_x}{m} = \frac{-(0.0500)(9.8\ m/s^2)(m)}{m}$$

$$a_x = -0.49\ m/s^2$$

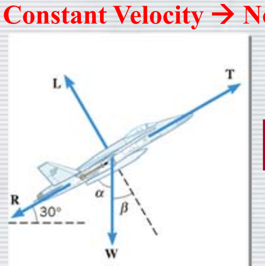
$$v_x^2 = v_{0,x}^2 + 2ax$$

$$x = \frac{v_x^2 - v_{0,x}^2}{2a} = 16.3\ m$$

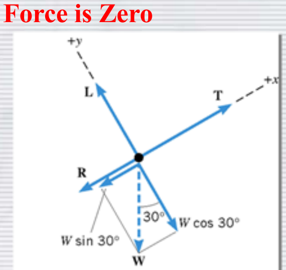
Example:

A jet travels with constant speed at an angle of 30 degrees above the horizontal. The plane has a weight whose magnitude is W=86,500 N. The engine provides a forward thrust of magnitude T=103,000 N. A lift force from the air (like a normal force) acts on the plane in a direction perpendicular to the wings. A drag force (like a kinetic friction) acts on the plane in a direction opposite the motion. Find the magnitude of the lift force and the drag force.

Constant Velocity → No Acceleration → Net Force is Zero



Free-body Diagram



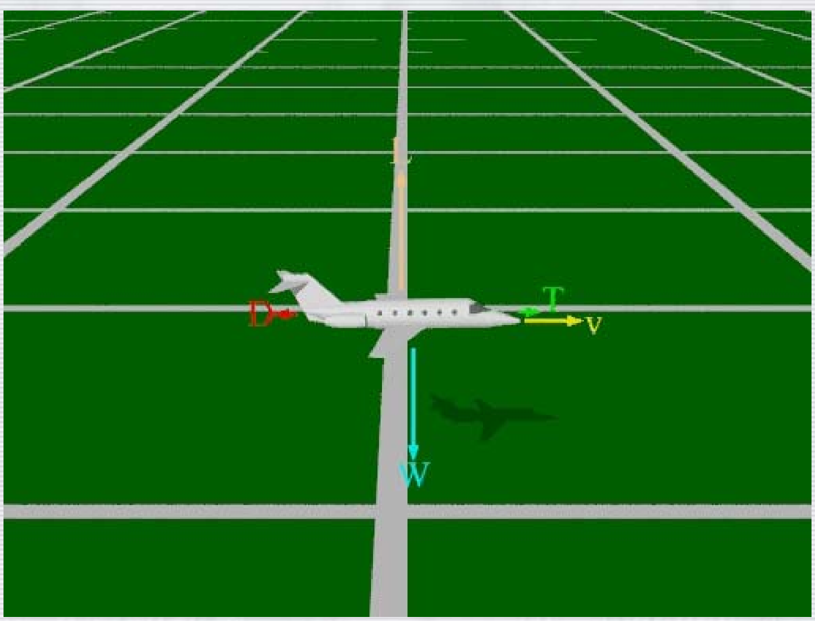
Example (continued)

$$\sum F_x = 0 = T - R - W \sin 30^\circ$$

$$R = T - W \sin 30^\circ$$
$$= 59750 \ N$$

$$\sum F_y = 0 = L - W \cos 30^\circ$$

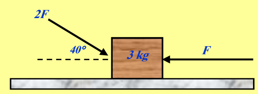
$$L = W \cos 30^\circ$$
$$= 74900 \ N$$

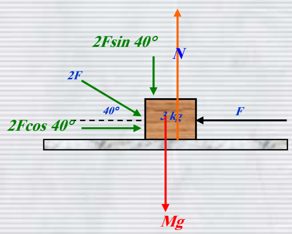


Previous Exams problems

The horizontal surface on which the block slides is frictionless. If F= 30 N and m=3 kg, what is the magnitude of the acceleration of the block?

(a) 6.4 m/s²
(b) 5.7 m/s²
(c) 6.1 m/s²
(d) 5.3 m/s²
(e) 2.8 m/s²





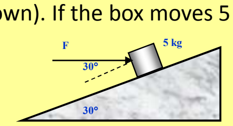
$$\sum F = ma$$

$$2F\cos\theta - F = ma$$

$$\therefore\ a = \frac{1}{m}(2F\cos\theta - F) = 5.32\ m/s^2$$

A 5 kg box is pushed up a 30⁰ rough incline by a 50N force (as shown). If the box moves 5 m at a constant speed, calculate

1) Show all the forces acting on the box.
2) Force of gravity.
3) The coefficient of friction between the box and the incline
4) The friction force



$(2)\quad W_g = mg\sin\theta = 24.5\ \ N$

$(3)\quad \sum F_x = ma \quad , \quad v = \text{constant} \quad \Rightarrow \quad a = 0$

$F\cos\theta\text{-}mg\sin\theta - f_k = 0$

$\therefore\quad f_k = F\cos\theta\text{-}mg\sin\theta = \mu_k N$

$\text{but}\quad \sum F_y = N - F\sin\theta - mg\cos\theta = 0$

$\therefore\quad N = F\sin\theta + mg\cos\theta = 67.435\ \ N$

$\Rightarrow\quad \mu_k = \dfrac{F\cos\theta\text{-}mg\sin\theta}{N} = 0.279$

$(4)\quad f_k = \mu_k N = 18.8\ \ N$