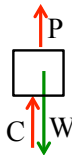


1. A woman is straining to lift a large crate, without success, as it is too heavy. The woman exerts on the crate an upward force with magnitude P , the contact force of the floor on the crate has magnitude C , and the weight of the crate is W .

While the person is trying unsuccessfully to lift the crate, what is the relationship between magnitudes of the forces P , C , and W ?

- A) $C = W$
 B) $P + C < W$
 C) $P + C > W$
 D) $P = C$
 E) $P - W < C$
 F) $W - P = -C$
 G) $P + C = W$
 H) $P = W$

Forces on
crate



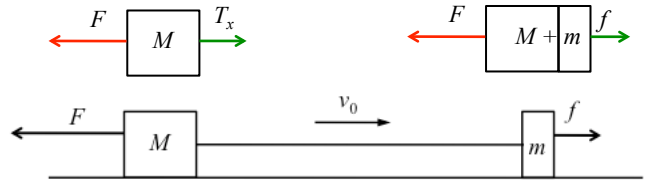
$$F_{\text{Net}} = 0 = C + P + (-W)$$

$$C + P = W$$

2. Consider the head on collision of a Garbage Truck with a Chevy Volt without any rebound. Which vehicle experiences the largest force? The largest magnitude of force is always experienced by the vehicle with the

- A) the largest initial speed
 B) the smallest initial speed
 C) the largest mass
 D) the smallest mass
 E) the largest initial momentum
 F) the smallest initial momentum
 G) the largest initial energy
 H) ... Both vehicles experience the same magnitude of force.

Apply Newton's 3rd Law: At contact point, forces of equal magnitude and opposite direction act.



3. A massless string connects a large mass M to a small mass m , and both are moving to the right (+) with an initial velocity, v_0 , as shown in the figure. A force *magnitude*, F , acts to the left on the larger mass, and a smaller force *magnitude*, f , acts to the right on the smaller mass. Find the acceleration, a_x of the system and then find the tension force, T_x acting on the larger mass. Which answer below has the correct a_x and T_x ?

- A) $a_x = \frac{f - F}{M + m}$, $T_x = F + Ma_x$
 B) $a_x = \frac{F}{M + m}$, $T_x = F + Ma_x$
 C) $a_x = \frac{f}{M + m}$, $T_x = F + Ma_x$
 D) $a_x = \frac{F - f}{M + m}$, $T_x = F + Ma_x$
 E) $a_x = \frac{F}{M + m}$, $T_x = F + Ma_x$
 F) $a_x = \frac{F}{M + m}$, $T_x = Ma_x$
 G) $a_x = \frac{F}{M + m}$, $T_x = f$
 H) $a_x = \frac{F}{M + m}$, $T_x = Ma_x + f$

System mass is $M + m$.

$\vec{F}_{\text{Net}}$ system: $\vec{F}_{\text{Net}} = f + (-F)$.

$$a_x = \frac{F_{\text{Net}}}{M + m} = \frac{f - F}{M + m}$$

$\vec{F}_{\text{Net}}$ on M : $\vec{F}_{\text{Net}} = T_x + (-F)$

$$\vec{F}_{\text{Net}} = T_x + (-F) = Ma_x$$

$$T_x = F + Ma_x$$

4. A mass, $m = 80.0 \text{ kg}$, traveling at a velocity of $+15.8 \text{ m/s}$ prior to being subjected to a force, $F = 2900 \text{ N}$ in the opposite direction, for 0.750 s . What is the speed of the mass afterward?

- A) $+43.0 \text{ m/s}$
 B) -25.2 m/s
 C) $+8.62 \text{ m/s}$
 D) -17.8 m/s
 E) -11.4 m/s
 F) $+17.8 \text{ m/s}$
 G) $+25.2 \text{ m/s}$
 H) -8.62 m/s

$$a_x = -F/m$$

$$v_x = v_{0x} + a_x t$$

$$= [15.8 + (-2900 / 80.0) 0.750] \text{ m/s}$$

$$= -11.4 \text{ m/s}$$

5. Acting on an object with mass, $m = 55.0 \text{ kg}$, are two forces: $F_1 = 65.0 \text{ N}$, $\theta = 59.0^\circ$, and $F_2 = 35.0 \text{ N}$, $\phi = 32.0^\circ$, as shown in the diagram. What is the magnitude of the object's acceleration?

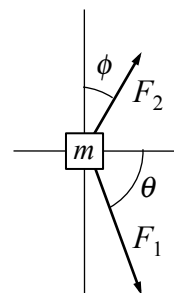
- A) 1.00 m/s^2
 B) 1.06 m/s^2
 C) 1.34 m/s^2
 D) 1.23 m/s^2

- E) 1.44 m/s^2
 F) 1.29 m/s^2
 G) 1.49 m/s^2
 H) 1.58 m/s^2

$$F_x = F_1 \cos \theta + F_2 \sin \theta = 52.0 \text{ N}$$

$$F_y = -F_1 \sin \theta + F_2 \cos \theta = -26.0 \text{ N}$$

$$a = F / m = \sqrt{F_x^2 + F_y^2} = 1.06 \text{ m/s}^2$$



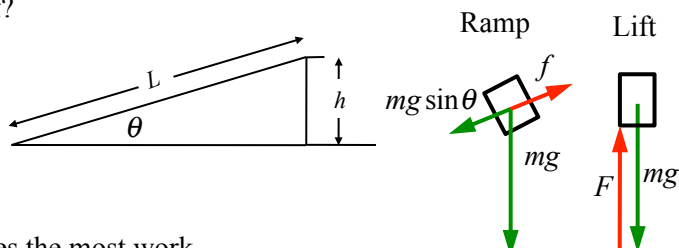
6. A box must be lifted to a high shelf. Starting at the ground the box is pushed up a frictionless ramp of various angles (θ) at the same slow but constant speed, or is lifted straight upward at a much larger but also constant speed. Which ramp angle or the vertical rapid lift will require the most amount of work in lifting the box to the shelf?

- A) $\theta = 10^\circ$
 B) $\theta = 20^\circ$
 C) $\theta = 30^\circ$
 D) $\theta = 40^\circ$

- E) $\theta = 50^\circ$
 F) $\theta = 60^\circ$
 G) The vertical lift requires the most work.

H) All ramps and the vertical lift require the same amount of work.

Speed constant $\rightarrow F_{\text{Net}} = 0$. Ramp: $W = fL = [mg \sin \theta]L$ Lift: $W = mgh = mg[L \sin \theta]$



7. You push downward on a trunk at an angle of 25.0° below the horizontal with a force of 750 N . If the trunk is on a flat surface and the coefficient of static friction is 0.760 , what is the most massive trunk you will be able to move?

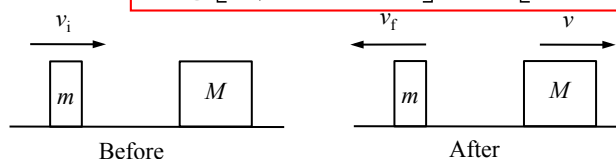
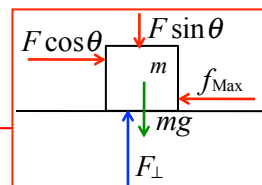
- A) 54.4 kg
 B) 68.2 kg
 C) 58.9 kg
 D) 82.3 kg

- E) 48.7 kg
 F) 63.7 kg
 G) 77.2 kg
 H) 72.3 kg

$$f_{\text{max}} = \mu_s F_{\perp}, \quad F_{\perp} = mg + F \sin \theta$$

$$f_{\text{max}} = \mu_s (mg + F \sin \theta) < F \cos \theta \text{ (to slide)}$$

$$m < \frac{F}{g} \left[\frac{\cos 25^\circ}{\mu_s} - \sin 25^\circ \right] = \frac{750}{9.81} \left[\frac{0.9063}{0.760} - 0.4226 \right] \text{ kg} = 58.9 \text{ kg}$$



8. A block of mass $m = 2.20 \text{ kg}$ moving with a speed $v_i = 9.10 \text{ m/s}$ on a frictionless surface, makes an elastic collision with mass M at rest, as shown above. After the collision the mass m is observed to have a speed of $v_f = 0.700 \text{ m/s}$. What is the value of the mass M ?

- A) 2.57 kg
 B) 2.93 kg
 C) 3.29 kg
 D) 1.15 kg

- E) 1.77 kg
 F) 1.97 kg
 G) 2.22 kg
 H) 3.71 kg

$$p_i = mv_i = 20.02 \text{ kg} \cdot \text{m/s}; \quad p_f = m(-v_f) + Mv$$

$$K_i = \frac{1}{2} mv_i^2 = 91.1 \text{ J}; \quad K_f = \frac{1}{2} mv_f^2 + \frac{1}{2} Mv^2$$

1) p conserved: $m(-v_f) + Mv = 20.02 \text{ kg} \cdot \text{m/s} \rightarrow Mv = 21.56 \text{ kg} \cdot \text{m/s}$

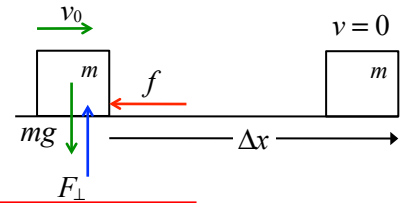
2) K conserved: $\frac{1}{2} mv_f^2 + \frac{1}{2} Mv^2 = 91.1 \text{ J} \rightarrow Mv^2 = 181.1 \text{ J}$

$$M = (Mv)^2 / (Mv^2) = [(21.56)^2 / (181.1)] \text{ kg} = 2.57 \text{ kg}$$

Since only speed was given for v_f and not direction, all students will get credit for this problem

9. A puck slides on a board a total of 12 m before coming to rest. The coefficient of kinetic friction is 0.10 between the puck and the board. What was the initial speed of the puck?

- A) 9.72 m/s
B) 3.88 m/s
C) 5.50 m/s
D) 7.64 m/s
E) 16.7 m/s
F) 4.85 m/s
G) 25.0 m/s
H) 13.5 m/s



$$K_f = 0; \quad f_k = \mu_k mg$$

$$\text{By friction: } W = f_k(\cos\theta)\Delta x = -\mu_k mg\Delta x$$

$$\text{But also, } W = K_f - K_i = -K_i = -\frac{1}{2}mv_0^2$$

$$-\mu_k mg\Delta x = -\frac{1}{2}mv_0^2, \quad v_0 = \sqrt{2\mu_k g\Delta x} = 4.85 \text{ m/s}$$

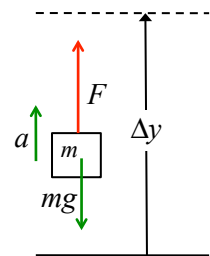
10. A crane lifts a 425 kg beam vertically upward a distance of 117 m. How much work is done by the crane on the beam if it accelerates upward at 1.79 m/s².

- A) $5.77 \times 10^5 \text{ J}$
B) $5.12 \times 10^5 \text{ J}$
C) $4.88 \times 10^5 \text{ J}$
D) $4.03 \times 10^5 \text{ J}$
E) $8.90 \times 10^4 \text{ J}$
F) $8.90 \times 10^3 \text{ J}$
G) $8.90 \times 10^5 \text{ J}$
H) 0.00 J

$$F_{\text{Net}} = ma = F - mg$$

$$F = mg + ma = m(g + a)$$

$$W = F\Delta x = m(g + a)\Delta x \\ = (425)(9.81 + 1.79)(117) \text{ J} \\ = 5.77 \times 10^5 \text{ J}$$

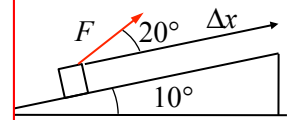


11. A sled is pulled at a constant speed up to the top of a 100.0 m long snow covered (frictionless) hill that makes an angle of 10° upward with respect to the horizontal. The sled is pulled with a rope that makes a 20° angle with respect to the direction of travel. If the rope does 5000 J of work in pulling the sled up the hill at a constant speed, what tension force did the rope apply to the sled?

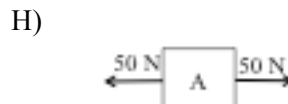
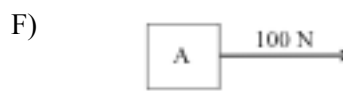
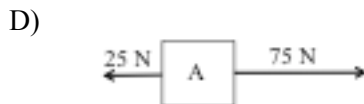
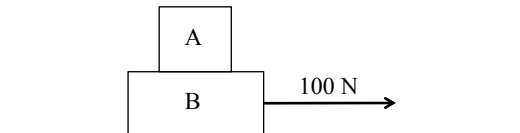
- A) 65.6 N
B) 72.6 N
C) 50.0 N
D) 53.2 N
E) 75.5 N
F) 79.3 N
G) 61.8 N
H) 57.7 N

$$W = F(\cos\theta)\Delta x; \quad \theta = \angle \text{ between } \vec{F} \text{ and } \Delta \vec{x}$$

$$F = \frac{W}{(\cos\theta)\Delta x} = \frac{5000 \text{ J}}{(\cos 20^\circ)(100 \text{ m})} = 53.2 \text{ N}$$

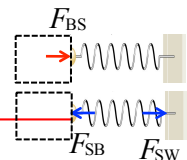


12. Two blocks, A and B, are being pulled to the right along a horizontal surface by a horizontal 100 N force, as shown in the figure. The blocks are moving together at a constant velocity of 2.0 m/s to the right, and both weigh the same. Which of the figures below shows a correct free-body diagram of the horizontal forces acting on upper block?



Constant velocity means $F_{\text{Net}} = 0$,
and no external force acts on top block

13. A box sliding on a frictionless surface at a speed v , hits an ideal spring attached to a wall and bounces off with the same speed as the initial speed. Consider the following statements regarding this collision and choose the statement that is true.



- A) This collision conserves energy and momentum of the box.
- B) This collision does not conserve the energy of the box.
- C) This collision conserves only momentum of the box
- D) This collision conserves neither momentum nor energy
- E) In the collision there is only a force on the box
- F) In the collision there is only a force on the spring.
- G) In the collision there is no force on the wall.

$\vec{F}_{BS}$ (force of box on spring)

$\vec{F}_{SB}$ (force of spring on box)

$\vec{F}_{BS}, \vec{F}_{SB}$ action-reaction pair $\rightarrow$ equal magnitudes

$\vec{F}_{SW}$ (force of spring on wall) same magnitude as $\vec{F}_{SB}$

$\vec{F}_{BS}$ has same magnitude and direction as $\vec{F}_{SW}$

H) In the collision the magnitude and direction of the spring force on the wall is always the same as the magnitude and direction of the force of the box on the spring.

14. A ball rolls down into a valley and then back up to the other side but only to 90% of the original starting height of 50 m above the valley floor. Assuming the ball loses the exactly the same % of its total energy on each trip across the valley, to what height above the valley floor does the ball get after 10 trips across the valley?

- A) 40.3 m
- B) 25.7 m
- C) 17.4 m
- D) 34.9 m
- E) 29.8 m
- F) 19.7 m
- G) 22.1 m
- H) 0.00 m

$$U_0 = mgh_0 \rightarrow h_0 = U_0/mg$$

$$U_1 = 0.9(U_0) \text{ and } h_1 = U_1/mg$$

$$U_2 = 0.9(U_1) = 0.9(0.9(U_0)) = (0.9)^2 U_0$$

$$\text{Therefore: } U_{10} = (0.9)^{10} U_0 = 0.359 U_0$$

$$h_{10} = U_{10}/mg = 0.359 U_0/mg = 0.359 h_0 = 0.359(50\text{m}) = 17.4\text{m}$$

15. A person carries a 7.0 kg bag of groceries 1.2 m above the floor at a constant velocity across a room 2.3 m wide. How much work was done on the bag of groceries during this motion?

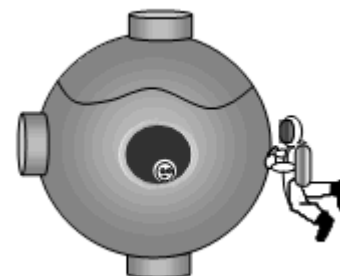
- A) 84 J
- B) 161 J
- C) 8.4 J
- D) 16.1 J
- E) 24.5 J
- F) 77.0 J
- G) 0.00 J
- H) 9.22 J

No horizontal force needed for constant velocity.

No change in the height of groceries, $\Delta y = 0$.

Therefore, no work done on the bag of groceries.

16. 70.0-kg astronaut pushes to the left on a spacecraft in “gravity-free” space. The spacecraft has a total mass of 1.00×10^4 kg. After the push, the astronaut is observed to move to the right with a velocity +16.2 m/s. After the push, what is the velocity of the spacecraft?



- A) 0.092×10^{-1} m/s
- B) 1.19×10^{-1} m/s
- C) 1.25×10^{-1} m/s
- D) 1.13×10^{-1} m/s
- E) 1.33×10^{-1} m/s
- F) 1.45×10^{-1} m/s
- G) 1.37×10^{-1} m/s
- H) 0.0 m/s

Momentum is conserved. $p_i = 0$

$$p_f = m_s v_s + m_A v_A = 0$$

$$v_s = -m_A v_A / m_s = -(70\text{kg})(16.2\text{m/s}) / (1.00 \times 10^4\text{kg})$$

$$= -1.13 \times 10^{-1} \text{ m/s}$$

Since the problem asked for velocity and not speed, the minus sign was missing from all answers. All students will get credit for this problem.