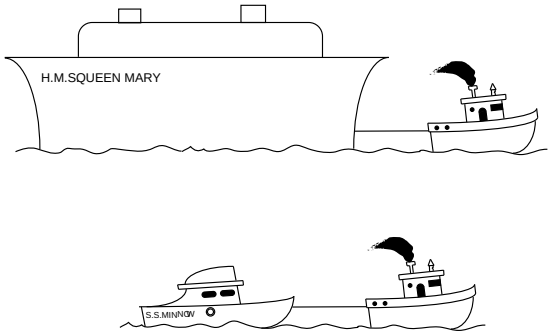
## Auxiliary Material: APPENDIX: Multiple-Choice Questions: Correct Responses Italicized (dashed lines separate a set of related questions from another set)

(1) A tugboat pulls a ship of mass $M$ into the harbor with a constant tension force $\vec{F}$ in the horizontal tow cable. Both the tugboat and the ship start from rest. After the ship has been towed a distance $d$ in time $t$, the magnitude of its momentum will be
(a) $Fd$
(b) $(1/2)(F/M)t^2$
(c) $(F/M)t^2/d$
(d) $(1/2)(F/M)dt^2$
*(e)* $Ft$

(2) Two identical tugboats pull other ships as shown below, starting from rest. The Queen Mary is a much more massive ship than the Minnow. Both tugboats pull with the same horizontal force. Neglect other forces. After both tugboats have been pulling for the same amount of time, which one of the following is true about the Queen Mary and the Minnow?




(a) The Queen Mary will have a greater magnitude of momentum.
(b) The Minnow wil have a greater magnitude of momentum.
*(c) Both ships will have the same magnitude of momentum.*
(d) Both ships will have the same kinetic energy.
(e) The Queen Mary will have a greater kinetic energy.

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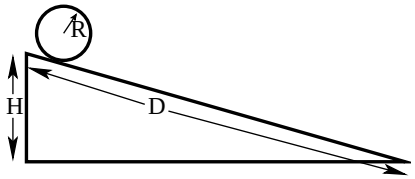
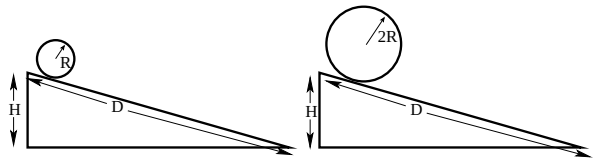
(3) A hoop of mass $M = 2$ kg, radius $R = 1$ m, and moment of inertia $MR^2$ starts from rest and rolls without slipping down a ramp that is $D = 20$ m long and $H = 5$ m high. Find its speed at the bottom of the ramp.




(a) 11 m/s
(b) 10 m/s

(c) 8.9 m/s
*(d) 7.1 m/s*
(e) 5 m/s

(4) A hoop of mass $M$ and radius $R$ rolls down a ramp of height $H$ and length $D$ starting from rest. It arrives at the bottom with speed $v_0$. If a second hoop with twice the mass ($2M$) and twice the radius ($2R$) rolls down the same ramp starting from rest, find its speed at the bottom in terms of $v_0$.




(a) $v_0/4$
(b) $v_0/2$
*(c) $v_0$*
(d) $2v_0$
(e) $4v_0$

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(5) While in a playground, you slide down from the top of a frictionless slide starting from rest. Your mass is 100 kg and the height of the slide is 5 m. Assume that the acceleration due to gravity has a magnitude of 10 m/$s^2$. Which one of the following is your speed at the bottom of the slide?
(a) 1 m/s
*(b) 10 m/s*
(c) 100 m/s
(d) 1000 m/s
(e) None of the above.

(6) While in a playground, you and your niece take turns sliding down a frictionless slide. Your mass is 75 kg while your little niece's mass is only 25 kg. Assume that both of you begin sliding from rest from the same height. Which one of the following statements best describes who has a larger speed at the bottom of the slide?
*(a) Both of you have the same speed at the bottom.*
(b) Your niece, because she is not pressing down against the slide as strongly so her motion is closer to free fall than yours.
(c) You, because your greater weight causes a greater downward acceleration.
(d) Your niece, because lighter objects are easier to accelerate.
(e) You, because you take less time to slide down.

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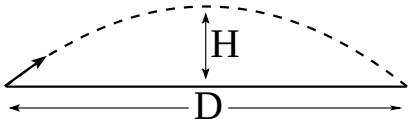
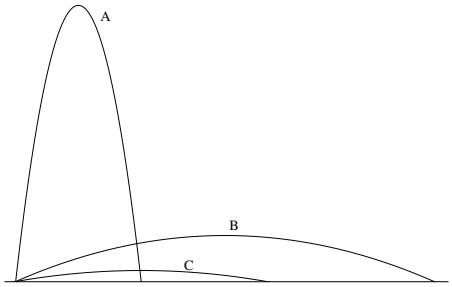
(7) A projectile is fired from a level surface with an initial velocity, $\vec{v}$ (components $(v_x, v_y)$), where the y-axis is vertical and the x-axis is horizontal. Find the time it takes the projectile to reach its maximum height $H$. $g$ is the magnitude of the acceleration due to gravity.




(a) $v_x/g$
(b) $2v_x/g$
*(c)* $v_y/g$
(d) $2v_y/g$
(e) $\sqrt{(v_x^2+v_y^2)}/g$

(8) An artillery unit fires at three targets on the ground simultaneously at the same launch speed but at different angles, as shown below. The trajectories shown are qualitatively correct. Which of the three shells will hit its target LAST?




*(a) A*
(b) B
(c) C
(d) All three hit at the same time
(e) Impossible to say without knowing the actual launch angles for each shell

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(9) Batman falls vertically at 5 m/s in a boat traveling horizontally at 10 m/s. He comes to rest in the boat. The mass of Batman is 100 kg and the mass of the boat is 100 kg. What is the final speed of the boat with Batman in it?
(a) 10 m/s
*(b) 5 m/s*
(c) 15 m/s
(d) 7.5 m/s
(e) None of the above

(10) Rain starts falling vertically down into a cart with frictionless wheels which is initially moving at a constant velocity on a horizontal surface. The rain drops come to rest with respect to the cart after striking it, and rain water accumulates in the cart. Select all of the following statements that must be true about this situation.

(1) The cart will continue to move at a constant velocity because the rain is falling vertically while the cart is moving horizontally.
(2) The cart will continue to move at a constant velocity because

the total mechanical energy of the cart-rain system is conserved.
(3) The cart will slow down because the horizontal momentum of the cart-rain system is conserved.

(a) (1) only
(b) (2) only
*(c) (3) only*
(d) (1) and (2) only
(e) None of the above

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(11) An ice skater is spinning on essentially frictionless ice with her arms extended. Then, she pulls her arms in close to her body, cutting her moment of inertia in half. There are no net external forces or torques on her. Which one of the following statements correctly describes the effect of pulling her arms in?
(a) She slows down and her angular momentum decreases.
(b) She speeds up, and her angular momentum increases.
(c) Due to the conservation of angular momentum, her angular speed is unchanged.
*(d) She speeds up, but her angular momentum is unchanged.*
(e) She slows down, but her angular momentum is unchanged.

(12) A star collapses into a white dwarf, shrinking to 1/100th of its initial radius. Assume that there are no external torques on the star and that it loses no mass as it collapses. You may treat it as a uniform sphere. If its initial angular momentum and angular speed are $L_0$ and $\omega_0$, respectively, what are those variables after the collapse?
(a) $L = L_0$, $\omega = \omega_0/100$
(b) $L = 100L_0$, $\omega = 100\omega_0$
(c) $L = 100L_0$, $\omega = 10,000\omega_0$
(d) $L = L_0/100$, $\omega = 100\omega_0$
*(e)* $L = L_0$, $\omega = 10,000\omega_0$

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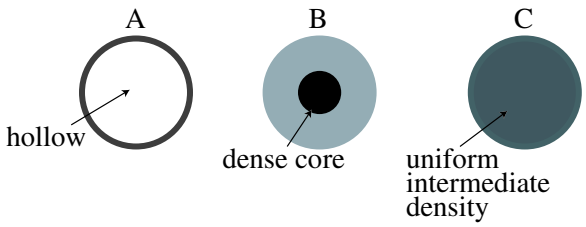
(13) A hollow ball and a solid ball have the same mass and radius. You race them by rolling them down the same ramp, starting from rest. Which one of the following is a correct description of the race?
(a) The hollow ball goes faster because its moment of inertia is greater.
*(b) The solid ball goes faster because its moment of inertia is smaller.*
(c) The race will be a tie because the balls have the same mass and radius.
(d) The hollow ball will pull ahead at first, then the solid ball will pass it as its greater kinetic energy takes over.
(e) The solid ball will pull ahead at first, then the hollow ball will pass it as its greater kinetic energy takes over.

(14) Three balls are manufactured with the same mass and radius, as shown below. Ball $A$ is hollow, while ball $B$ has a light plastic outer coat over a small dense core. Ball $C$ is a uniform solid of intermediate density. You start the balls from rest and they roll without slipping

down the same incline. Predict the order in which they reach the bottom of the ramp (first to last).




(a) A, B, C
*(b) B, C, A*
(c) A, C, B
(d) B, then C and A together
(e) All three balls will arrive at the same time.

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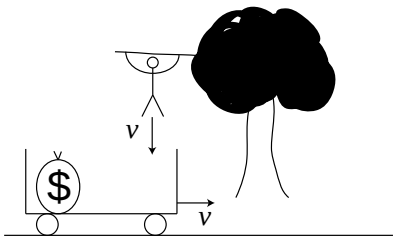
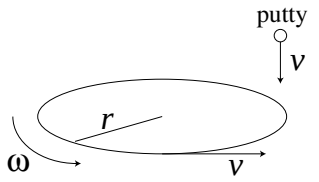
(15) You are a bandit, waiting in a tree to ambush a cart full of money. The cart is rolling along a level road at speed $v$. Its wheels make it essentially frictionless. As it passes under the tree, you drop straight down out of the tree into the cart, as shown. You land with a speed equal to that of the cart and come to rest with respect to the cart. Which one of the following both correctly describes what happens to the cart as a result of the collision, and gives a valid explanation.




(a) It speeds up, because your velocity adds to the cart's.
(b) Its speed is unchanged because your vertical velocity cannot affect the horizontal velocity of the cart.
(c) Its speed is unchanged because of energy conservation.
*(d) It slows down, by conservation of the horizontal component of the total linear momentum.*
(e) It stops, because your force on the cart is equal in magnitude and opposite in direction to the force of its motion.

(16) You do an experiment in which you drop a blob of putty onto a freely spinning turntable, as shown. The turntable has a mass $m$, radius $r$, and is spinning in a horizontal plane at an angular speed $\omega$, with its rim moving at speed $v$. You may treat the turntable as a uniform disk. The putty blob has a mass $m/2$ and you drop it right on the rim of the turntable. It hits there while moving straight down at speed $v$ and comes to rest with respect to the turntable. Which one of the following statements correctly describes what happens to the turntable as a result of the collision, and gives a valid explanation?




(a) It speeds up, because the putty's velocity adds to the turntable's.
(b) It continues to spin at the same rate because the putty's vertical velocity cannot affect the horizontal spin of the turntable.
(c) Its speed is unchanged because of conservation of energy.
*(d) It slows down by conservation of angular momentum.*
(e) It comes to a stop because the torque the putty exerts on the turntable must be equal in magnitude and opposite in direction to the torque of the turntable's motion.

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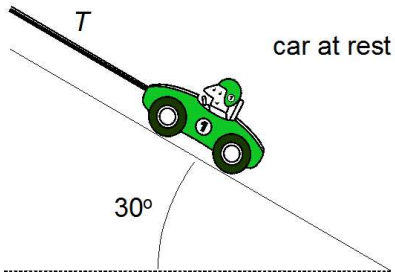
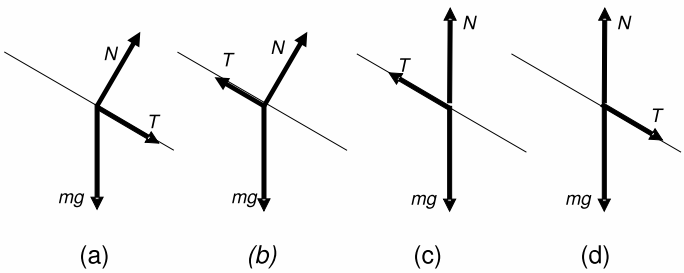
Note: These trigonometric results might be useful in the next four questions: $sin30^0 = 0.5$ $cos30^0 = 0.866$ to three places.

- **Setup for the next two questions**

**A car which weighs $15,000$ N is at rest on a frictionless $30^0$ incline, as shown below. The car is held in place by a light strong cable parallel to the incline.**




(17) Which one of the following is the correct free body diagram of the car (with correct directions)? $N$, $mg$, and $T$ are the magnitude of the normal force, the weight of the car and the tension force, respectively.

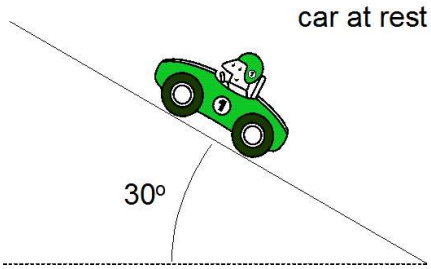



(e) None of the above.

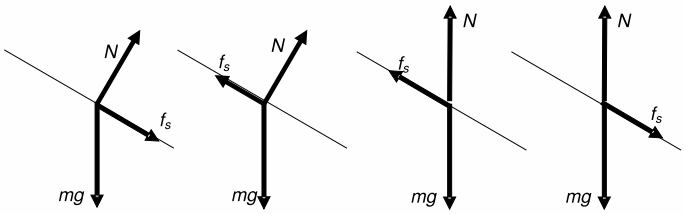
(18) Find the magnitude of tension force $\vec{T}$ in the cable.
*(a)* $7,500\ N$
(b) $10,400$ N
(c) $11,700$ N
(d) $13,000$ N
(e) $15,000$ N

- **Setup for the next two questions**

**A car which weighs $15,000$ N is at rest on a $30^0$ incline, as shown below. The coefficient of static friction between the car's tires and the road is $0.90$, and the coefficient of kinetic friction is $0.80$.**




(19) Which one of the following is the correct free body diagram of the car (with correct directions)? $N$, $mg$, and $f_s$ are the magnitude of the normal force, the weight of the car and the static frictional force, respectively.




(e) None of the above.

(20) Find the magnitude of the frictional force on the car.
*(a)* $7,500\ N$
(b) $10,400$ N
(c) $11,700$ N
(d) $13,000$ N
(e) $15,000$ N

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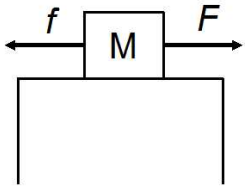
(21) Arnold and you are both pulling on a box of mass $M$ that is at rest on a frictionless surface, as shown below. Arnold is much stronger than you. You pull horizontally as hard as you can, with a force $\vec{f}$, and Arnold keeps the mass from moving by pulling horizontally with a force $\vec{F}$. Which one of the following is a correct statement about the magnitude of Arnold's force $\vec{F}$? $g$ is the magnitude of the acceleration due to gravity.




*(a) $F = f$ because the mass is not accelerating.*
(b) $F = f + Mg$ because Arnold must balance out your force and the weight.
(c) $F > f$ because Arnold is stronger and pulls harder.
(d) $F < f$ because Arnold is stronger and need not pull as hard as you.
(e) $F + f = Mg$ to maintain equilibrium.

(22) You are trying to slide a table across a horizontal floor. You push horizontally on the table with a force of 400 N. The table does not move. What is the magnitude of the frictional force the rug exerts on the table? The coefficient of static friction between the table and the rug is 0.60, and the coefficient of kinetic friction is 0.50. The table's weight is 1000 N.
(a) 0 N
*(b) 400 N*
(c) 500 N
(d) 600 N
(e) 1000 N

(23) A packing crate is at rest on a horizontal surface. It is acted on by three horizontal forces: 600 N to the left, 200 N to the right and friction. The weight of the crate is 400 N. If the 600 N force is removed, the resultant force acting on the crate is
*(a) zero*
(b) 200 N to the right
(c) 200 N to the left
(d) 400 N to the left
(e) impossible to determine from the information given

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(24) You are working at a bookstore. Your first task is to push a box of books 1.5 m along a frictionless ramp at a constant speed. You push parallel to the ramp with a steady force of 500 N. Find the work done on the box **by you**.
(a) 200 J
(b) 300 J
*(c) 750 J*
(d) 1000 J
(e) Impossible to calculate without knowing the angle of the ramp.

(25) You are working at a bookstore. Your second task is to push a box of books 1.5 m along a rough ramp at a constant speed. You push parallel to the ramp with a steady force of 500 N. A frictional force of 300 N opposes your efforts. Find the work done on the box **by you**.
(a) 200 J
(b) 300 J
*(c)* 750 *J*
(d) 1000 J
(e) Impossible to calculate without knowing the angle of the ramp.

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