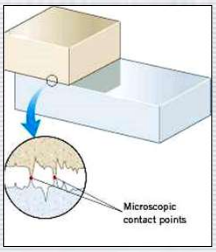
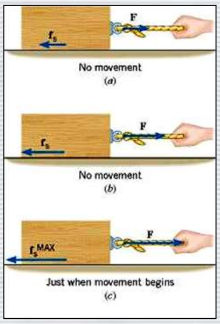
The Frictional Force:

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.**



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

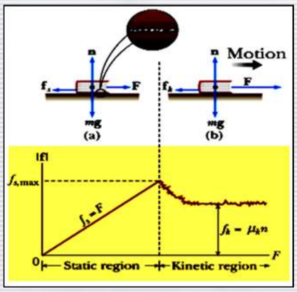
$$\text{Magnitude of "kinetic" frictional force} = f_k = \mu_k F_N$$

The following *empirical* laws hold true about friction:

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

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

- 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.



STATIC AND KINETIC FRICTION

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STATIC AND KINETIC FRICTION

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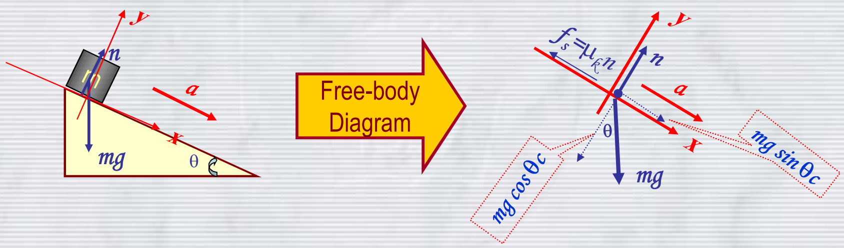
Example

وضعت كتلة على سطح خشن مائل بالنسبة إلى الأفقي. إذا زيدت زاوية الميل حتى تبدأ الكتلة في الحركة. أثبت أنه من خلال قياس هذه الزاوية الحرجة ، θ_c، يمكن للمرء تحديد معامل الاحتكاك الساكوني ، 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

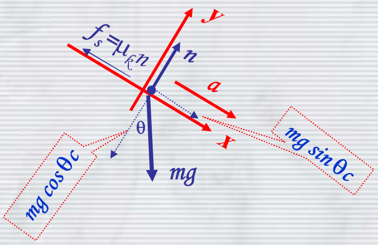
y component. $\sum F_y = n - mg\cos\theta_c = 0 \Rightarrow n = mg\cos\theta_c \quad (2)$

Eq. (1) becomes;

$\because \; f_s = \mu_s n$

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

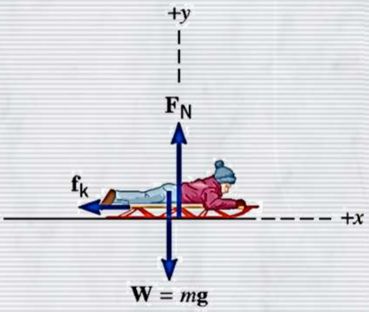
$$\mu_s = \frac{mg\sin\theta_c}{mg\cos\theta_c} = \tan\theta_c$$



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:

$$F_x = \mu_k \times F_N$$

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

$$F_x = (0.0500)(9.8\,\mathrm{m/s^2})(m)$$

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!

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

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

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

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

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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

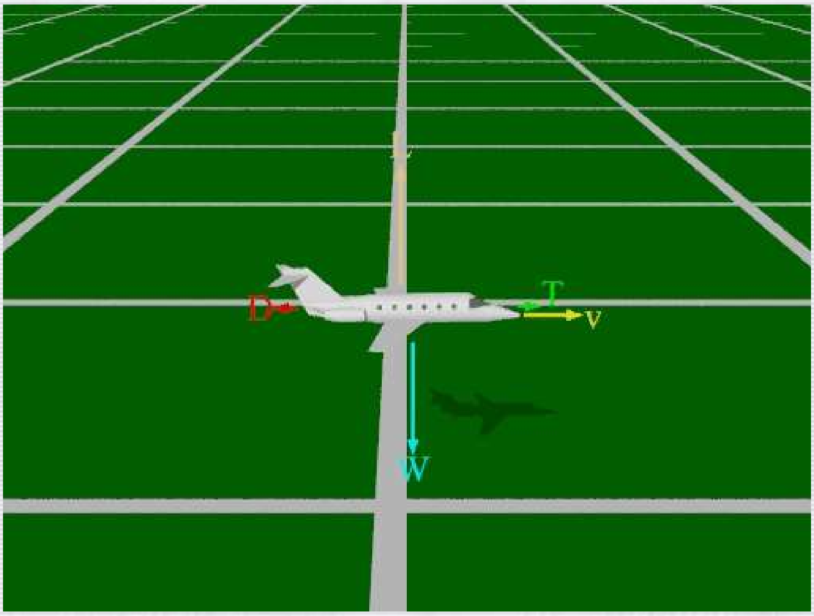
Example (continued)

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

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

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

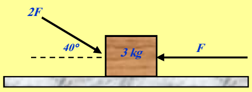
$$L = W \cos 30^\circ$$
$$= 74900 \ N$$

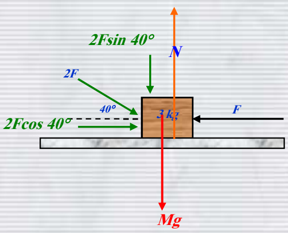


Previous Exams problems

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



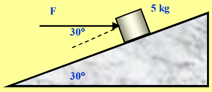


$$\sum F = ma$$

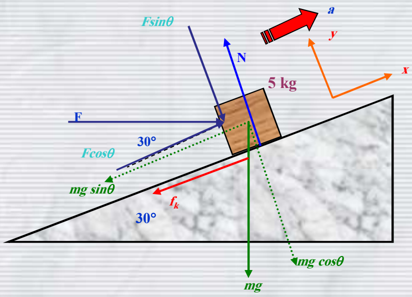
$$2F\cos\theta - F = ma$$

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

A 5 kg box is pushed up a 30^0 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



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

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

$$F\cos\theta - mg\sin\theta - f_k = 0$$

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

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

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

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

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

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