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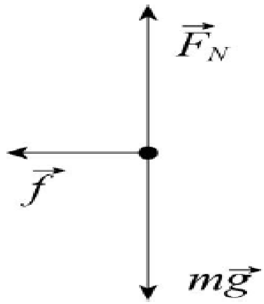
Chapter: Problems Based on Friction (EE117) Worksheet # 04

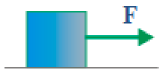
Q1. A baseball player with mass m = 79 kg, sliding into second base, is retarded by a frictional force of magnitude 470 N. What is the coefficient of kinetic friction μ_k between the player and the ground?

Solution: The free-body diagram for the player is shown to the right. F_N is the normal force of the ground on the player, mg is the force of gravity, and f is the force of friction. The force of friction is related to the normal force by $f = k F_N$. We use Newton's second law applied to the vertical axis to find the normal force. The vertical component of the acceleration is zero, so we obtain $F_N - mg = 0$; thus, $F_N = mg$. Consequently,

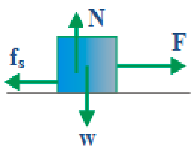
$$\mu_k = \frac{f}{F_N} = \frac{470\ \text{N}}{(79\ \text{kg})\ (9.8\ \text{m/s}^2)} = 0.61.$$



Q2. An object rests on a horizontal floor. The coefficient static friction is 0.4 and acceleration of gravity is 9.8 m/s2. Determine (a) The maximum force of the static friction (b) The minimum force of F



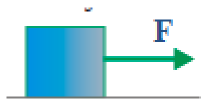
Given:
Mass (m) = 1 kg
The coefficient static friction (μ_s) = 0.4
The acceleration of gravity (g) = 9.8 m/s^2
Weight (w) = m g = (1 kg) (10 m/s2) = 10 kg m/s^2 = 10 Newton
Normal force (N) = w = 10 Newton



Required:
(a) The maximum force of the static friction (b) The minimum force of F

Solution:
(a) The maximum force of the static friction
fs = μ_s N
fs = (0.4) (9.8 N) = 3.92 Newton
(b) The minimum force of F
If the force F is exerted on the object but the object isn't moved, so there must be the force of static friction exerted by the floor on the object. If the object will start to move, the force of the static friction is exceeded, there must be the force of the kinetic friction. Object start moves if F is greater than the maximum force of the static friction.
So the minimum force of F = maximum force of the static friction = 3.92 Newton.

Q3. 1 kg box is pulled along a horizontal surface by a force F, so the box is moving at a constant velocity. If the coefficient kinetic friction is 0.1, determine the magnitude of the force F. ($g = 9.8\ m/s^2$)



Given:

The coefficient kinetic friction (μ_k) = 0.1
Box's mass (m) = 1 kg
Acceleration of gravity (g) = $9.8\ m/s^2$
Weight (w) = m g = $(1\ kg)(9.8\ m/s^2)$ = 9.8 kg m/s2 = 9.8 Newton
Normal force (N) = w = 9.8 Newton

Required : F

Solution :

Newton's first law states that if no net force acts on an object, every object continues in it's state of rest, or constant velocity in a straight line.
So if the object moves at a constant velocity, there must no net force ($\Sigma F = 0$). Force F is exerted on the object in the right direction so that the force of the kinetic friction is exerted on the object to the left direction.

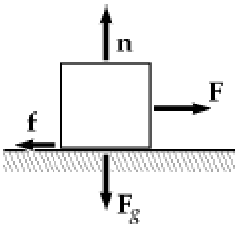
$\sum F = 0$
$F - f_k = 0$
$F = f_k$

The force of the kinetic friction:
$f_k = \mu_k N = (0.1)(9.8\ N) = 0.98$ Newton
object moves with constant velocity, $F = f_k = 0.98$ Newton

Q4. A 25.0-kg block is initially at rest on a horizontal surface. A horizontal force of 75.0 N is required to set the block in motion. After it is in motion, a horizontal force of 60.0 N is required to keep the block moving with constant speed. Find the coefficients of static and kinetic friction from this information.

Solution:

For equilibrium: $f = F$ and $n = F_g$. Also, $f = \mu n$ i.e.,



$$\mu = \frac{f}{n} = \frac{F}{F_g}$$

$$\mu_s = \frac{75.0\ N}{25.0(9.80)\ N} = \boxed{0.306}$$

and

$$\mu_k = \frac{60.0\ N}{25.0(9.80)\ N} = \boxed{0.245}.$$

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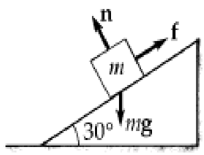
Q5. A 3.00-kg block starts from rest at the top of a 30.0°incline and slides a distance of 2m down the incline in 1.50 s. Find (a) the magnitude of the acceleration of the block, (b) the coefficient of kinetic friction between block and plane, (c) the friction force acting on the block, and (d) the speed of the block after it has slid 2.00 m.

$m = 3.00\text{ kg},\ \theta = 30.0°,\ x = 2.00\text{ m},\ t = 1.50\text{ s}$



(a) $x = \frac{1}{2}at^2$:

$$2.00\text{ m} = \frac{1}{2}a(1.50\text{ s})^2$$
$$a = \frac{4.00}{(1.50)^2} = \boxed{1.78\text{ m/s}^2}$$

$\sum \mathbf{F} = \mathbf{n} + \mathbf{f} + m\mathbf{g} = m\mathbf{a}$:

$$\text{Along } x:\quad 0 - f + mg\sin 30.0° = ma$$
$$f = m(g\sin 30.0° - a)$$
$$\text{Along } y:\quad n + 0 - mg\cos 30.0° = 0$$
$$n = mg\cos 30.0°$$

(b) $\mu_k = \frac{f}{n} = \frac{m(g\sin 30.0° - a)}{mg\cos 30.0°}$, $\mu_k = \tan 30.0° - \frac{a}{g\cos 30.0°} = \boxed{0.368}$

(c) $f = m(g\sin 30.0° - a)$, $f = 3.00(9.80\sin 30.0° - 1.78) = \boxed{9.37\text{ N}}$

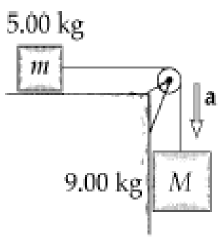
(d) $v_f^2 = v_i^2 + 2a(x_f - x_i)$

where $x_f - x_i = 2.00\text{ m}$

$$v_f^2 = 0 + 2(1.78)(2.00) = 7.11\text{ m}^2/\text{s}^2$$
$$v_f = \sqrt{7.11\text{ m}^2/\text{s}^2} = \boxed{2.67\text{ m/s}}$$

Q6. A 9.00-kg hanging weight is connected by a string over a pulley to a 5.00-kg block that is sliding on a flat table (Fig.). If the coefficient of kinetic friction is 0.200, find the tension in the string.

Solution:



$T - f_k = 5.00a$ (for 5.00 kg mass)

$9.00g - T = 9.00a$ (for 9.00 kg mass)

Adding these two equations gives:

$$9.00(9.80) - 0.200(5.00)(9.80) = 14.0a$$
$$a = 5.60\text{ m/s}^2$$
$$\therefore T = 5.00(5.60) + 0.200(5.00)(9.80)$$
$$= \boxed{37.8\text{ N}}$$