Lecture 6
BOOK CHAPTER 6

(Force and Motion-II)

6-2 Friction:

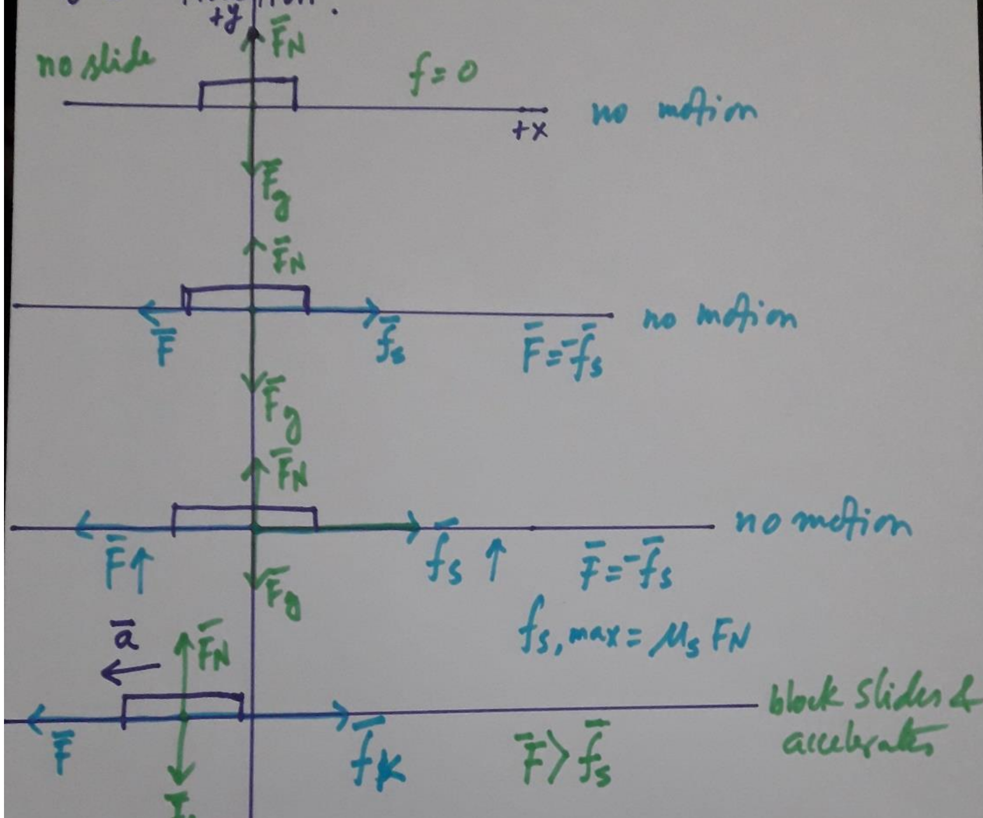


Fig. frictional force

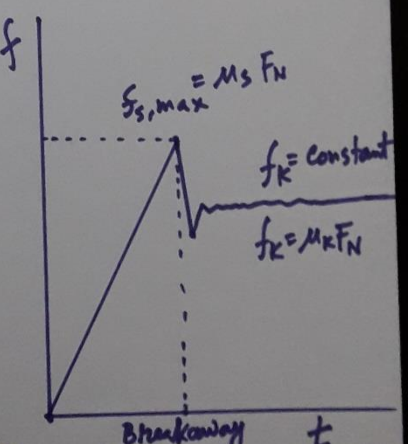


Fig: f as a function of t

6-3 Properties of friction:

Frictional force has three properties.

① $f_s \parallel F$

$$\vec{f}_s = -\vec{F}$$

② $f_{s,max} = \mu_s F_N$

normal force

coefficient of static friction

maximum static frictional force

③ $f_K = \mu_K F_N$

normal force

coefficient of kinetic friction

Kinetic frictional force

6-1 FRICTION:

There is no attempt at sliding. Thus, no friction and no motion.

Frictional force = 0

Force $\vec{F}$ attempts sliding but is balanced by the frictional force. No motion.

Frictional force = F

Force $\vec{F}$ is now stronger but is still balanced by the frictional force. No motion.

Frictional force = F

Force $\vec{F}$ is now even stronger but is still balanced by the frictional force. No motion.

Frictional force = F

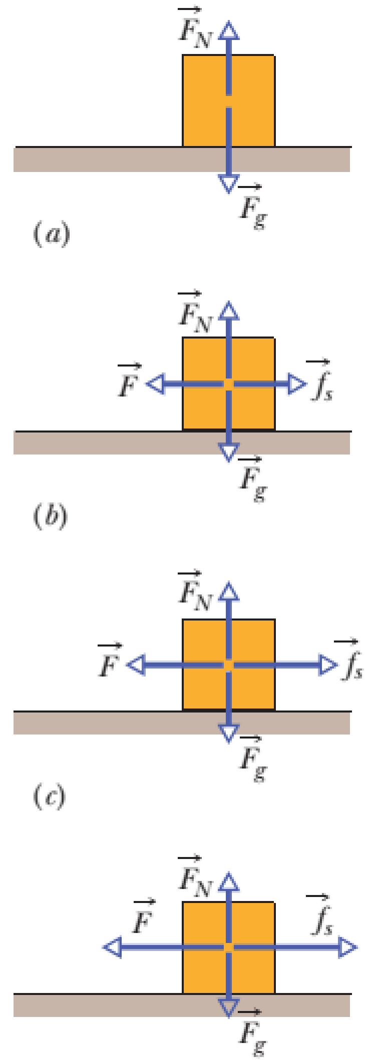


Figure 6-1 (*a*) The forces on a stationary block. (*b–d*) An external force $\vec{F}$, applied to the block, is balanced by a static frictional force $\vec{f}_s$. As F is increased, f_s also increases, until f_s reaches a certain maximum value. (*Figure continues*)

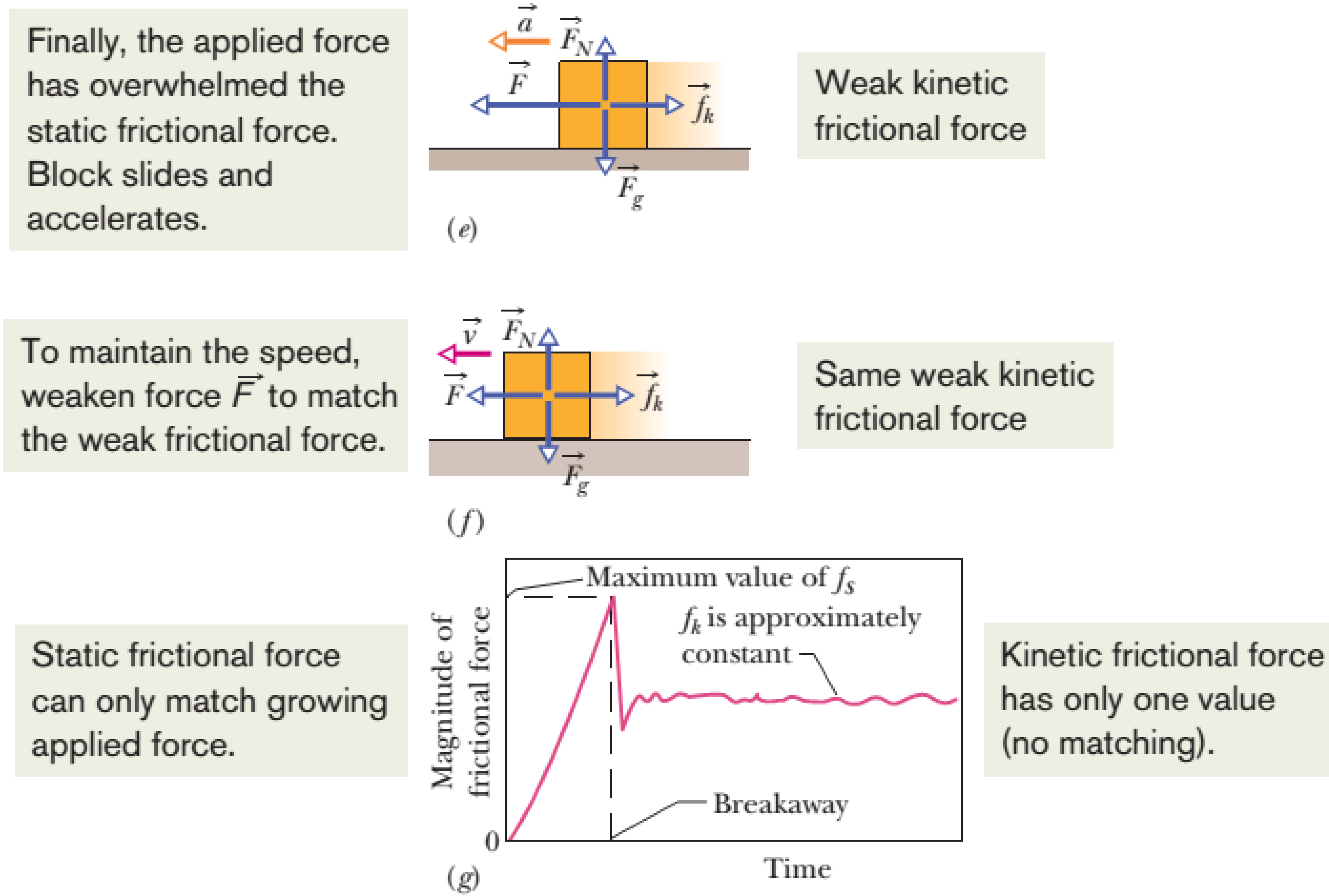


Figure 6-1 (*Continued*) (*e*) Once f_s reaches its maximum value, the block "breaks away," accelerating suddenly in the direction of $\vec{F}$. (*f*) If the block is now to move with constant velocity, F must be reduced from the maximum value it had just before the block broke away. (*g*) Some experimental results for the sequence (*a*) through (*f*). **In *WileyPLUS*, this**

Properties of friction:

Property 1. If the body does not move, then the static frictional force and the component of that is parallel to the surface balance each other. They are equal in magnitude, and is directed opposite that component of F.

$$f_s = - F_x$$

Property 2. The magnitude of has a maximum value fs, max that is given by

$$f_{s,max} = \mu_s F_N$$

where ms is the coefficient of static friction and F_N is the magnitude of the normal force on the body from the surface.
If the magnitude of the component of that is parallel to the surface exceeds fs, max, then the body begins to slide along the surface.

Property 3. If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a value fk given by

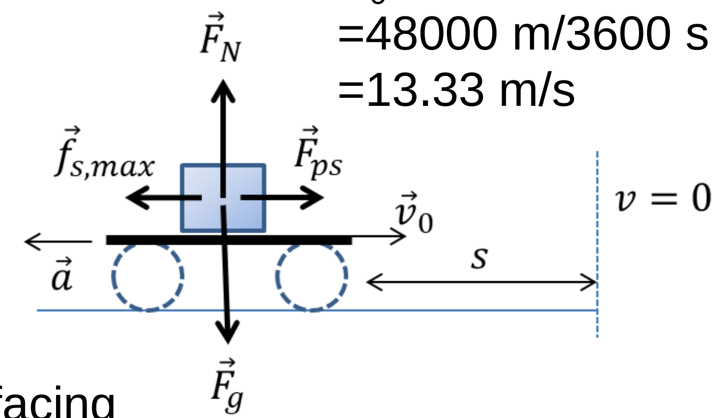
$$f_k = \mu_k F_N$$

where mk is the coefficient of kinetic friction.
Thereafter, during the sliding, a kinetic frictional force opposes the motion.

Problem 1 (Book chapter 6)

The floor of a railroad flatcar is loaded with loose crates having a coefficient of static friction of 0.25 with the floor. If the train is initially moving at a speed of 48 km/h, in how short a distance can the train be stopped at constant acceleration without causing the crates to slide over the floor?

V_0= 48 km/h
=48000 m/3600 s
=13.33 m/s



Answer:

Since the crates are not sliding, the net force on the crates along horizontal axis (x-axis) is zero. That is

$$F_{ps} + (-f_{s,max}) = 0$$

[Assuming the crates facing maximum static friction because they are not sliding]

$$F_{ps} = f_{s,max}$$

$$ma = \mu_s F_N = \mu_s mg$$

[Since, along vertical axis (y-axis), $F_N - mg = 0$

$$a = \mu_s g = (0.25)(9.8) = 2.45\ m/s^2$$

To find the value of s for the train, we use the formula

$$v^2 = v_0^2 + 2(-a)s$$

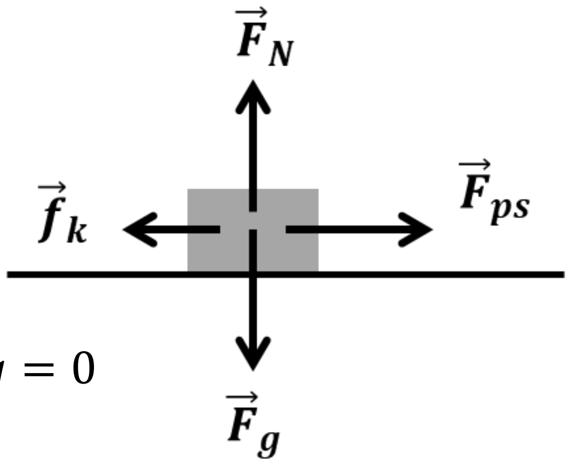
[a is negative for the train]

$$0 = (13.33)^2 + 2(-2.45)s$$

$$s = \frac{177.69}{4.9} = 36.26\ m$$

Problem 7 (Book chapter 6)

A person pushes horizontally with a force of 220 N on a 55 kg crate to move it across a level floor. The coefficient of kinetic friction between the crate and the floor is 0.35. What is the magnitude of (a) the frictional force and (b) the acceleration of the crate?



Answer:

(a) For the kinetic frictional force, we have

$$f_k = \mu_k F_N = \mu_k(mg)$$

[Along y-axis, $F_N - mg = 0$
Therefore, $F_N = mg$]

$$f_k = (0.35)(55)(9.8) = 188.65\ N$$

(b) The net force along x-axis, [where a is the acceleration of the crate along x-axis]

$$F_{ps} - f_k = ma$$

$$220 - 188.65 = (55)a$$

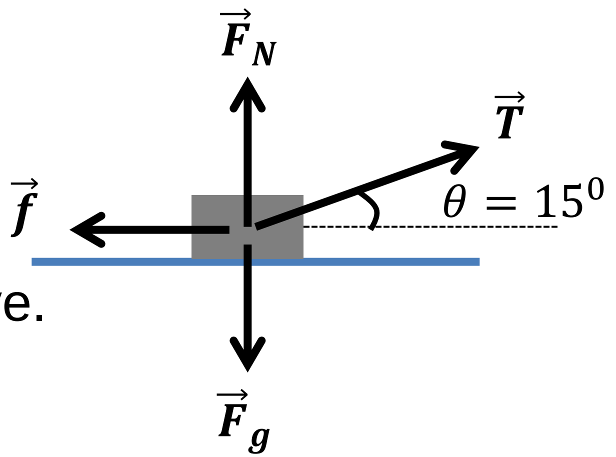
$$31.35 = (55)a$$

Therefore,

$$a = \frac{31.35}{55} = 0.57\ m/s^2$$

Problem 11 (Book chapter 6)

A 68 kg crate is dragged across a floor by pulling on a rope attached to the crate and inclined 15^0 above the horizontal. (a) If the coefficient of static friction is 0.50, what minimum force magnitude is required from the rope to start the crate moving? (b) If $\mu_k = 0.35$, what is the magnitude of the initial acceleration of the crate?



Answer:

Ty = $T \sin\theta$ and Tx = $T\cos\theta$

The cerate is facing maximum static frictional force ($f_{s,max}$), because it is just start to move.

Hence, the net force along x-axis is

$$T\cos\theta - f_{s,max} = 0$$

$$T\cos\theta - \mu_s F_N = 0$$

$$T\cos\theta = \mu_s F_N$$

$$T = \frac{\mu_s F_N}{\cos\theta} = \frac{0.50 F_N}{\cos 15^0} = \frac{0.50 F_N}{0.9659}$$

$$T = 0.5176\, F_N \quad \text{------------------} \quad (1)$$

The net force along y-axis is: Newton's 2nd law

$$F_N + T\sin\theta - mg = 0$$

$$F_N = mg - T\sin\theta$$

$$F_N = (68)(9.8) - T\sin 15^0$$

$$F_N = 666.4 - 0.2588\, T \quad \text{------------------} \quad (2)$$

By substituting the value of F_N $from\ equation$ (2) $in\ equation$ (1), $we\ get$

$$T = 0.5176(666.4 - 0.2588\,T)$$

$$T = 344.93 - 0.134\,T$$

$$T + 0.134T = 344.93$$

$$1.134\,T = 344.93$$

$$T = \frac{344.93}{1.134} = 304.17\,N$$

(b) Now, we assume that the crate is moving with an acceleration a.

Hence, the net force along x-axis is

$$T\cos\theta - f_k = ma$$

$$T\cos\theta - \mu_k F_N = ma$$

$$a = \frac{T\cos\theta - \mu_k(666.4 - 0.2588\,T)}{m}$$

$$a = \frac{304.17\cos 15^0 - 0.35[666.4 - (0.2588)(304.17)]}{68}$$

$$a = \frac{(304.17)(0.9615) - 233.24 + 27.55)}{68} = \frac{86.769}{68} = 1.276\ m/s^2$$