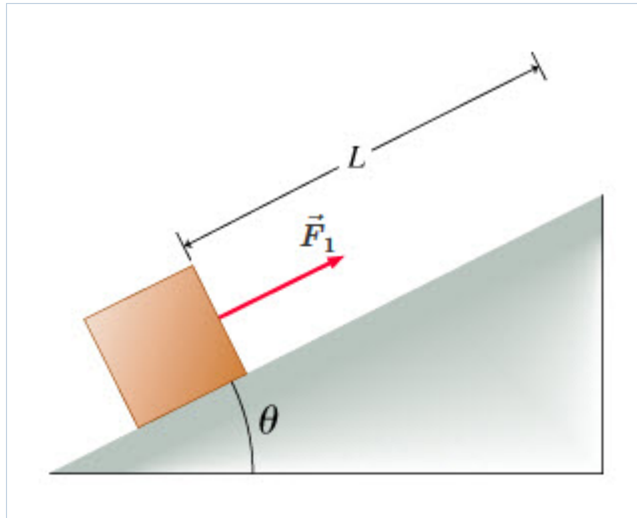
Work Energy and Power in-class assignment

Due: 11:59pm on Sunday, July 17, 2022

You will receive no credit for items you complete after the assignment is due. Grading Policy

Pulling a Block on an Incline with Friction

A block of weight mg sits on an inclined plane as shown in . A force of magnitude F_1 is applied to pull the block up the incline at constant speed. The coefficient of kinetic friction between the plane and the block is μ.



Part A

What is the total work $W_{\rm fric}$ done on the block by the force of friction as the block moves a distance L up the incline?

Express the work done by friction in terms of any or all of the variables μ, m, g, θ, L, and F_1.

Hint 1. How to start

Draw a free-body force diagram showing all real forces acting on the block.

Hint 2. Find the magnitude of the friction force

Write an expression for the magnitude $F_{\rm fric}$ of the friction force.

Express your answer in terms of any or all of the variables μ, m, g, and θ.

Hint 1. Find the magnitude of the normal force

What is the magnitude N of the normal force?

Express your answer in terms of m, g, and θ.

ANSWER:

$N = mg\cos(\theta)$

ANSWER:

F_{fric} = $\mu mg\cos(\theta)$

ANSWER:

W_{fric} = $-\mu mgL\cos\theta$

Correct

Part B

What is the total work W_{F_1} done on the block by the applied force $\vec{F}_1$ as the block moves a distance L up the incline?

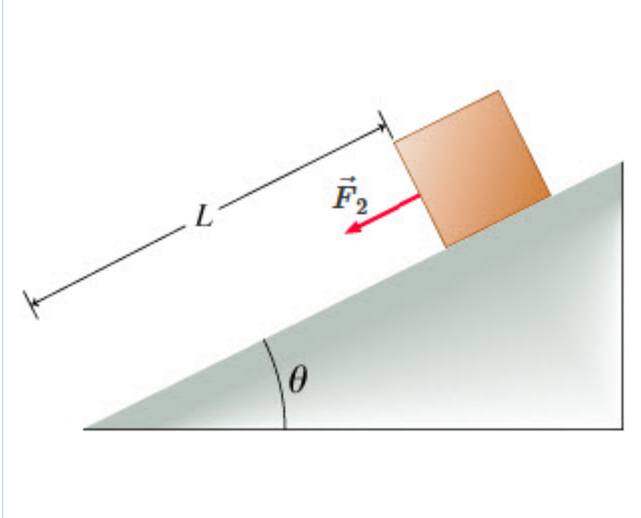
Express your answer in terms of any or all of the variables μ, m, g, θ, L, and F_1.

ANSWER:

W_{F_1} = $F_1 L$

Correct

Now the applied force is changed to $\vec{F}_2$, so that instead of pulling the block up the incline, the force pulls the block down the incline at a constant speed as shown in .



Part C

What is the total work W_{fric} done on the block by the force of friction as the block moves a distance L down the incline?

Express your answer in terms of any or all of the variables μ, m, g, θ, L, and F_2.

ANSWER:

W_{fric} = $-\mu mgL\cos\theta$

Correct

Part D

What is the total work W_{F_2} done on the box by the appled force in this case?

Express your answer in terms of any or all of the variables μ, m, g, θ, L, and F_2.

ANSWER:

W_{F_2} = $F_2 L$

Correct

Exercise 6.14

You apply a constant force $\vec{F} = (-68.0\ \mathrm{N})\hat{\imath} + (36.0\ \mathrm{N})\hat{\jmath}$ to a 380 kg car as the car travels 50.0 m in a direction that is 240.0 $^\circ$ counterclockwise from the $+x$-axis.

Part A

How much work does the force you apply do on the car?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

W = 141 J

Correct

Exercise 6.16

A 1.50 kg book is sliding along a rough horizontal surface. At point A it is moving at 3.21 $\mathrm{m/s}$, and at point B it has slowed to 1.25 $\mathrm{m/s}$.

Part A

How much work was done on the book between A and B?

ANSWER:

W_{AB} = -6.56 J

Correct

Part B

If -0.750J of work is done on the book from B to C, how fast is it moving at point C?

ANSWER:

v_C = 0.750 $\mathrm{m/s}$

Correct

Part C

How fast would it be moving at C if 0.750J of work were done on it from B to C?

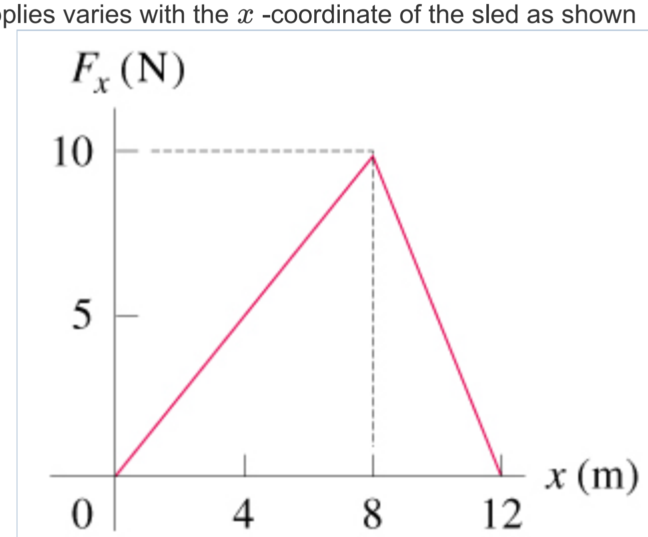
ANSWER:

v_C = 1.60 $\mathrm{m/s}$

Correct

Exercise 6.36

A child applies a force $\vec{F}$ parallel to the x -axis to a 10.0-kg sled moving on the frozen surface of a small pond. As the child controls the speed of the sled, the x -component of the force she applies varies with the x -coordinate of the sled as shown in the figure .



Part A

Calculate the work done by the force $\vec{F}$ when the sled moves from x=0 to x=8.0m.

Express your answer using two significant figurs.

ANSWER:

W = 40 J

Correct

Part B

Calculate the work done by the force $\vec{F}$ when the sled moves from x=8.0m to x =12.0m.

Express your answer using two significant figurs.

ANSWER:

W = 20 J

Correct

Part C

Calculate the work done by the force $\vec{F}$ when the sled moves from x=0 to x =12.0m.

.

Express your answer using two significant figurs.

ANSWER:

W = 60 J

Correct

Exercise 6.39

A 4.0-kg box moving at 4.0 $\mathrm{m/s}$ on a horizontal, frictionless surface runs into a light spring of force constant 65 $\mathrm{N/cm}$.

Part A

Use the work-energy theorem to find the maximum compression of the spring.

Express your answer using two significant figures.

ANSWER:

x = 9.9 cm

Correct

Exercise 6.41

An air-track glider of mass 0.100 kg is attached to the end of a horizontal air track by a spring with force constant 20.0 $\mathrm{N/m}$. Initially the spring is unstreched and the glider is moving at 1.50 $\mathrm{m/s}$ to the right. With the air track turned off, the coefficient of kinetic friction is μ_{k}=0.47.

Part A

How large would the coefficient of static friction μ_{s} have to be to keep the glider from springing back to the left when it stops instantaneously?

Express your answer giving two significant figures.

ANSWER:

μ_{s} = 1.8

Correct

Part B

If the coefficient of static friction between the glider and the track is μ_{s} = 0.90, what is the maximum initial speed v_1 that the glider can be given and still remain at rest after it stops instantaneously?

Express your answer giving two significant figures.

ANSWER:

v_1 = 0.89 $\mathrm{m/s}$

Correct

Exercise 6.51

Part A

How many joules of energy does a 100-watt light bulb use per hour?

Express your answer using two significant figures.

ANSWER:

W = 3.6×10^{5} J

Correct

Part B

How fast would a 75 kg person have to run to have that amount of energy?

Express your answer using two significant figures.

ANSWER:

v = 98 $\mathrm{m/s}$

Correct

Exercise 6.60

You are applying a constant horizontal force $\vec{F} = (-8.70\ \mathrm{N})\hat{\imath} + (3.00\ \mathrm{N})\hat{\jmath}$ to a crate that is sliding on a factory floor.

Part A

At the instant that the velocity of the crate is $\vec{v} = (3.30\ \mathrm{m/s})\hat{\imath} + (2.20\ \mathrm{m/s})\hat{\jmath}$, what is the instantaneous power supplied by this force?

Express your answer with the appropriate units.

ANSWER:

P = -22.1 W

Correct

Exercise 6.3

A factory worker pushes a crate of mass 30.0 kg a distance of 4.85 m along a level floor at constant velocity by pushing horizontally on it. The coefficient of kinetic friction between the crate and floor is 0.26.

Part A

What magnitude of force must the worker apply?

Express your answer using two significant figures.

ANSWER:

F = 76 N

Correct

Part B

How much work is done on the crate by this force?

Express your answer using two significant figures.

ANSWER:

W = 370 J

Correct

Part C

How much work is done on the crate by friction?

Express your answer using two significant figures.

ANSWER:

W_f = -370 J

Correct

Part D

How much work is done by the normal force?

ANSWER:

W_{nf} = 0 J

Correct

Part E

How much work is done by gravity?

ANSWER:

W_g = 0 J

Correct

Part F

What is the total work done on the crate?

ANSWER:

W_{net} = 0 J

Correct

Understanding Work Done by a Constant Force

Learning Goal:
To explore the definition of work and learn how to find the work done by a force on an object.

The word "work" has many meanings when used in everyday life. However, in physics work has a very specific definition. This definition is important to learn and understand. Work and energy are two of the most fundamental and important concepts you will learn in your study of physics. Energy cannot be created or destroyed; it can only be transformed from one form to another. How this energy is transferred affects our daily lives from microscopic processes, such as protein synthesis, to macroscopic processes, such as the expansion of the universe!

When energy is transferred either to or away from an object by a force $\vec{F}$ acting over a displacement $\vec{d}$, work W is done on that object. The amount of work done by a *constant* force can be found using the equation

$$W = Fd\cos\theta,$$

where F is the magnitude of $\vec{F}$, d is the magnitude of $\vec{d}$, and θ is the angle between $\vec{F}$ and $\vec{d}$.

The SI unit for work is the joule, J. A single joule of work is not very big. Your heart uses about $0.5\,\mathrm{J}$ each time it beats, and the 60-watt lightbulb in your desk lamp uses $216,000\,\mathrm{J}$ each hour. A joule is defined as follows:

$$1\,\mathrm{J} = 1\,\mathrm{N\,m} = 1\,\frac{\mathrm{kg\,m^2}}{\mathrm{s^2}}$$

The net work done on an object is the sum of the work done by each individual force acting on that object. In other words,

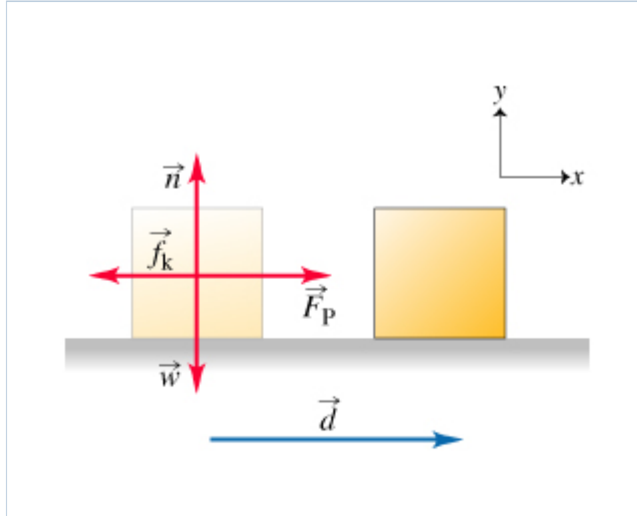
$$W_{net} = W_1 + W_2 + W_3 + \cdots = \sum_i W_i\ .$$

The net work can also be expressed as the work done by the net force acting on an object, which can be represented by the following equation:

$$W_{\text{net}} = F_{\text{net}} d \cos\theta.$$

Knowing the sign of the work done on an object is a crucial element to understanding work. Positive work indicates that an object has been acted on by a force that tranfers energy to the object, thereby increasing the object's energy. Negative work indicates that an object has been acted on by a force that has reduced the energy of the object.

The next few questions will ask you to determine the sign of the work done by the various forces acting on a box that is being pushed across a rough floor. As illustrated in the figure , the box is being acted on by a normal force $\vec{n}$, the force due to gravity $\vec{w}$, the force of kinetic friction $\vec{f}_{\text{k}}$, and the pushing force $\vec{F}_{\text{p}}$. The displacement of the box is $\vec{d}$.



Part A

Which of the following statements accurately describes the sign of the work done on the box by the force of the push?

Hint 1. Find the angle

The work done on the box by the pushing force depends on the angle θ between $\vec{F}_{\text{p}}$ and the displacement $\vec{d}$. What is this angle?

ANSWER:

- (●) 0 degrees
- ( ) 45 degrees
- ( ) 90 degrees
- ( ) 180 degrees

ANSWER:

- (●) positive
- ( ) negative
- ( ) zero

Correct

Part B

Which of the following statements accurately decribes the sign of the work done on the box by the normal force?

Hint 1. Finding theta

The work done on the box by the normal force depends on the angle θ between $\vec{n}$ and the displacement $\vec{d}$. What is this angle?

ANSWER:

- ○ 0 degrees
- ○ 45 degrees
- ◉ 90 degrees
- ○ 180 degrees

ANSWER:

- ○ positive
- ○ negative
- ◉ zero

Correct

Part C

Which of the following statements accurately decribes the sign of the work done on the box by the force of kinetic friction?

Hint 1. Finding theta

The work done on the box by the force of kinetic friction depends on the angle θ between $\vec{f}_{\mathrm{k}}$ and the displacement $\vec{d}$. What is this angle?

ANSWER:

- ○ 0 degrees
- ○ 45 degrees
- ○ 90 degrees
- ◉ 180 degrees

ANSWER:

- ○ positive
- ◉ negative
- ○ zero

Correct

Part D

Which of the following statements accurately decribes the sign of the work done on the box by the force of gravity?

Hint 1. Finding the angle

The work done on the box by the weight depends on the angle θ between $\vec{w}$ and the displacement $\vec{d}$. What is this angle?

ANSWER:

- ○ 0 degrees
- ○ 45 degrees
- ◉ 90 degrees
- ○ 180 degrees

ANSWER:

- ○ positive
- ○ negative
- ◉ zero

Correct

Making generalizations

You may have noticed that the force due to gravity and normal forces do no work on the box. Any force that is perpendicular to the displacement of the object on which it acts does no work on the object.
The force of kinetic friction did negative work on the box. In other words, it took energy away from the box. Typically, this energy gets transformed into heat, like the heat that radiates from your skin when you get a rug burn due to the friction between your skin and the carpet. A force that acts on an object in a direction opposite to the direction of the object's displacement does negative work on the object.

The pushing force acts on the box in the same direction as the object's displacement and does positive work on the box.

These generalizations allow physicists to rewrite the equation for work as

$$W = F_{||}d,$$

where $F_{||}$ is the component of $\vec{F}$ that is either parallel or antiparallel to the displacement. If $F_{||}$ is parallel to $\vec{d}$, as in the case of $\vec{F}_{\mathrm{p}}$, then the work done is positive. If $F_{||}$ is antiparallel to $\vec{d}$, as in the case of $\vec{f}_{\mathrm{k}}$, then the work done is negative.

Part E

You have just moved into a new apartment and are trying to arrange your bedroom. You would like to move your dresser of weight 3,500 N across the carpet to a spot 5 m away on the opposite wall. Hoping to just slide your dresser easily across the floor, you do not empty your clothes out of the drawers before trying to move it. You push with all your might but cannot move the dresser before becoming completely exhausted. How much work do you do on the dresser?

ANSWER:

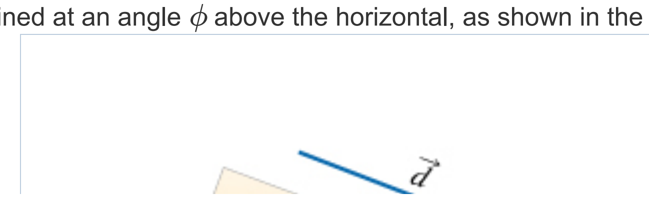
- ○ $W > 1.75 \times 10^4$ J
- ○ $W = 1.75 \times 10^4$ J
- ○ 1.75×10^4 J $>$ W $>$ 0 J
- ◉ $W = 0$ J

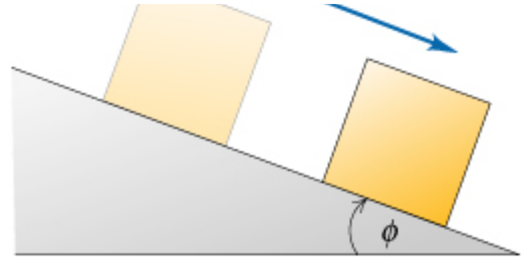
Correct

Remember that to a physicist work means something very specific, and since you were unable to move the dresser, $d = 0$ and therefore $W = 0$. However, you got tired and sweaty trying to move the dresser, just as you do when you go to "work out" at the gym.Your muscles are not static strips of fibrous tissue. They continually contract and expand a slight amount when you exert them. Chemical energy from food is being transformed into the energy needed to move your muscles. Work is being done inside your muscles, but work is not being done on the dresser.

Part F

A box of mass m is sliding down a frictionless plane that is inclined at an angle ϕ above the horizontal, as shown in the figure . What is the work done on the box by the force due to gravity w, if the box moves a distance d?





Hint 1. Finding Theta.

The work done on the box by the force of gravity depends on the angle between the weight and the displacement; this is the angle θ that goes into the equation

$$W = Fd\cos\theta.$$

ANSWER:

- ○ $W = wd\cos\phi$
- ◉ $W = wd\cos(90-\phi)$
- ○ $W = 0$
- ○ None of these

Correct
The angle given to you in a problem is not always the same angle that you use in the equation for work!

Part G

The planet Earth travels in a circular orbit at constant speed around the Sun. What is the net work done on the Earth by the gravitational attraction between it and the Sun in one complete orbit? Assume that the mass of the Earth is given by $M_{\rm e}$, the mass of the Sun is given by $M_{\rm s}$, and the Earth-Sun distance is given by $r_{\rm es}$.

Hint 1. Newton's law of universal gravitation

The magnitude of the force of attraction between two objects of masses M_1 and M_2 that are separated by a distance r is given by:

$$F = G\frac{M_1 M_2}{r^2}.$$

Hint 2. Circumference of a circle

The circumference of a circle with radius r is

$$C = 2\pi r$$

Hint 3. Finding the angle

The work done on the Earth by the gravitational attraction between it and the Sun depends on the angle between the gravitational force and the displacement of the Earth; this is the angle θ that goes into

$$W = Fd\cos\theta.$$

The force of attraction always points from the Earth toward the Sun along the radius of the Earth's orbit. At any instant in time the displacement of the Earth is considered to be tangent to its orbit; perpendicular to the radius.

ANSWER:

- ○ $W = 2\pi G \frac{M_e M_s}{r_{es}}$
- ○ $W = G\pi M_e M_s$
- ◉ $W = 0$
- ○ None of these.

Correct

An object undergoing uniform circular motion experiences a net force that is directed in toward the center of the circle; this net force is called the centripetal force. This force is always perpendicular to the distance the object moves and therefore never does any work on the object.

Part H

A block of mass m is pushed up against a spring with spring constant k until the spring has been compressed a distance x from equilibrium. What is the work done on the block by the spring?

Hint 1. Hooke's Law

The force exerted by a spring with spring constant k is given by

$$\vec{F} = -k\vec{x},$$

where x is the spring's displacement from equilibrium position x_{eq}.

ANSWER:

- ○ $W = kx^2$
- ○ $W = -kx^2$
- ○ $W = 0$
- ◉ None of these.

Correct

The equation for work presented in this problem requires that the force be constant. Because the force exerted on an object varies with the spring's displacement from equilibrium ($\vec{F} = k\vec{x}$) you cannot use $W = Fd\cos\theta$ to find the work done by a spring. In actuality the work done by a spring is given by the equation

$$W_{\text{spring}} = -\frac{1}{2}kx^2.$$

Congratulations! Now that you have the basics down and have been exposed to some tricky situations involving the equation for work, you are ready to apply this knowledge to new situations.

Score Summary:

Your score on this assignment is 99.8%.
You received 99.78 out of a possible total of 100 points.