Lecture 18

Weds: Warm Up 7

Thurs: Discussion / ~~Ex~~ Quiz

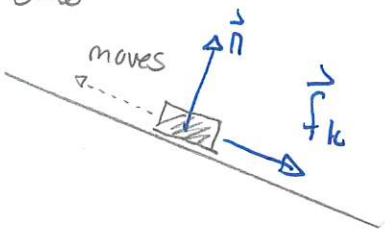
Ex 160, 161, 162, 168, 172, 173

Friction

There are two types of friction.

Kinetic friction

* surfaces move relative to each other



* friction is opposite to direction of motion
* magnitude of friction

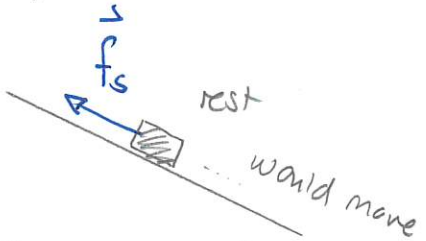
$$f_k = \mu_k n$$

where μ_k = coefficient of kinetic friction

n = normal force

Static friction

* surfaces are at rest with respect to each other



* the static friction oppose the motion that would otherwise occur
* magnitude is adjustable and depends on the circumstances. The maximum possible if

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

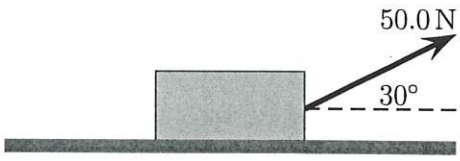
where μ_s = coefficient of static friction

DEMO: Physlink - Coefficients of friction.

Quiz! 30% - 70%

157 Dynamics of a single object with friction

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 0.250. The primary aim of this exercise will be to determine the acceleration of the box. *(111F2023)*



a) Draw a free body diagram for the block.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net } x} = \Sigma F_x = \cdots \tag{9}$$
$$F_{\text{net } y} = \Sigma F_y = \cdots \tag{10}$$

Insert as much information as possible about the components of acceleration at this stage. Can you describe in words what these equations are telling you to do?

c) Determine the magnitude of the gravitational force. Let n be the *magnitude* of the normal force. Using this write an expression for the magnitude of the friction force. Do you know the exact number for the friction force at this point?

d) List all the components of all the forces, using one of the two formats below.

$$w_x = \cdots$$
$$w_y = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$\vdots$$

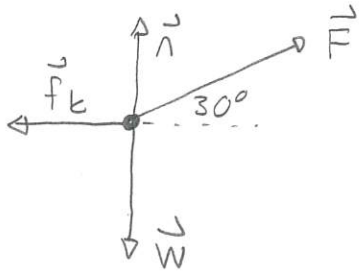
Force	x comp	y comp
$\vec{\mathbf{w}}$		
$\vec{\mathbf{n}}$		
$\vdots$		

e) Use Eq. (9) to obtain an equation relating various quantities that appear in this problem. Do the same with Eq. (10). Does either give the acceleration immediately? Can one of then at least give the normal force immediately?

f) Determine the normal force and use this result to find the acceleration.

g) What tension would be required for the box to have acceleration 4.00 m/s^2 to the right?

Answer: a)



b) $\sum F_{ix} = ma_x$

$\sum F_{iy} = ma_y = 0$ (stays on surface)

c) $w = mg = 15.0\,kg \times 9.8\,m/s^2 = 147\,N$

$f_k = \mu_k n = 0.250n$

	x	y
$\vec{W}$	0	−147 N
$\vec{n}$	0	n
$\vec{F}$	43.3 N	25.0 N
$\vec{f}_k$	−0.250n	0

d) $F_x = F\cos 30°$

$= 50.0\,N \cos 30°$

$= 43.3\,N$

$F_y = F\sin 30°$

$= 50.0\,N \sin 30°$

$= 25.0\,N$

e) $\sum F_{ix} = ma_x \Rightarrow 43.3\,N - 0.250n = 15.0\,kg\, a_x$

f) $\sum F_{iy} = 0 \Rightarrow -147\,N + 25\,N + n = 0$

$\Rightarrow -122\,N = n \Rightarrow n = 122\,N$

$43.3\,N - 0.250 \times 122\,N = 15.0\,kg\, a_x$

$\Rightarrow 43.3\,N - 30.5\,N = 15.0\,kg\, a_x$

$\Rightarrow 12.8\,N = 15.0\,kg\, a_x$

$\Rightarrow a_x = \frac{12.8\,N}{15.0\,kg} = 0.85\,m/s^2$

Newton's Third Law

Many physical situations involve interacting objects. If both objects move, and especially accelerate, then we need to consider forces that they exert on each other. Examples of this include:

a) colliding objects

b) objects connected by ropes Wikipedia: ~~Dubeque~~ Duquesne Incline

c) planets orbiting stars

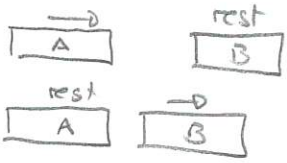
Consider a collision between carts

DEMO: Carts colliding.

By considering accelerations we can reason about forces exerted by one cart on another

Before

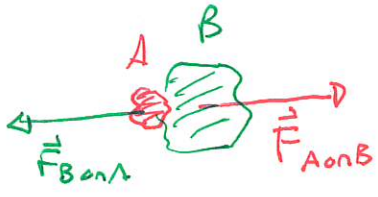
After



	Cart A	Cart B
velocity	$\vec{v}_i$ $\vec{v}_f = 0$	$\vec{v}_i = 0$ $\vec{v}_f$
change in v	$\Delta\vec{v}$	$\Delta\vec{v}$
acceleration	$\vec{a}$	$\vec{a}$
net force	$\vec{F}_{net\,A}$	$\vec{F}_{net\,B}$

The net force result from the force that one cart exerts on the other. This is an example of Newton's Third Law

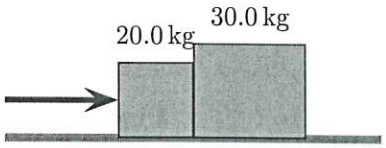
If object A exerts a force on object B then
* object B exerts a force on A
* the forces are exactly opposite
* the magnitudes are equal.



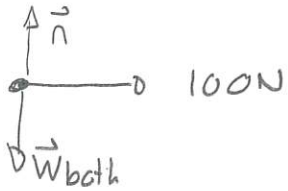
Quiz 2 40%

174 Pushing boxes in contact

Two boxes can move along a frictionless horizontal surface. The boxes maintain contact with each other. A person pushes with a 100 N force on the box at the left. Determine the force that the box at the left exerts on the box at the right. *(111F2023)*



Consider both as one object and get accel.

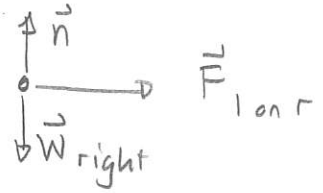


$$\Sigma F_{ix} = ma_x$$

$$100N = 50.0kg\ a_x$$

$$\Rightarrow a_x = 2.0 m/s^2$$

Now consider box on right

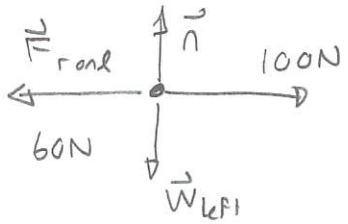


$$\Sigma F_{ix} = M_{right}\ a_x$$

$$F_{l\ on\ r} = 30.0kg \times 2.0 m/s^2$$

$$= 60N$$

For the box on the left



$$\Sigma F_{ix} = M_{left}\ a_x$$

$$100N - 60N = 20.0kg\ a_x$$

$$\Rightarrow a_x = 2.0 m/s^2$$

agrees!

So the 30 kg box exerts at 60N force on the 20kg box