

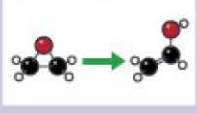
5. Kinetic energy, Work, and power

5.1 Energy in our Daily lives

Energy forms

The main forms of energy are:

- chemical
- heat
- electrical
- sound
- light
- magnetic
- elastic potential or strain energy
- kinetic
- gravitational potential
- nuclear

Type of energy	Description	Type of energy	Description
Kinetic 	The energy in moving objects – also called movement energy	Electrical 	Energy in moving charges or static electric charges
Heat 	Also called thermal energy	Elastic potential 	Stored energy in stretched or squashed objects
Light 	Also called radiant energy	Nuclear 	Stored in the nuclei of atoms
Gravitational potential (GPE) 	Energy stored in raised objects	Internal energy 	Contained in a thermodynamic system
Chemical 	Stored energy in fuel, foods and batteries	Strain energy 	Released when atoms in a molecule rearrange themselves in a chemical reaction
Sound 	Energy released by vibrating objects		

5.2 Kinetic Energy

the energy associated with the motion of a moving object: **kinetic energy**.

$$K = \frac{1}{2} mv^2$$

SI unit, the **joule (J)**

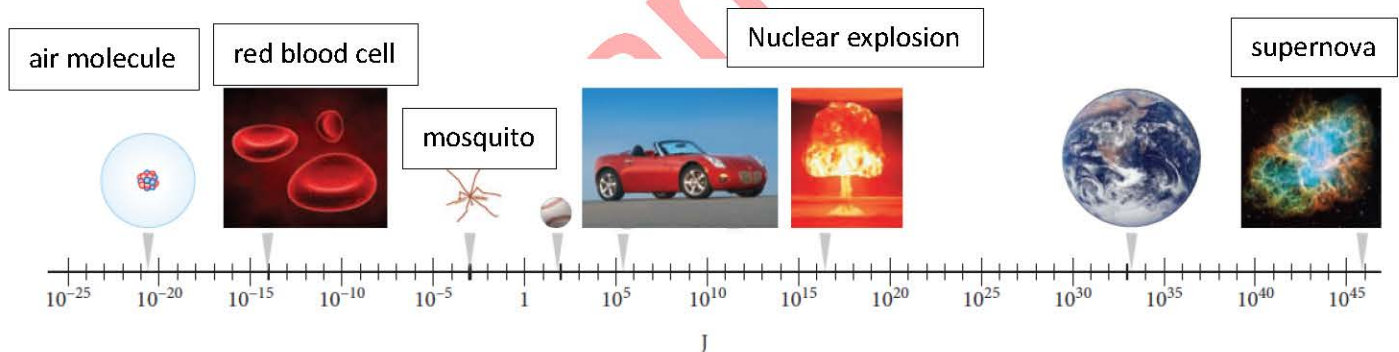
Energy unit: $1 \text{ J} = 1 \text{ N.m} = 1 \text{ kgm}^2/\text{s}^2$

Some other frequently used energy units are the electron-volt (eV), the food calorie (Cal), and the mega-ton of TNT (Mt):

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

$$1 \text{ Cal} = 4186 \text{ J}$$

$$1 \text{ Mt} = 4.18 \times 10^{15} \text{ J}$$



Note all objects must be in motion to have a kinetic energy

STOP TO THINK 10.3

Rank in order, from greatest to least, the kinetic energies of the sliding pucks.



EXAMPLE 5.1 Falling Vase**PROBLEM**

A crystal vase (mass = 2.40 kg) is dropped from a height of 1.30 m and falls to the floor, as shown in Figure 5.7. What is its kinetic energy just before impact? (Neglect air resistance for now.)

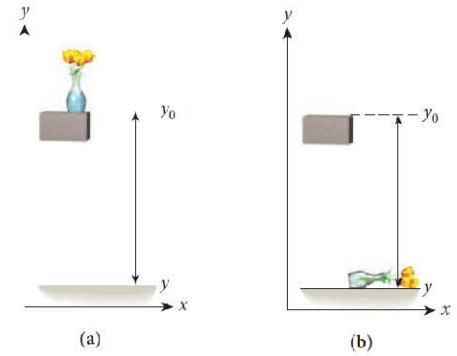
SOLUTION

$$v_y^2 = v_{y0}^2 - 2g(y - y_0)$$

$$v^2 = v_x^2 + v_y^2 = 0 + v_y^2 = v_y^2$$

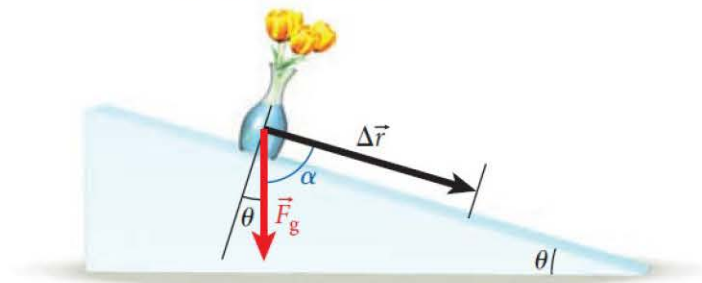
$$v^2 = v_y^2 = 2g(y_0 - y)$$

$$K = \frac{1}{2}mv^2 = (2.40 \text{ kg})(9.81 \text{ m/s}^2)(1.30 \text{ m}) = 30.6 \text{ J.}$$

**5.3 Work**

Work is the energy transferred to or from an object as the result of the action of a force.

- Positive work is a transfer of energy to the object
- Negative work is a transfer of energy from the object.

5.4 Work Done by a Constant Force

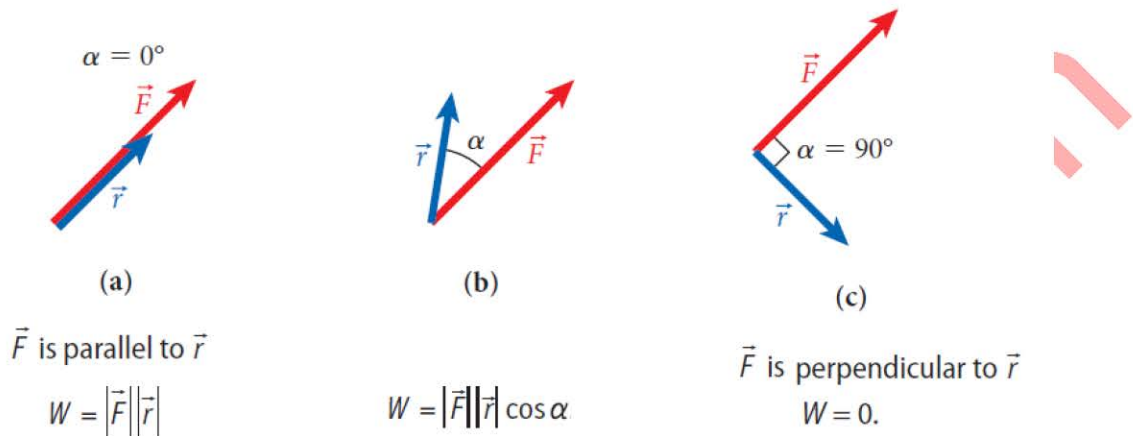
$$v^2 = v_0^2 + 2a\Delta r$$

$$v^2 = (2g \cos \alpha) \Delta r \Rightarrow K = \frac{1}{2}mv^2 = mg \Delta r \cos \alpha$$

The kinetic energy transferred to the vase was the result of positive work done by the gravitational force.

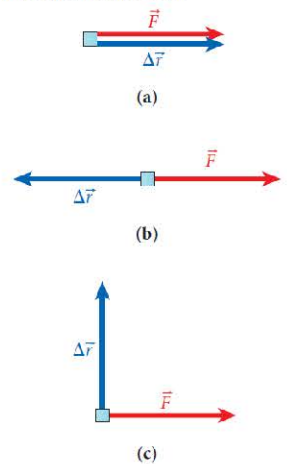
$$\Delta K = mg \Delta r \cos \alpha = W_g$$

Because $mg = |\vec{F}_g|$ and $\Delta r = |\Delta \vec{r}|$, we can write the work done on the vase as $W = |\vec{F}| |\Delta \vec{r}| \cos \alpha$, where α is the angle between $\vec{F}$ and $\Delta \vec{r}$



Concept Check 5.1

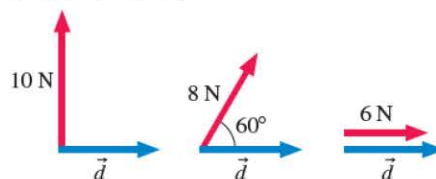
Consider an object undergoing a displacement $\Delta \vec{r}$ and experiencing a force $\vec{F}$. In which of the three cases shown below is the work done by the force on the object zero?



STOP TO THINK 10.2

Which force does the most work?

- A. The 10 N force
- B. The 8 N force
- C. The 6 N force
- D. They all do the same amount of work.



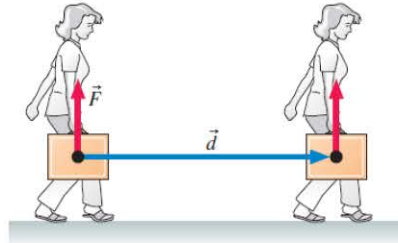
Note:

If a force always acts perpendicular to an object's direction of motion, that force cannot change the object's kinetic energy.

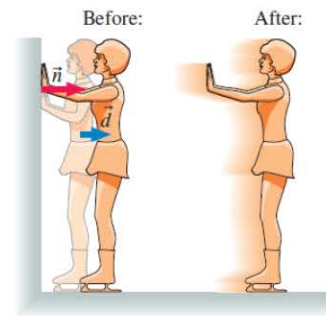
Forces that do no work



If the object undergoes no displacement while the force acts, no work is done.



A force perpendicular to the displacement does no work.



If the part of the object on which the force acts undergoes no displacement, no work is done.

The total work done on an object is **ZERO** when it moves with constant speed.

The work-energy equation The total energy of a system changes by the amount of work done on it:

work equals change in kinetic energy

$$W = \Delta K$$

and

work equals change in potential energy

and

$$W_g = mg(y_0 - y)$$

Thus, the work done by the gravitational force during the object's upward motion is

$$W_g = -mgh$$

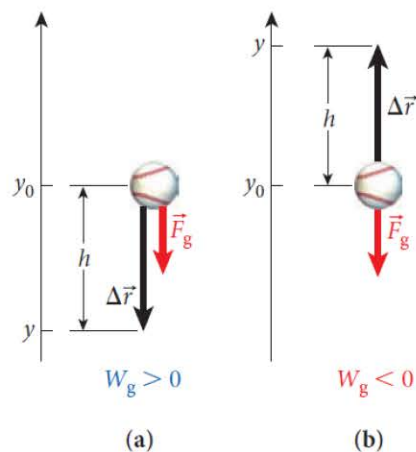
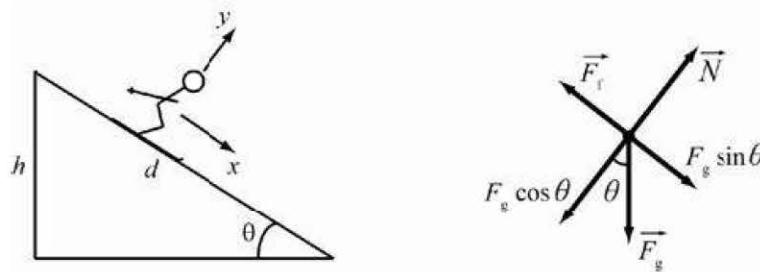


FIGURE 5.10 Work done by the gravitational force. (a) The object during free fall. (b) Tossing an object upward.

A ski jumper glides down a 30.0° slope for 24.4 m before taking off from a negligibly short horizontal ramp. If the jumper's takeoff speed is 13.7 m/s , what is the coefficient of kinetic friction between skis and slope?

Would the value of the coefficient of friction be different if expressed in SI units? If yes, by how much would it differ?



$$W = W_g + W_f = \frac{1}{2}mv^2, \quad W_g = mgh, \quad W_f = F_f d$$

$$W_f = W - W_g \Rightarrow F_f d = \frac{1}{2}mv^2 - mgh \Rightarrow -\mu N d = m \left(\frac{1}{2}v^2 - gh \right)$$

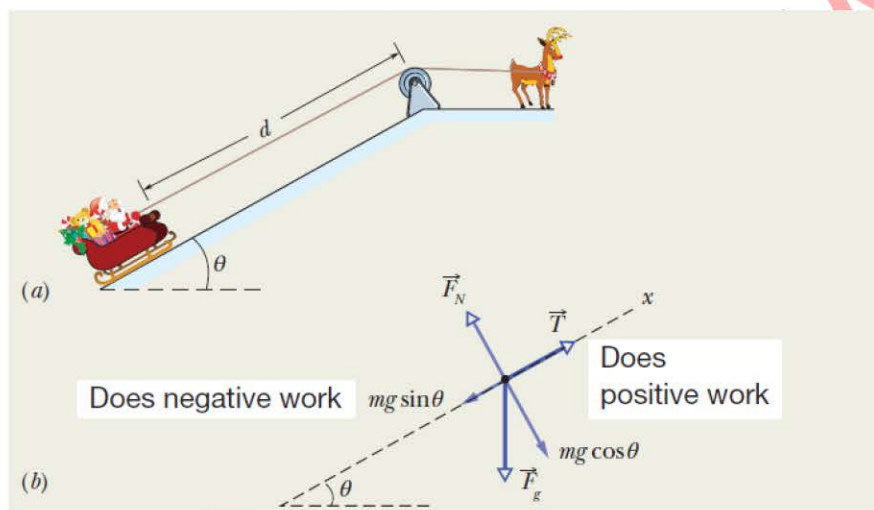
$$\mu = \frac{1}{gd \cos \theta} \left(gh - \frac{1}{2}v^2 \right)$$

In this problem an object is pulled along a ramp, but the object starts and ends at rest and thus has no overall change in its kinetic energy (that is important).

A rope pulls a 200 kg sleigh (which you may know) up a slope at incline angle $\theta = 30^\circ$, through distance $d = 20$ m. The sleigh and its contents have a total mass of 200 kg.

The snowy slope is so slippery that we take it to be frictionless.

How much work is done by each force acting on the sleigh?



Work W_N by the normal force.

$$W_N = F_N d \cos 90^\circ = 0$$

Work W_g by the gravitational force

$$F_{gx} = mg \sin \theta = (200 \text{ kg})(9.8 \text{ m/s}^2) \sin 30^\circ = 980 \text{ N}.$$

$$W_g = F_{gx} d \cos 180^\circ = (980 \text{ N})(20 \text{ m})(-1) = -1.96 \times 10^4 \text{ J}.$$

Work W_T by the rope's force.

$$0 = W_N + W_g + W_T = 0 - 1.96 \times 10^4 \text{ J} + W_T$$

$$W_T = 1.96 \times 10^4 \text{ J}.$$

Sample Problem 7.05

An elevator cab of mass $m = 500$ kg is descending with speed $v_i = 4.0$ m/s when its supporting cable begins to slip, allowing it to fall with constant acceleration $\vec{a} = \vec{g}/5$

(a) During the fall through a distance $d = 12$ m, what is the work W_g done on the cab by the gravitational force $\vec{F}_g$?

$$W_g = mgd \cos 0^\circ = (500 \text{ kg})(9.8 \text{ m/s}^2)(12 \text{ m})(1) \\ = 5.88 \times 10^4 \text{ J} \approx 59 \text{ kJ.} \quad (\text{Answer})$$

(b) During the 12 m fall, what is the work W_T done on the cab by the upward pull $\vec{T}$ of the elevator cable?

$$T - F_g = ma$$

$$W_T = Td \cos \phi = m(a + g)d \cos \phi$$

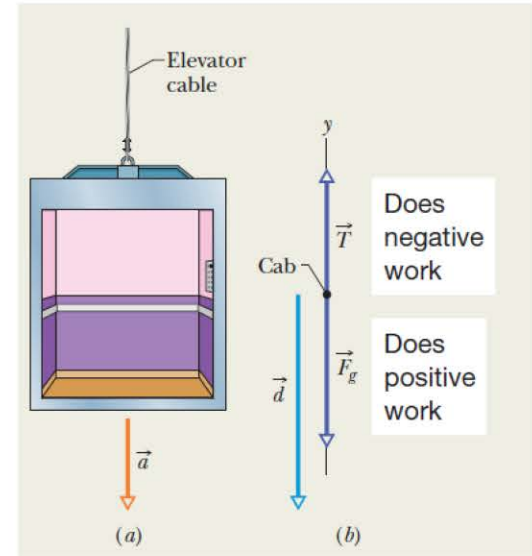
$$W_T = m \left(-\frac{g}{5} + g \right) d \cos \phi = \frac{4}{5} mgd \cos \phi \\ = \frac{4}{5} (500 \text{ kg})(9.8 \text{ m/s}^2)(12 \text{ m}) \cos 180^\circ \\ = -4.70 \times 10^4 \text{ J} \approx -47 \text{ kJ.}$$

(c) What is the net work W done on the cab during the fall?

$$W = W_g + W_T = 5.88 \times 10^4 \text{ J} - 4.70 \times 10^4 \text{ J} \\ = 1.18 \times 10^4 \text{ J} \approx 12 \text{ kJ.}$$

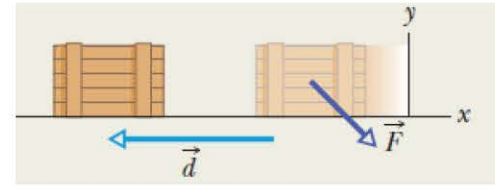
(d) What is the cab's kinetic energy at the end of the 12 m fall?

$$K_f = K_i + W = \frac{1}{2}mv_i^2 + W \\ = \frac{1}{2}(500 \text{ kg})(4.0 \text{ m/s})^2 + 1.18 \times 10^4 \text{ J} \\ = 1.58 \times 10^4 \text{ J} \approx 16 \text{ kJ.}$$



Example

During a storm, a crate of crepe is sliding across a slick, oily parking lot through a displacement $\vec{d} = (-3.0 \text{ m})\hat{x}$ while a steady wind pushes against the crate with a force $\vec{F} = (2.0 \text{ N})\hat{x} + (-6.0 \text{ N})\hat{y}$. The situation and coordinate axes are shown in Fig.



(a) How much work does this force do on the crate during the displacement?

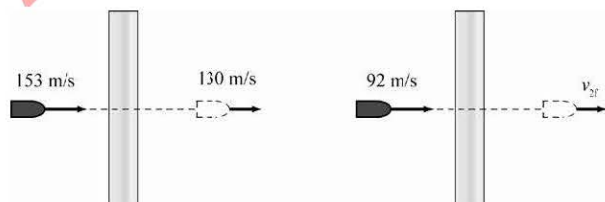
$$\begin{aligned} W &= \vec{F} \cdot \vec{d} = [(2.0 \text{ N})\hat{x} + (-6.0 \text{ N})\hat{y}] \cdot [(-3.0 \text{ m})\hat{x}] \\ &= (-6.0 \text{ J}) + 0 = -6.0 \text{ J}. \end{aligned}$$

(b) If the crate has a kinetic energy of 10 J at the beginning of displacement $\vec{d}$, what is its kinetic energy at the end of $\vec{d}$?

Because the force does negative work on the crate, it reduces the crate's kinetic energy.

$$K_f = K_i + W = 10 \text{ J} + (-6.0 \text{ J}) = 4.0 \text{ J}.$$

A bullet moving at a speed of **153 m/s** passes through a plank of wood. After passing through the plank, its speed is **130. m/s**. Another bullet, of the same mass and size but moving at **92.0 m/s**, passes through an identical plank. **What will this second bullet's speed be after passing through the plank?** Assume that the resistance offered by the plank is independent of the speed of the bullet.

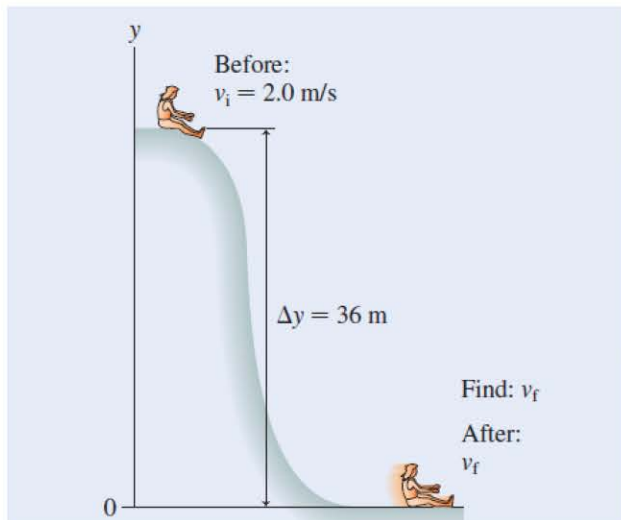


$$\frac{1}{2}m(v_{1f}^2 - v_{1i}^2) = \frac{1}{2}m(v_{2f}^2 - v_{2i}^2)$$

$$v_{2f} = \sqrt{v_{1f}^2 - v_{1i}^2 + v_{2i}^2}$$

Law of conservation of energy The total energy of an isolated system remains constant:

$$\Delta K + \Delta U_g = 0$$



$$K_f + (U_g)_f = K_i + (U_g)_i$$

$$K_f = K_i + ((U_g)_i - (U_g)_f) = K_i + \Delta U_g = K_i + mg\Delta y$$

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + mg\Delta y$$

$$v_f = \sqrt{v_i^2 + 2g\Delta y} = \sqrt{(2.0 \text{ m/s})^2 + 2(9.8 \text{ m/s}^2)(36 \text{ m})} = 27 \text{ m/s}$$

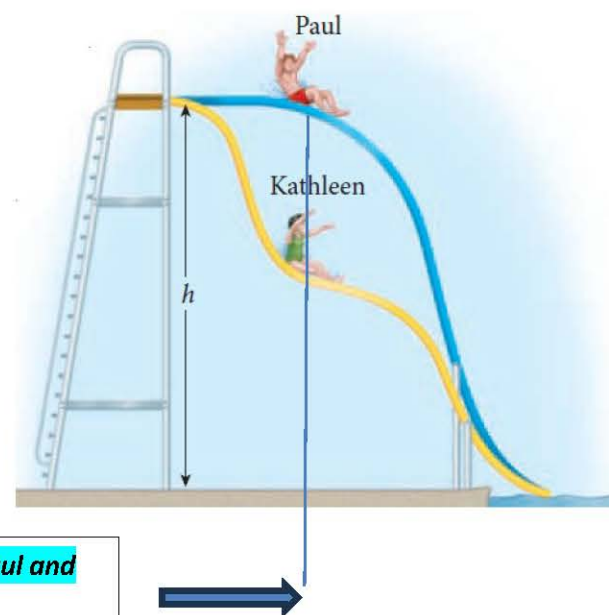
the same but with $v_i = 0$:

$$v_f = \sqrt{2g\Delta y} = \sqrt{2(9.8 \text{ m/s}^2)(36 \text{ m})} = 27 \text{ m/s}$$

$v_f = \sqrt{2gh}$. Their final velocity is independent of both their mass and the shape of path

so they will have the same final speed at the bottom

Kathleen will likely reach the bottom **first** since she will **accelerate faster** initially and will attain a larger speed sooner



At that position Kathleen will be faster than Paul and will have greater kinetic energy

Solved Problem 5.1 Shot Put**Problem**

Shot put competitions use metal balls with a mass of **7.26 kg**. A competitor throws the shot at an angle of **43.3°** and releases it from a height of **1.82 m** above where it lands, and it lands a horizontal distance of **17.7 m** from the point of release.

What is the kinetic energy of the shot as it leaves the thrower's hand?

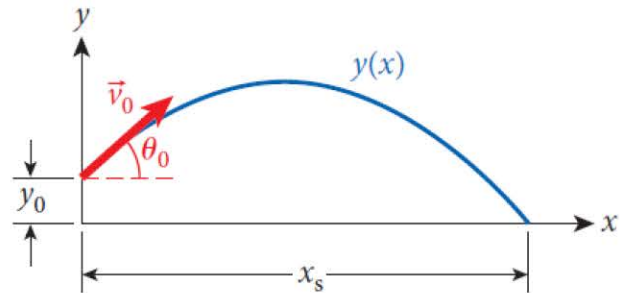
$$y = y_0 + x \tan \theta_0 - \frac{x^2 g}{2v_0^2 \cos^2 \theta_0}$$

$$0 = y_0 + x_s \tan \theta_0 - x_s^2 \frac{g}{2v_0^2 \cos^2 \theta_0}$$

$$v_0^2 = \frac{x_s^2 g}{2 \cos^2 \theta_0 (y_0 + x_s \tan \theta_0)}$$

$$K = \frac{1}{2} m v_0^2 = \frac{m x_s^2 g}{4 \cos^2 \theta_0 (y_0 + x_s \tan \theta_0)}$$

$$K = 569 \text{ J}$$

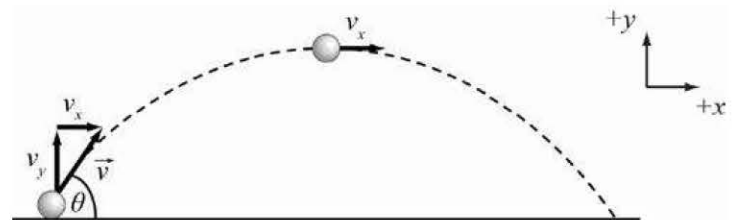


What is the kinetic energy of an ideal projectile of mass **20.1 kg** at the apex (highest point) of its trajectory, if it was launched with an initial speed of **27.3 m/s** and at an initial angle of **46.9°** with respect to the horizontal?

$$E = \frac{1}{2} m v_x^2 \text{ (at the apex, } v_y = 0); v_x = v \cos \theta$$

$$K = \frac{1}{2} m v^2 \cos^2 \theta$$

$$E = \frac{1}{2} (20.1 \text{ kg}) (27.3 \text{ m/s})^2 \cos^2 (46.9^\circ) = 3.497 \cdot 10^3 \text{ J}$$



5.5 Work Done by a Variable Force

$$W = \int_{x_i}^{x_f} F(x) dx = \int_{x_i}^{x_f} ma dx$$

$$ma dx = m \frac{dv}{dt} dx$$

$$\frac{dv}{dt} = \frac{dv}{dx} \frac{dx}{dt} = \frac{dv}{dx} v$$

$$W = \int_{v_i}^{v_f} mv dv = m \int_{v_i}^{v_f} v dv$$

$$= \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2.$$

A particle of mass m is subjected to a force acting in the x -direction. $F_x = (3.00 + 0.500x)$ N. Find the work done by the force as the particle moves from $x = 0.00$ to $x = 4.00$ m.

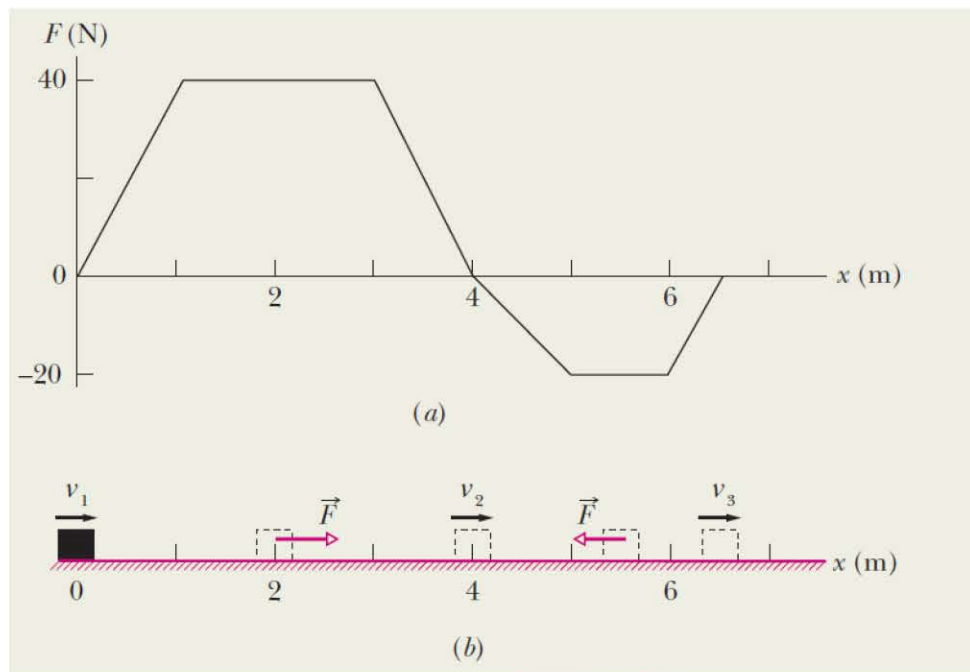
$$W = \int_{x_i}^{x_f} F(x) dx = \int_0^4 (3.0 + 0.50x) dx$$

$$W = \int_0^{4.0} (3.0 + 0.50x) dx = \left[3x + \frac{1}{4} x^2 \right]_{x=0}^{x=4.0} = 3(4) + \frac{1}{4} (4)^2 - 0 = 12 + 4 = 16 \text{ J}$$

$$W = 16 \text{ J}$$

An **8.0 kg** block slides along a frictionless floor as a force acts on it, starting at $x_1 = 0$ and ending at

$x_3 = 6.5 \text{ m}$. the magnitude and direction of the force vary according to the graph shown



The block's kinetic energy at x_1 is $K_1 = 280 \text{ J}$.

What is the block's speed at $x_1 = 0$, $x_2 = 4.0 \text{ m}$, and $x_3 = 6.5 \text{ m}$?

1. at $x_1 = 0$

$$K_1 = \frac{1}{2}mv_1^2,$$

$$280 \text{ J} = \frac{1}{2}(8.0 \text{ kg})v_1^2,$$

$$v_1 = 8.37 \text{ m/s} \approx 8.4 \text{ m/s}.$$

2. from $x_1 = 0$ to $x_2 = 4.0$ m

Positive work is being done on the block. We split the area under the plot into a triangle at the left, a rectangle in the center, and a triangle at the right.

$$\frac{1}{2}(40 \text{ N})(1 \text{ m}) + (40 \text{ N})(2 \text{ m}) + \frac{1}{2}(40 \text{ N})(1 \text{ m}) = 120 \text{ N} \cdot \text{m} \\ = 120 \text{ J.}$$

$$K_2 = K_1 + W \\ = 280 \text{ J} + 120 \text{ J} = 400 \text{ J} \\ K_2 = \frac{1}{2}mv_2^2, \\ 400 \text{ J} = \frac{1}{2}(8.0 \text{ kg})v_2^2, \\ v_2 = 10 \text{ m/s.}$$

3. from $x_2 = 4.0$ m to $x_3 = 6.5$ m

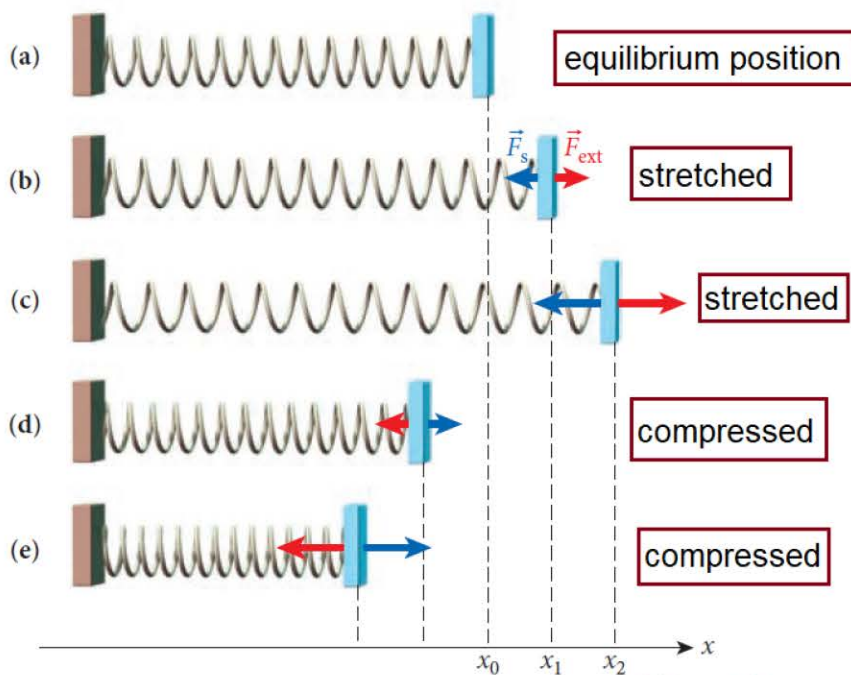
$$\frac{1}{2}(20 \text{ N})(1 \text{ m}) + (20 \text{ N})(1 \text{ m}) + \frac{1}{2}(20 \text{ N})(0.5 \text{ m}) = 35 \text{ N} \cdot \text{m} \\ = 35 \text{ J.}$$

work done by the force in that range is -35 J .

$$K_3 = K_2 + W \\ = 400 \text{ J} - 35 \text{ J} = 365 \text{ J} \\ K_3 = \frac{1}{2}mv_3^2, \\ 365 \text{ J} = \frac{1}{2}(8.0 \text{ kg})v_3^2 \\ v_3 = 9.55 \text{ m/s} \approx 9.6 \text{ m/s}$$

The block is still moving in the positive direction of the x axis, a bit faster than initially.

5.6 Spring Force



Hooke's Law

$$F_s = -k(x - x_0)$$

$$F_s = -kx$$

k , that appears in Hooke's Law is called the **spring constant** and has units of $\text{N/m} = \text{kg/s}^2$

The spring force is an important example of a **restoring force**: It always acts to restore the end of the spring to its equilibrium position.

EXAMPLE 5.3 Spring Constant**PROBLEM 1**

A spring has a length of 15.4 cm and is hanging vertically from a support point above it (Figure 5.15a). A weight with a mass of 0.200 kg is attached to the spring, causing it to extend to a length of 28.6 cm (Figure 5.15b). What is the value of the spring constant?

SOLUTION 1

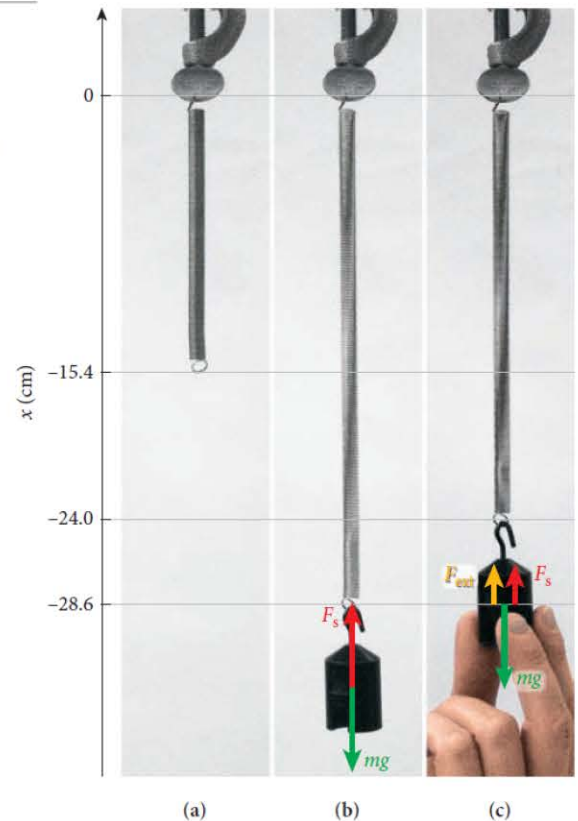
$$k = -\frac{F_s}{x - x_0} = -\frac{1.962 \text{ N}}{(-0.286 \text{ m}) - (-0.154 \text{ m})} = 14.9 \text{ N/m}$$

PROBLEM 2

How much force is needed to hold the weight at a position 4.6 cm above –28.6 cm (Figure 5.15c)?

SOLUTION 2

$$F_{\text{ext}} + F_s = 0 \Rightarrow F_{\text{ext}} = -F_s = kx = (0.046 \text{ m})(14.9 \text{ N/m}) = 0.68 \text{ N}.$$

**Work Done by the Spring Force**

$$W_s = -k \int_{x_0}^x x' dx' = -\frac{1}{2} kx^2 + \frac{1}{2} kx_0^2$$

If we set $x_0 = 0$ and start at the equilibrium position

$$W_s = -\frac{1}{2} kx^2$$

Concept Check 5.3

If you compress a spring a distance h from its equilibrium position and do work W_h in the process, how much work will be required to compress the same spring a distance $2h$?

- a) W_h
- b) $2W_h$
- c) $0.5W_h$
- d) $4W_h$
- e) $0.25W_h$

SOLVED PROBLEM 5.2 Compressing a Spring

A massless spring located on a smooth horizontal surface is compressed by a force of 63.5 N, which results in a displacement of 4.35 cm from the initial equilibrium position. As shown in Figure 5.16, a steel ball of mass 0.075 kg is then placed in front of the spring and the spring is released.

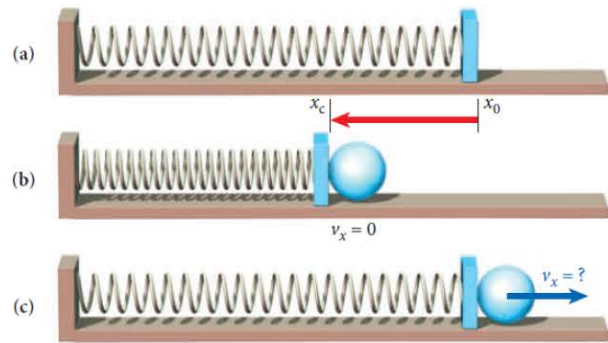
PROBLEM

What is the speed of the steel ball when it is shot off by the spring, that is, right after it loses contact with the spring? (Assume there is no friction between the surface and the steel ball; the steel ball will then simply slide across the surface and will not roll.)

SOLUTION

$$v_x = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(\frac{1}{2}kx_c^2)}{m}} = \sqrt{\frac{kx_c^2}{m}} = \sqrt{\frac{F_{\text{ext}}x_c}{m}}$$

$$v_x = \sqrt{\frac{(-63.5 \text{ N})(-0.0435 \text{ m})}{0.075 \text{ kg}}} = 6.06877 \text{ m/s}$$



5.7 Power

Power is the rate at which work is done. Mathematically, this means that the power, P , is the time derivative of the work, W :

$$P = \frac{dW}{dt}.$$

It is also useful to define the average power, $\bar{P}$ as

$$\bar{P} = \frac{W}{\Delta t}.$$

The SI unit of power is the **watt** (W)

$$1\text{W} = 1\text{ J/s} = 1\text{ kgm}^2/\text{s}^3$$

$$1\text{ kWh} = (1000\text{W})(3600\text{ s}) = 3.6 \times 10^6\text{ J}$$

Is each of the following statements **true** or **false**?

- a) Work cannot be done in the absence of motion. **True**
- b) More power is required to lift a box slowly than to lift a box quickly. **False**
- c) A force is required to do work. **True**

EXAMPLE 5.4 Accelerating a Car

PROBLEM

Returning to the example of an accelerating car, let's assume that the car, of mass 1550 kg, can reach a speed of 60 mph (26.8 m/s) in 7.1 s. What is the average power needed to accomplish this?

SOLUTION

We already found that the car's kinetic energy at 60 mph is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(1550\text{ kg})(26.8\text{ m/s})^2 = 557\text{ kJ}.$$

The work to get the car to the speed of 60 mph is then

$$W = \Delta K = K - K_0 = 557\text{ kJ}.$$

The average power needed to get to 60 mph in 7.1 s is therefore

$$\bar{P} = \frac{W}{\Delta t} = \frac{5.57 \cdot 10^5\text{ J}}{7.1\text{ s}} = 78.4\text{ kW} = 105\text{ hp}.$$

$$P = \frac{W}{\Delta t} = \frac{\Delta K}{\Delta t} = \frac{\Delta(\frac{1}{2}mv^2)}{\Delta t} = \frac{1}{2}v^2 \frac{\Delta m}{\Delta t}$$

$$P = \frac{1}{2}v^2 \frac{\Delta m}{\Delta t} = \frac{1}{2}v^2 \frac{\rho \Delta V}{\Delta t} = \frac{1}{2}v^2 \frac{\rho A l}{\Delta t} = \frac{1}{2}v^2 \frac{\rho(\pi R^2)(v \Delta t)}{\Delta t} = \frac{1}{2}v^3 \rho \pi R^2$$

Power, Force, and Velocity

$$P = \frac{dW}{dt} = \frac{\vec{F} \cdot d\vec{r}}{dt} = \vec{F} \cdot \vec{v} = Fv \cos \alpha$$

SOLVED PROBLEM 5.4 Riding a Bicycle

PROBLEM

A bicyclist coasts down a 4.2° slope at a steady speed of 5.1 m/s. Assuming a total mass of 82.2 kg (bicycle plus rider), what power output must the cyclist expend to pedal up the same slope at the same speed?

SOLUTION

Power = Fv .

$$\sum F_x = ma_x = 0 \Rightarrow F - mg \sin \theta = 0 \Rightarrow F = mg \sin \theta$$

$$P = 2(82.2 \text{ kg})(9.81 \text{ m/s}^2)\sin(4.2^\circ)(5.1 \text{ m/s}) = 602.391 \text{ W.}$$



G11 Adv	Physics – Unit 5	الفيزياء – الوحدة الخامسة	T2 – 2024 - 2025
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A constant force delivers an average power of 6 watts to move an object. If the object has an average velocity of 3 m/s and the force acts in the direction of motion of the object, what is the magnitude of the force?	قوة ثابتة تسلم قدرة متوسطة تبلغ 6 watt لتحريك جسم. إذا كان لديك الجسم سرعة متوسطة قدرها 3m/s والقوة تعمل في اتجاه حركة الجسم، فما هو مقدار القوة؟
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A curling stone with a mass of 19.96 kg is given an initial velocity of 2.46 m/s. The stone slides on the ice with a coefficient of kinetic friction of 0.0109. How far does the stone slide before it stops?	حجر تجعيد كتلته 19.96 kg ، كانت سرعته الابتدائية 2.46 m/s ينزلق الحجر على الجليد بمعامل احتكاك حركي قدره 0.0109. إلى أي مدى ينزلق الحجر قبل أن يتوقف؟
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- a) 18.7 m
b) 28.3 m
c) 34.1 m
d) 39.2 m

$$\Delta K = W$$

$$\frac{1}{2}mv^2 = \mu_k mgx$$

Anas uses a horizontal force of 20N to push a 4 kg box along a horizontal surface for 3 m, then lifts the box up to a shelf 1 m high. What is the total work done on the box?	استخدم أنس قوة أفقية مقدارها 20 N لدفع صندوق كتلته 4 Kg على سطح أفقي مسافة 3 m، ثم رفع الصندوق إلى رف بارتفاع 1 m ما هو الشغل الإجمالي الذي تم إنجازه على الصندوق؟
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In which of the following cases is the work done is **zero**?

- A. Work done by the porter on a suitcase in lifting it from the platform on to his head.
- B. Work done by the force of gravity on suitcase as the suitcase falls from porter's head.
- C. Work done by the porter standing on platform with suitcase on his head.
- D. Work done by force of gravity on a ball thrown up vertically up into the sky.

In which of the following cases the total work done on a car equals **zero**?

- A. The car moves with a constant velocity.
- B. The car moves with a decreasing velocity.
- C. The car moves in an opposite direction to the force.
- D. The car moves with a constant acceleration.

A car, of mass m , traveling at a speed v_1 can brake to a stop within a distance d . If the car speeds up by a factor of 2, so that $v_2 = 2v_1$, **by what factor is its stopping distance increased**, assuming that the braking force F is approximately independent of the car's speed?

$$\frac{(1/2)mv_2^2 = Fd_2}{(1/2)mv_1^2 = Fd_1} \rightarrow d_2 = d_1 \frac{v_2^2}{v_1^2} = d_1 \frac{(2v_1)^2}{v_1^2} = 4d_1$$

- A- $2d$
- B- $4d$
- C- $d/2$
- D- $d/4$

Two cars are moving. The first car has twice the mass of the second car but only **half as much kinetic energy**. **When both cars increase their speed by 5.00 m/s**, they then have the **same kinetic energy**. **Calculate the original speeds of the two cars.**

$$m_1 = 2m_2 \quad K_1 = \frac{1}{2}K_2$$

$$\frac{1}{2}(2m_2v_1^2) = \frac{1}{4}m_2v_2^2 \Rightarrow v_1 = \frac{1}{2}v_2$$

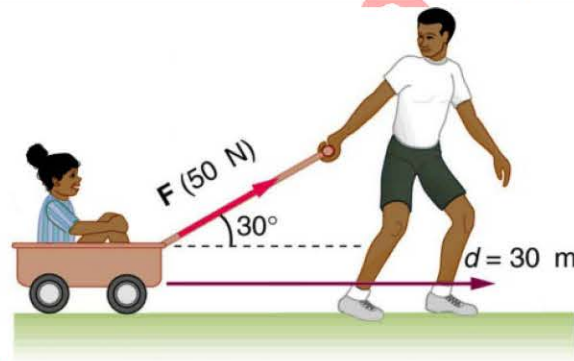
$$\frac{1}{2}m_1(v_1 + \Delta v)^2 = \frac{1}{2}m_2(v_2 + \Delta v)^2$$

A constant force, $\vec{F} = (4.79, -3.79, 2.09) \text{ N}$, acts on an object of mass 18.0 kg, causing a displacement of that object by $\vec{r} = (4.25, 3.69, -2.45) \text{ m}$. **What is the total work done by this force?**

$$W = F_x r_x + F_y r_y + F_z r_z$$

A wagon is pulled with a rope that makes an angle of 30° to the horizontal as shown in the figure. The tension in the rope is 50.0 N. **What is the work done by the force on the wagon** if it moves 30 m on the horizontal surface?

يتم سحب عربة بحبل يصنع زاوية قياسها 30° مع الأفقي، كما هو موضح في الشكل. قوة الشد في الحبل 50.0 N ما الشغل الذي تبذله القوة المؤثرة على العربة إذا تحركت مسافة 30 m على السطح الأفقي؟



- A. 1500 J
- B. 3300 J
- C. 1300 J
- D. 2500 J

A **1000 W** electric motor lifts a **100 kg** safe at constant velocity. **The vertical distance through which the motor can raise the safe in 10 s is most nearly**

محرك كهربائي قدرته **1000 W** يرفع خزانة وزنها **100 Kg** بسرعة ثابتة. **المسافة الرأسية التي يمكن للمحرك من خلالها رفع الخزانة خلال 10 s تقريبًا**

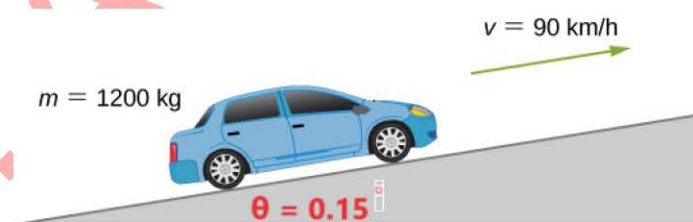
- A. 1 m
- B. 3 m
- C. 10 m
- D. 100 m

A spring is being stretched **0.07 m** from its equilibrium position. If this stretching requires of **35.0 J** work, **what is the spring constant?**

تم مد زنبرك مسافة **0.07 m** من موضع اتزانته. إذا كان هذا التمدد يتطلب شغلًا مقداره **35.0 J** ، **فما ثابت الزنبرك؟**

$$\text{Work} = \frac{1}{2} k x^2$$

$$k = \frac{2 \times \text{Work}}{x^2}$$



$$m\vec{g} \cdot \vec{v} = mgv \sin \theta$$

By assumption, 75% of the power is supplied against gravity

$$0.75 P = mgv \sin \theta$$

Ball A has half the mass and eight times the kinetic energy of ball B.

What is the speed ratio v_A/v_B ?

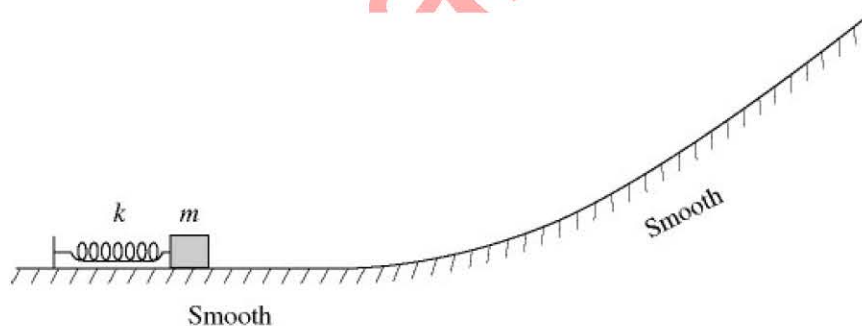
- A. 16
- B. 4
- C. 1/16
- D. 1/4

A **4.0-kg** object is moving with speed **2.0 m/s**. A **1.0-kg** object is moving with speed **4.0 m/s**. Both objects encounter the same constant braking force, and are brought to rest.

Which object travels the greater distance before stopping?

- A) the 4.0-kg object
- B) the 1.0-kg object
- C) Both objects travel the same distance.
- D) It is impossible to know without knowing how long each force acts.

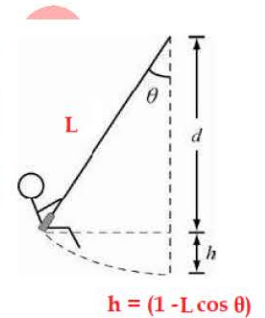
Answer: C



If we repeat this experiment with a box of mass 2m	If we repeat this experiment but instead compress the spring a distance of 2x	If we repeat this experiment but instead use a spring having force constant 2k
the lighter box will go twice as high up the incline as the heavier box	just as it moves free of the spring, the box will be traveling twice as fast as before.	A) the box will go up the incline twice as high as before. B) just as it moves free of the spring, the kinetic energy of the box will be twice as great as before. C) just as it moves free of the spring, the speed of the box will be times as great as before.

A father pulls his son, whose mass is **25.0 kg** and who is sitting on a swing with ropes of length

3.00 m, backward until the ropes make an angle of **33.6°** with respect to the vertical. He then releases his son from rest. **What is the speed of the son at the bottom of the swinging motion?**



A crane lowers a girder into place at constant speed. Consider the work W_G done by **gravity** and the work W_T done by the **tension** in the cable. **Which is true?**

- A. $W_G > 0$ and $W_T > 0$
- B. $W_G > 0$ and $W_T < 0$
- C. $W_G < 0$ and $W_T > 0$
- D. $W_G < 0$ and $W_T < 0$

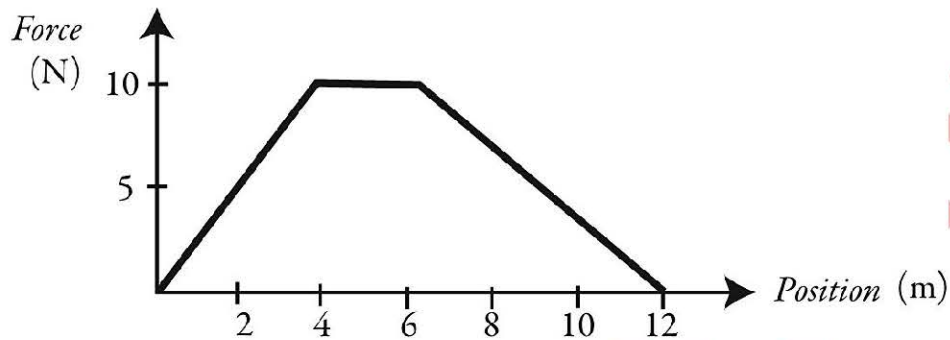
The bob of a pendulum of length ℓ is pulled a side from its equilibrium position through an angle θ and then released. The bob will; then pass through its equilibrium position with a speed $\underline{v}$, where v equals to :

- A. $\sqrt{2g\ell(1 - \sin\theta)}$
- B. $\sqrt{2g\ell(1 + \cos\theta)}$
- C. $\sqrt{2g\ell(1 - \cos\theta)}$
- D. $\sqrt{2g\ell(1 + \sin\theta)}$



An object is acted upon by a force that represented by the force vs. position graph in the figure. **What is the work done as the object moves**

- (a) after the first 6 m?
- (b) from 4 m to 6 m?
- (c) from 6 m to 12 m?



Answer: (a) 40 J (b) 20 J (c) 30 J

A force given by $\vec{F}(x) = 5x^3 \hat{x}$ (in N/m³) acts on a 1.00-kg mass moving on a frictionless surface. The mass moves from $x = 2.00$ m to $x = 6.00$ m.

- a) How much work is done by the force?
- b) If the mass has a speed of 2.00 m/s at $x = 2.00$ m, what is its speed at $x = 6.00$ m?

$$(a) \quad W = \int_{x_i}^{x_f} (5x^3) dx = \left[\frac{5}{4} x^4 \right]_{x_i}^{x_f} = \frac{5}{4} (x_f^4 - x_i^4)$$

$$(b) \quad W = \Delta K = K_f - K_i = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = \frac{1}{2} m (v_f^2 - v_i^2) \Rightarrow v_f^2 = \frac{2W}{m} + v_i^2 \Rightarrow v_f = \sqrt{\frac{2W}{m} + v_i^2}$$

CALCULATE:

$$(a) \quad W = \left(\frac{5}{4} \frac{\text{N}}{\text{m}^3} \right) [(6.00 \text{ m})^4 - (2.00 \text{ m})^4] = 1600 \text{ J}$$

$$(b) \quad v_f = \sqrt{\frac{2(1600 \text{ J})}{1.00 \text{ kg}} + (2.00 \text{ m/s})^2} = 56.6039 \text{ m/s}$$

A traveler pulls on a suitcase strap at an angle 36° above the horizontal. If 908 J of work are done by the strap while moving the suitcase a horizontal distance of 15 m , what is the tension in the strap?

- A) 75 N
- B) 61 N
- C) 85 N
- D) 92 N

In the figure, a constant external force $P = 160 \text{ N}$ is applied to a 20.0-kg box, which is on a rough horizontal surface. While the force pushes the box a distance of 8.00 m , the speed changes from 0.500 m/s to 2.60 m/s . The work done by friction during this process is closest to



- A) -1040 J
- B) $+1110 \text{ J}$
- C) $+1170 \text{ J}$
- D) $+1040 \text{ J}$

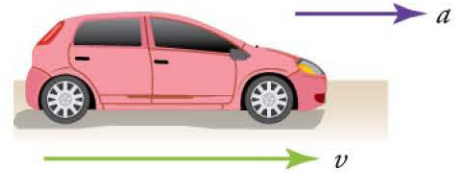
A road worker moves a 32 kg road marking machine by pushing it with a force of magnitude F , making an angle of 25° below the horizontal. The marking machine rolls at a constant speed of 0.5 m/s on a horizontal asphalt road surface. The coefficient of rolling friction between the marking machine and the asphalt is 0.18 . Find the power delivered by the worker.

- A. 14 W
- B. 31 W
- C. 123 W
- D. 150 W

car of mass **942.4 kg** accelerates from rest with a constant power output of **140.5 hp**. Neglecting air resistance, **what is the speed of the car after 4.55 s?**

(1 hp = 735.5 watt)

$$v_f = \sqrt{\frac{2P\Delta t}{m}}$$



An ideal spring has the spring constant **$k = 440. \text{ N/m}$** . **Calculate the distance** this spring must be stretched from its equilibrium position for **25.0 J** of work to be done.

$$W = \frac{1}{2}kx^2$$

