#13 Friction Pre-class

Due: 11:00am on Friday, September 21, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

Exercise 5.31

A crate of 42.1-kg tools rests on a horizontal floor. You exert a gradually increasing horizontal push on it and observe that the crate just begins to move when your force exceeds 327N . After that you must reduce your push to 224N to keep it moving at a steady 27.9$\mathrm{cm/s}$.

Part A

What is the coefficient of static friction between the crate and the floor?

ANSWER:

μ_s = 0.793

Correct

Part B

What is the coefficient of kinetic friction between the crate and the floor?

ANSWER:

μ_k = 0.543

Correct

Part C

What push must you exert to give it an acceleration of 1.49 $\mathrm{m/s^2}$?

ANSWER:

F = 287 N

Correct

Part D

Suppose you were performing the same experiment on this crate but were doing it on the moon instead, where the acceleration due to gravity is 1.62 $\mathrm{m/s^2}$. What magnitude push would cause it to move?

ANSWER:

F = 54.1 N

Correct

Part E

What would its acceleration be if you maintained the push in part C?

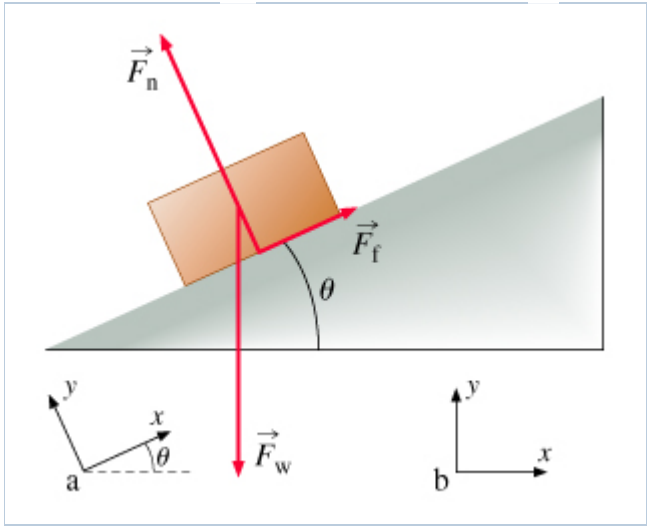
ANSWER:

a = 5.93 $\mathrm{m/s^2}$

All attempts used; correct answer displayed

Block on an Incline

A block lies on a plane raised an angle θ from the horizontal. Three forces act upon the block: $\vec{F}_{\text{w}}$, the force of gravity; $\vec{F}_{\text{n}}$, the normal force; and $\vec{F}_{\text{f}}$, the force of friction. The coefficient of friction is large enough to prevent the block from sliding .



Part A

Consider coordinate system a, with the *x* axis along the plane. Which forces lie along the axes?

ANSWER:

- $\vec{F}_{\mathrm{f}}$ only
- $\vec{F}_{\mathrm{n}}$ only
- $\vec{F}_{\mathrm{w}}$ only
- (•) $\vec{F}_{\mathrm{f}}$ and $\vec{F}_{\mathrm{n}}$
- $\vec{F}_{\mathrm{f}}$ and $\vec{F}_{\mathrm{w}}$
- $\vec{F}_{\mathrm{n}}$ and $\vec{F}_{\mathrm{w}}$
- $\vec{F}_{\mathrm{f}}$ and $\vec{F}_{\mathrm{n}}$ and $\vec{F}_{\mathrm{w}}$

Correct

Part B

Which forces lie along the axes of the coordinate system b, in which the *y* axis is vertical?

ANSWER:

- $\vec{F}_{\rm f}$ only
- $\vec{F}_{\rm n}$ only
- $\vec{F}_{\rm w}$ only
- $\vec{F}_{\rm f}$ and $\vec{F}_{\rm n}$
- $\vec{F}_{\rm f}$ and $\vec{F}_{\rm w}$
- $\vec{F}_{\rm n}$ and $\vec{F}_{\rm w}$
- $\vec{F}_{\rm f}$ and $\vec{F}_{\rm n}$ and $\vec{F}_{\rm w}$

Correct

Now you are going to ignore the general rule (actually, a strong suggestion) that you should pick the coordinate system with the most vectors, especially unknown ones, along the coordinate axes. You will find the normal force, $\vec{F}_{\rm n}$, using vertical coordinate system b. In these coordinates you will find the magnitude $F_{\rm n}$ appearing in both the *x* and *y* equations, each multiplied by a trigonometric function.

Part C

Because the block is not moving, the sum of the *y* components of the forces acting on the block must be zero. Find an expression for the sum of the *y* components of the forces acting on the block, using coordinate system b.

Express your answer in terms of some or all of the variables $F_{\rm n}$, $F_{\rm f}$, $F_{\rm w}$, and θ.

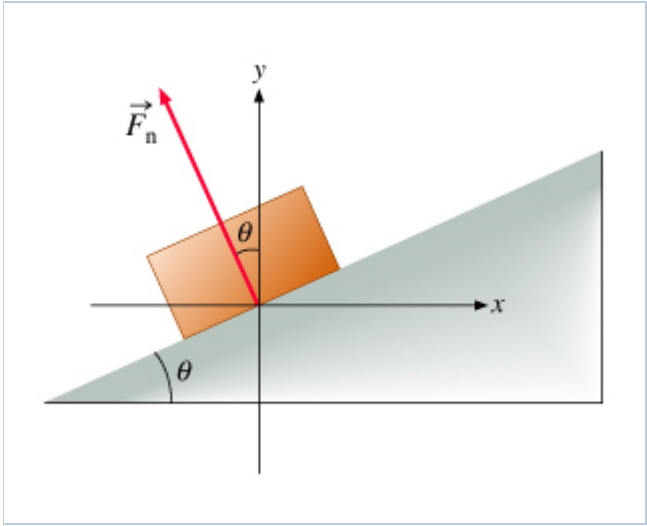
Hint 1. Find the *y* component of $\vec{F}_{\rm n}$

Write an expression for $F_{\rm ny}$, the *y* component of the force $\vec{F}_{\rm n}$, using coordinate system b.

Express your answer in terms of F_n and θ.

Hint 1. Some geometry help - a useful angle

The smaller angle between $\vec{F}_n$ and the *y*-axis is also θ, as shown in the figure.



ANSWER:

$F_{ny} = F_n \cos(\theta)$

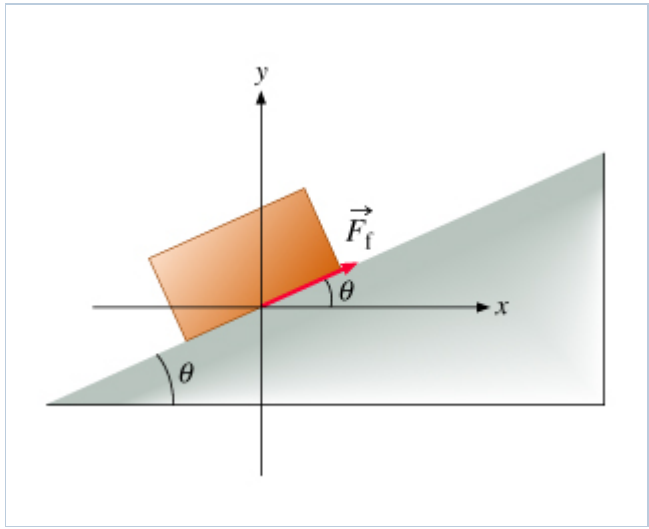
Hint 2. Find the *y* component of $\vec{F}_f$

Write an expression for F_{fy}, the *y* component of the force $\vec{F}_f$, using coordinate system b.

Express your answer in terms of F_f and θ.

Hint 1. Some geometry help - a useful angle

The smaller angle between $\vec{F}_f$ and the *x*-axis is also θ, as shown in the figure.



ANSWER:

$F_{fy} = F_f \sin(\theta)$

ANSWER:

$\sum F_y = 0 = \cos\theta F_n - F_w + F_f \sin\theta$

Correct

Part D

Because the block is not moving, the sum of the *x* components of the forces acting on the block must be zero. Find an expression for the sum of the *x* components of the forces acting on the block, using coordinate system b.

Express your answer in terms of some or all of the variables $F_{\rm n}$, $F_{\rm f}$, $F_{\rm w}$, and θ.

Hint 1. Find the *x* component of $\vec{F}_{\rm n}$

Write an expression for $F_{\rm nx}$, the *x* component of the force $\vec{F}_{\rm n}$, using coordinate system b.

Express your answer in terms of $F_{\rm n}$ and θ.

ANSWER:

$F_{\rm nx} = -F_n \sin(\theta)$

ANSWER:

$\sum F_x = 0 = -\sin\theta F_n + \cos\theta F_f$

Correct

Part E

To find the magnitude of the normal force, you must express $F_{\rm n}$ in terms of $F_{\rm w}$ since $F_{\rm f}$ is an unknown. Using the equations you found in the two previous parts, find an expression for $F_{\rm n}$ involving $F_{\rm w}$ and θ but not $F_{\rm f}$.

Hint 1. How to approach the problem

From your answers to the previous two parts you should have two force equations ($\sum F_y = 0$ and $\sum F_x = 0$). Combine these equations to eliminate F_f. The key is to multiply the equation for the *y* components by $\cos\theta$ and the equation for the *x* components by $\sin\theta$, then add or subtract the two equations to eliminate the term $F_\mathrm{f}\cos(\theta)\sin(\theta)$.

An alternative motivation for the algebra is to eliminate the trig functions in front of F_n by using the trig identity $\sin^2(\theta) + \cos^2(\theta) = 1$. At the very least this would result in an equation that is simple to solve for F_n.

ANSWER:

$F_\mathrm{n} = F_w\cos\theta$

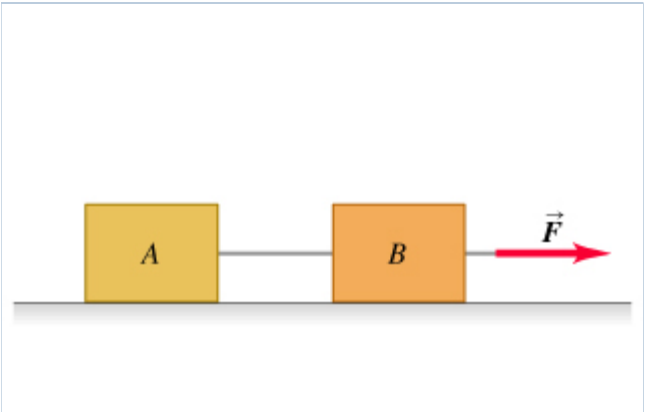
Correct

Congratulations on working this through. Now realize that in coordinate system a, which is aligned with the plane, the *y*-coordinate equation is $\sum F_y = F_\mathrm{n} - F_\mathrm{W}\cos(\theta) = 0$, which leads immediately to the result obtained here for F_n.

CONCLUSION: A thoughtful examination of which coordinate system to choose can save a lot of algebra.

Exercise 5.37

Two crates connected by a rope lie on a horizontal surface (the figure). Crate *A* has mass m_A and crate *B* has mass m_B. The coefficient of kinetic friction between each crate and the surface is μ_k. The crates are pulled to the right at constant velocity by a horizontal force $\vec{F}$.



Part A

In terms of m_A, m_B, and μ_k, calculate the magnitude of the force $\vec{F}$.

Express your answer in terms of some or all of the variables m_A, m_B, μ_k, and appropriate constants.

ANSWER:

$F = g(m_A + m_B)\mu_k$

Correct

Part B

In terms of m_A, m_B, and μ_k, calculate the tension in the rope connecting the blocks. Include the free-body diagram or diagrams you used to determine each answer.

Express your answer in terms of some or all of the variables m_A, m_B, μ_k, and appropriate constants.

ANSWER:

$T = g(m_A)\mu_k$

Correct

Score Summary:

Your score on this assignment is 93.9%.
You received 14.09 out of a possible total of 15 points.