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HW03_CH04

Due: 11:32pm on Wednesday, September 23, 2009

Note: To understand how points are awarded, read your instructor's Grading Policy.

Free-Body Diagrams

Description: Instructions for creating free-body diagrams are provided. Students practice creating diagrams for two different physical situations.

Learning Goal: To gain practice drawing free-body diagrams

Whenever you face a problem involving forces, always start with a free-body diagram.

To draw a free-body diagram use the following steps:

1. Isolate the object of interest. It is customary to represent the object of interest as a point in your diagram.
2. Identify all the forces acting on the object and their directions. Do not include forces acting on other objects in the problem. Also, do not include quantities, such as velocities and accelerations, that are not forces.
3. Draw the vectors for each force acting on your object of interest. When possible, the length of the force vectors you draw should represent the relative magnitudes of the forces acting on the object.

In most problems, after you have drawn the free-body diagrams, you will explicitly label your coordinate axes and directions. Always make the object of interest the origin of your coordinate system. Then you will need to divide the forces into x and y components, sum the x and y forces, and apply Newton's first or second law.

In this problem you will only draw the free-body diagram.

Suppose that you are asked to solve the following problem:

> Chadwick is pushing a piano across a level floor (see the figure). The piano can slide across the floor without friction. If Chadwick applies a horizontal force to the piano, what is the piano's acceleration?

To solve this problem you should start by drawing a free-body diagram.

Part A

Determine the object of interest for the situation described in the problem introduction.

Hint A.1 **How to approach the problem**

You should first think about the question you are trying to answer: What is the acceleration of the piano? The object of interest in this situation will be the object whose acceleration you are asked to find.

ANSWER: For this situation you should draw a free-body diagram for the piano.

Part B

Identify the forces acting on the object of interest. From the list below, select the forces that act on the piano.

Check all that apply.

ANSWER:

- acceleration of the piano
- gravitational force acting on the piano (piano's weight)
- speed of the piano
- gravitational force acting on Chadwick (Chadwick's weight)
- force of the floor on the piano (normal force)
- force of the piano on the floor
- force of Chadwick on the piano
- force of the piano pushing on Chadwick

Now that you have identified the forces acting on the piano, you should draw the free-body diagram. Draw the length of your vectors to represent the relative magnitudes of the forces, but you don't need to worry about the exact scale. You won't have the exact value of all of the forces until you finish solving the problem. To maximize your learning, you should draw the diagram yourself before looking at the choices in the next part. You are on your honor to do so.

Part C

Select the choice that best matches the free-body diagram you have drawn for the piano.

Hint C.1 **Determine the directions and relative magnitudes of the forces**

Which of the following statements best describes the correct directions and relative magnitudes of the forces involved?

ANSWER:

- The normal force and weight are both upward and the pushing force is horizontal.
- The normal force and weight are both downward and the pushing force is horizontal.
- The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a greater magnitude than the weight.
- The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force and weight have the same magnitude.
- The normal force is upward, the weight is downward, and the pushing force is horizontal. The normal force has a smaller magnitude than the weight.

ANSWER:

If you were actually going to solve this problem rather than just draw the free-body diagram, you would need to define the coordinate system. Choose the position of the piano as the origin. In this case it is simplest to let the y axis point vertically upward and the x axis point horizontally to the right, in the direction of the acceleration.

Chadwick now needs to push the piano up a ramp and into a moving van. Is Chadwick strong enough to push the piano up the ramp alone or must he get help? Estimate the force needed to push the piano up the ramp. Neglect friction.

Part D

Determine the object of interest for this situation.

ANSWER: For this situation, you should draw a free-body diagram for the piano.

Now draw the free-body diagram of the piano in this new situation. Follow the same sequence of steps that you followed for the first situation. Again draw your diagram before you look at the choices below.

Part E

Which diagram accurately represents the free-body diagram for the piano?

ANSWER:

In working problems like this one that involve an incline, it is most often easiest to select a coordinate system that is not vertical and horizontal. Instead, choose the *x* axis so that it is parallel to the incline and choose the *y* axis so that it is perpendicular to the incline.

Newton's 1st Law

Description: Conceptual. Introduces Newton's first law and follows with questions. (version for algebra-based courses)

Learning Goal: To understand Newton's 1st law.

Newton's *Principia* states this first law of motion:

An object subject to no net force maintains its state of motion, either at rest or at constant speed in a right line.

This law may be restated as follows: If the sum of all forces acting on an object is zero, then the acceleration of that object is zero. Mathematically this is just a special case of the 2nd law of motion, , when . When studying Newtonian mechanics, it is best to remember the 1st law in two ways:

1. If the *net* force (i.e., sum of all forces) acting on an object is zero, the object will keep moving with constant velocity (which may be zero).
2. If an object is moving with constant velocity, that is, with zero acceleration, then the net force acting on that object must be zero.

Complete the following sentences to see if you can apply these ideas.

Part A

If a car is moving to the left with constant velocity, one can conclude that

ANSWER:

- there must be no forces applied to the car.
- the net force applied to the car is directed to the left.
- the net force applied to the car is zero.
- there is exactly one force applied to the car.

Part B

An object cannot remain at rest unless

ANSWER:

- there are no forces at all acting on it.
- the net force acting on it is zero.
- the net force acting on it is constant.
- there is only one force acting on it.

Part C

An object will have constant acceleration if

Hint C.1 **More help from Newton**

To solve this, you have to invoke Newton's 2nd law, .

Select the most general response.

ANSWER:

- there are no forces at all acting on it.
- the net force acting on it is zero.
- the net force acting on it is constant in magnitude and direction.
- there is only one force acting on it.

A Book on a Table

Description: Conceptual questions around Newton's third law. (Multiple choice.)

A book weighing 5 N rests on top of a table.

Part A

A downward force of magnitude 5 N is exerted on the book by the force of

ANSWER:

- the table
- gravity .
- inertia

Part B

An upward force of magnitude _____ is exerted on the _____ by the table.

ANSWER: 5 N / book

Part C

Do the downward force in Part A and the upward force in Part B constitute a 3rd law pair?

Hint C.1 **The force of gravity**

The force of gravity is another name for the force exerted by the earth (or any astronomical object) on objects near its surface.

Hint C.2 **Exploring Newton's 3rd law**

Indicate whether the following statements about Newton's 3rd law are true, false, or indeterminate.

1. According to Newton's 3rd law, every real force has a unique pair force.
2. The pair force is called a "fictitious force."
3. The force and pair force must act on different point masses.
4. The force and the pair force must always have the same magnitude and must also act in exactly opposite directions.

Enter t for true, f for false, or i for indeterminate for each statement, separating the answers with commas (e.g., if all but the first statement were true, you would enter f,t,t,t).

yes
no

Part D

The reaction to the force in Part A is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____ .

Hint D.1 **The force of gravity**

The force of gravity is another name for the force exerted by the earth (or any astronomical object) on objects near its surface.

ANSWER: 5 N / earth / book / upward

Part E

The reaction to the force in Part B is a force of magnitude _____, exerted on the _____ by the _____. Its direction is _____.

ANSWER: 5 N / table / book / downward

Part F

Which of Newton's laws dictates that the forces in Parts A and B are equal and opposite?

ANSWER:

Newton's 1st or 2nd law
Newton's 3rd law

Since the book is at rest, the net force on it must be zero (1st or 2nd law). This means that the force exerted on it by the earth must be equal and opposite to the force exerted on it by the table.

Part G

Which of Newton's laws dictates that the forces in Parts B and E are equal and opposite?

ANSWER:

Newton's 1st or 2nd law
Newton's 3rd law

A Friction Experiment

Description: Short quantitative problem relating a pulling force to a frictional force and acceleration. Requires that students interpret graphical data. This problem is based on Young/Geller Quantitative Analysis 5.2

During an experiment, a crate is pulled along a rough horizontal surface by a constant force and the magnitude of the acceleration along the *x* direction, , is measured. The vector has a component along the *x* direction of magnitude . The experiment is repeated several times, with different values of each time.

Part A

Create a plot of the force of static friction, , versus the *x* component of the pulling force, , for the experiment. Let the point , along the horizontal axis, represent the minimum force required to accelerate the crate. Choose the graph that most accurately depicts the relationship among , , and .

Hint A.1 **Characteristics of static friction**

There are two important characteristics to keep in mind about the the force of static friction:

- Only a stationary object can be acted upon by the force of static friction.
- , where is the coefficient of static friction and is the magnitude of the normal force. This inequality means that the actual force of static friction can have any magnitude between zero and a maximum value of .

Hint A.2 **Find the force of static friction**

A horizontal force of magnitude is exerted on a stationary crate. The maximum force of static friction, , between the crate and the floor is 15 . Assume that is the only force, besides that of static friction, , acting horizontally on the crate.

What is when no horizontal force is applied to the crate, that is, when ? What is when ? What is the instant the crate starts to move?

Hint A.2.1 **Applying Newton's 2nd law**

A horizontal force is applied to the crate. However, the force of static friction, , opposes this force and causes the crate to remain stationary, meaning that . From Newton's 2nd law we know that

.

This yields

when applied to this specific problem.

Enter your answers numerically in newtons. Separate each answer with a comma. For example if the answers are 100, 200, and 50 enter `100,200,-50`.

ANSWER:

=

Now use what you have learned about the fore of static friction in the previous hint to determine the correct graph.

ANSWER: D

Notice that until the pulling force exceeds , the force of static friction is exactly equal in magnitude to the pulling force.

Part B

Create a plot of the force of kinetic friction, , versus the *x* component of the pulling force, , for the experiment. Let the point , along the horizontal axis, represent the minimum force required to accelerate the crate. Choose the graph that most accurately depicts the relationship among , , and .

Hint B.1 **Characteristics of kinetic friction**

There are three important characteristics to keep in mind about the force of kinetic friction:

- Only an object that is sliding with respect to a surface can be acted upon by the force of kinetic friction.
- points in a direction that is parallel to the surface of contact and opposes the motion of the object.
- , where is the coefficient of kinetic friction and is the magnitude of the normal force.

ANSWER: D

The most important things to keep in mind when dealing with kinetic friction are the following:

- Only an object that is sliding with respect to a surface can be acted upon by the force of kinetic friction.
- points in a direction that is parallel to the surface of contact and opposes the motion of the object.
- , where is the coefficient of kinetic friction and is the magnitude of the normal force.

Part C

After all the trials are completed, a graph of acceleration as a function of force is plotted. Assuming the presence of both static and kinetic friction, which of the following graphs is most nearly correct?

ANSWER: C

Board Pulled Out from under a Box

Description: A box is sitting on a board, with friction. Find the minimum force needed to pull the board out from under the box.

A small box of mass is sitting on a board of mass and length . The board rests on a frictionless horizontal surface. The coefficient of static friction between the board and the box is . The coefficient of kinetic friction between the board and the box is, as usual, less than .

Throughout the problem, use for the magnitude of the acceleration due to gravity. In the hints, use for the magnitude of the friction force between the board and the box.

Part A

Find , the constant force with the least magnitude that must be applied to the board in order to pull the board out from under the the box (which will then fall off of the opposite end of the board).

Hint A.1 **Condition for the board sliding out from under the box**

The board will slide out from under the box if the magnitude of the board's acceleration exceeds the magnitude of the maximum acceleration that friction can give to the box.

Hint A.2 **Find the acceleration of the box in terms of**

Assume that the coefficient of static friction between the board and the box is not known at this point. What is the magnitude of the acceleration of the box in terms of the friction force ?

Express your answer in terms of and .

ANSWER:

=

Hint A.3 **Find the largest acceleration of the box**

Now take the coefficient of static friction between the board and the box to be . What is the largest possible magnitude of the acceleration of the box?

Hint A.3.1 **Maximum force on the box**

Friction is the only horizontal force on the box. What is the largest possible value for ?

Express your answer in terms of some or all of the variables , , and .

ANSWER:

=

Hint A.4 **Find the sum of horizontal forces on the board**

Write down the sum of all the horizontal forces acting on the board. Take the positive *x* direction to be to the right.

Hint A.4.1 **Friction and Newton's 3rd law**

Remember, by Newton's 3rd law, if there is a force of magnitude acting on the box due to the board, there is a force of equal magnitude and opposite direction acting on the board due to the box.

Give your answer in terms of , , and any constants necessary.

ANSWER:

=

Hint A.5 **Find the acceleration of the board for large**

In Hint 4 you found the net horizontal force on the board. Now, find the acceleration of the board when the force of static friction reaches its maximum possible value.

Express your answer in terms of , , , , and .

ANSWER:

=

Hint A.6 **Putting it all together**

Reread Hint 1. In Hint 3, you found the largest possible acceleration of the box, . In Hint 5, you found the acceleration of the board, . What is the minimum value of the constant force, , so that ?

Express your answer in terms of some or all of the variables , , , , and . Do *not* include in your answer.

ANSWER:

=

Problem 4.10

Description: (a) How much tension must a rope withstand if it is used to accelerate a m car vertically upward at a?

Part A

How much tension must a rope withstand if it is used to accelerate a 1500 car vertically upward at 0.90 ?

Express your answer using two significant figures.

ANSWER:

=

Problem 4.12

Description: A m bucket is lowered vertically by a rope in which there is F_T of tension at a given instant. (a) What is the acceleration of the bucket? (b) Is it up or down?

A 14.0 bucket is lowered vertically by a rope in which there is 187 of tension at a given instant.

Part A

What is the acceleration of the bucket?

Express your answer using two significant figures.

ANSWER:

=

Part B

Is it up or down?

ANSWER:

down
up

Problem 4.24

Description: The two forces F_vec_1 and F_vec_2 shown in the figure (looking down) act on a m object on a frictionless tabletop. (a) If F_1 = F_1 and F_2 =F_2, find the absolute value of the net force on the object for (a). (b) If F_1 = F_1 and F_2 =F_2, find...

The two forces and shown in the figure (looking down) act on a 21.0 object on a frictionless tabletop.

Part A

If and , find the absolute value of the net force on the object for (a).

ANSWER:

=

Part B

If and , find the angle of the net force on the object for (a).

ANSWER:

= from the +*x* axis

Part C

If and , find the acceleration of the object for (a).

ANSWER:

=

Part D

If and , find the absolute value of the net force on the object for (b).

ANSWER:

=

Part E

If and , find the angle of the net force on the object for (b).

ANSWER:

= from the +*x* axis

Part F

If and , find the acceleration of the object for (b).

ANSWER:

=

Problem 4.29

Description: A window washer pulls herself upward using the bucket-pulley apparatus shown in the figure. The mass of the person plus the bucket is m. (a) How hard must she pull downward to raise herself slowly at constant speed? (b) If she increases this force...

A window washer pulls herself upward using the bucket-pulley apparatus shown in the figure. The mass of the person plus the bucket is 59 .

Part A

How hard must she pull downward to raise herself slowly at constant speed?

Express your answer using two significant figures.

ANSWER:

=

290

Part B

If she increases this force by 11 , what will her acceleration be?

Express your answer using two significant figures.

ANSWER:

=

Problem 4.52

Description: The carton shown in the figure lies on a plane tilted at an angle theta = theta to the horizontal, with mu_k = 0.12. (a) Determine the acceleration of the carton as it slides down the plane. (b) If the carton starts from rest x up the plane from its ...

The carton shown in the figure lies on a plane tilted at an angle to the horizontal, with .

Part A

Determine the acceleration of the carton as it slides down the plane.

Express your answer using two significant figures.

ANSWER:

=

Part B

If the carton starts from rest 9.10 up the plane from its base, what will be the carton's speed when it reaches the bottom of the incline?

Express your answer using two significant figures.

ANSWER:

=

Problem 4.54

Description: A roller coaster reaches the top of the steepest hill with a speed of v_0. It then descends the hill, which is at an average angle of theta and is x long. (a) Estimate its speed when it reaches the bottom. Assume mu_k = 0.18.

A roller coaster reaches the top of the steepest hill with a speed of 7.0 . It then descends the hill, which is at an average angle of 44 and is 45.0 long.

Part A

Estimate its speed when it reaches the bottom. Assume .

Express your answer using two significant figures.

ANSWER:

=

Score Summary:

Your score on this assignment is 0%.
You received 0 out of a possible total of 10 points, plus 0 points of extra credit.