Lecture 17

Fri: HW by 5pm

Mon: Warm Up 7 (D2L)

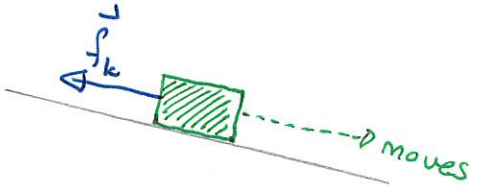
Today: Physics Club (SPS) noon, Wubben 218

Friction

Friction is a force exerted by one surface on another and it tends to oppose motion. There are two common types of friction that we consider:

1) Kinetic friction

This occurs when one surface slides relative to another. This has properties:



* direction = parallel to surface and opposite to motion
* magnitude = $f_k = \mu_k n$

where n = normal force

μ_k = coefficient of kinetic friction. (depends on the materials of the two surfaces)

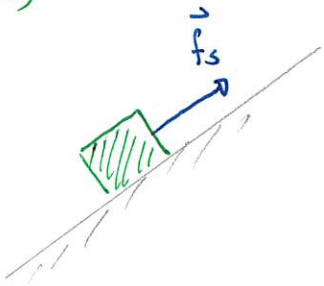
Quiz 1 85% – 70%
20% – 90%

Quiz 2 50% – 80%
50% – 70%

2) Static friction

Do example then this

This occurs when two surfaces do not slide but in the absence of friction they might. This has properties:



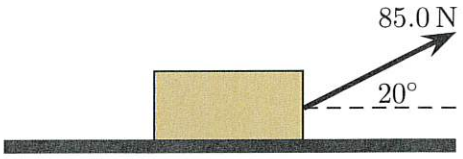
* direction = parallel to surface and opposite to direction in which motion would occur.
* magnitude = adjustable up to a maximum

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

where μ_s = coefficient of static friction (depends on the materials of the surface.)

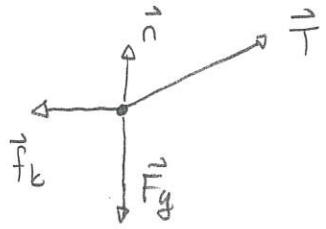
188 Dynamics of a single object with friction, 2

A 15.0 kg box moves rightward along a horizontal surface. A rope pulls with a force at the illustrated angle. The coefficient of kinetic friction is 0.350. Use *all of the steps of Newton's Second Law* to determine the acceleration of the box. *(131F2024)*



Answer:

Step ① FBD



Step ② $\Sigma F_{ix} = ma_x$

$\Sigma F_{iy} = ma_y = 0$ since no vertical motion

Step ③ $F_g = mg = 15\text{kg} \times 9.8\text{m/s}^2 = 147\text{N}$

$f_k = \mu_k n = 0.350n$

Step ④ Components

$T_x = T\cos 20°$

$= 85.0\text{N}\cos 20° = 79.9\text{N}$

$T_y = T\sin 20°$

$= 85.0\text{N}\sin 20° =$

	x	y
$\vec{F}_g$	0	-147N
$\vec{n}$	0	n
$\vec{T}$	79.9N	29.1N
$\vec{f}_k$	$-0.350n$	0

Step ⑤ Use Newton's 2nd Law

$\Sigma F_{ix} = ma_x \Rightarrow$ $79.9\text{N} - 0.350n = 85.0\text{kg}\, a_x$

$\Sigma F_{iy} = 0 \Rightarrow$ $-147\text{N} + n + 29.1\text{N} = 0 \Rightarrow n = 118\text{N}$

Then $79.9\text{N} - 0.350 \times 118\text{N} = 85.0\text{kg}\, a_x \Rightarrow 38.6\text{N} = 85.0\text{kg}\, a_x$

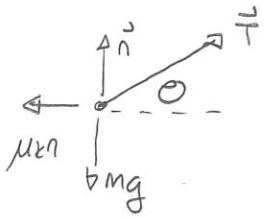
$\Rightarrow a_x = \cancel{2.20\text{m/s}^2}$

$a_x = 2.59\text{m/s}^2$

Quiz 3 30% - 60%

Quiz 4 90% - 96%
wrap pleze

Note that we could work more generally with variables



Then

$$\sum F_{ix} = ma_x \Rightarrow T\cos\theta - \mu_k n = m a_x$$

$$\sum F_{iy} = 0 \Rightarrow n + T\sin\theta - mg = 0$$

This is a system of two equations with two unknowns. Examples are:

1) Given T, θ, μ_k, M

Find n, a_x

2) Given θ, M, μ_k, a_x

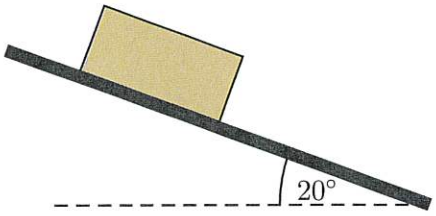
Find T, n

3) Given θ, m, T, a_x

Find μ_k, n

196 Speed at the bottom of a rough ramp, 2

20° ~~18°~~ A 25 kg box can move along a 6.0 m long rough ramp angled from the horizontal. The coefficient of kinetic friction between the box and the ramp is 0.25 and the coefficient of static friction is 0.30. The box is released from rest at the top of the ramp and moves down the ramp. *(131F2024)*



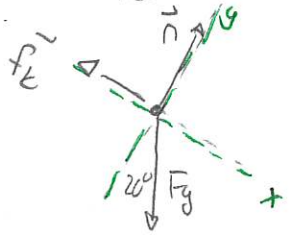
a) Determine the speed of the box when it reaches the bottom of the ramp.

b) Does the speed depend on ~~teir~~ mas of the box? the mass

c) What would be the minimum force, pushing parallel to the ramp, required to keep the box at rest?

Answers: a) Need Newton's 2nd Law → acceleration → kinematics

Step ① FBD



Step ② Newton's Second Law

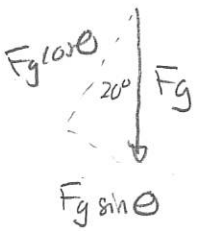
$\Sigma F_{ix} = ma_x$

$\Sigma F_{iy} = ma_y = 0$ (on tilted axes)

Step ③ $F_g = mg$

$f_k = \mu_k n$

Step ④ components



	x	y
$\vec{F}_g$	$F_g \sin\theta$	$-F_g \cos\theta$
$\vec{n}$	0	n
f_k	$-\mu_k n$	0

Step ⑤ $\Sigma F_{ix} = ma_x$

$F_g \sin\theta - \mu_k n = ma_x$

$\Rightarrow$ $mg \sin\theta - \mu_k n = ma_x$

$\Sigma F_{iy} = 0 \Rightarrow -F_g \cos\theta + n = 0$

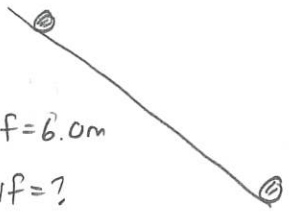
$\Rightarrow$ $n = mg\cos\theta$

Combine these $\Rightarrow$ $mg\sin\theta - \mu_k mg \sin\theta = ma_x$

$\Rightarrow$ $a_x = g(\sin\theta - \mu_k \cos\theta)$

$\Rightarrow$ $a = 9.80 m/s^2 (\sin 20° - 0.25 \cos 20°)$ $\Rightarrow$ $a = 1.05 m/s^2$

Now for kinematics



$x_i = 0$ $x_f = 6.0\,m$

$v_i = 0\,m/s$ $v_f = ?$

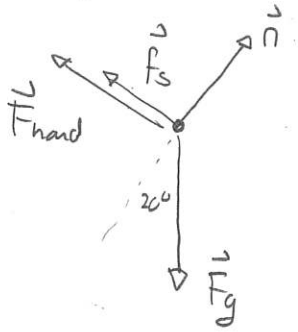
$a = 1.05\,m/s^2$

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

$$= (0\,m/s)^2 + 2(1.05\,m/s^2)(6.0\,m)$$

$$= 12.6\,m/s.$$

c) Here want max static friction



Again $\sum F_{ix} = 0 \Rightarrow -f_s - F_{hand} + mg\sin 20° = 0$

$\sum F_{iy} = 0 \Rightarrow n - mg\cos 20° = 0$

$\Rightarrow n = mg\cos 20°$

$\Rightarrow F_{hand} = mg\sin 20° - f_s$

When f_s is maximum $f_s = \mu_s n$

$\Rightarrow F_{hand} = mg\sin 20° - \mu_s n$

$= mg\sin 20° - \mu_s mg\cos 20°$

$= mg(\sin 20° - \mu_s \cos 20°)$

$= mg(0.013) \Rightarrow F_{hand} = 3.2\,N.$

Quiz 5