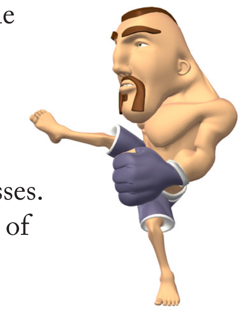
AP1 Dynamics

1. A mixed martial artist kicks his opponent in the nose with a force of 200 newtons. Identify the action-reaction force pairs in this interchange.



(A) foot applies 200 newton force to nose; nose applies a smaller force to foot because foot has a larger mass.
(B) foot applies 200 newton force to nose; nose applies a smaller force to foot because it compresses.
(C) foot applies 200 newton force to nose; nose applies a larger force to foot due to conservation of momentum.
(D) foot applies 200 newton force to nose; nose applies an equal force to the foot.

Answer: (D) foot applies 200 newton force to nose; nose applies an equal force to the foot.

Basic application of Newton's 3rd Law.

EK: 3.A.3 A force exerted on an object is always due to the interaction of that object with another object. 3.A.4 If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 3.A.3.3 The student is able to describe a force as an interaction between two objects and identify both objects for any force. 3.A.4.1 The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. 3.A.4.2 The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

AP1 Dynamics

2. Joanne exerts a force on a basketball as she throws the basketball to the east. Which of the following is always true?

(A) Joanne accelerates to the west.
(B) Joanne feels no net force because she and the basketball are initially the same object.
(C) The basketball pushes Joanne to the west.
(D) The magnitude of the force on the basketball is greater than the magnitude of the force on Joanne.

Answer: (C) The basketball pushes Joanne to the west.

Newton's 3rd Law of Motion states that if Joanne applies a force on the basketball to the east, the basketball must apply a force back on Joanne in opposite direction, to the west.

EK: 3.A.3 A force exerted on an object is always due to the interaction of that object with another object.

SP: 6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 3.A.3.1 The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. 3.A.3.2 The student is able to challenge a claim that an object can exert a force on itself. 3.A.3.3 The student is able to describe a force as an interaction between two objects and identify both objects for any force.

3. A book and a feather are pushed off the edge of a cliff simultaneously. The book reaches the bottom of the cliff before the feather. Correct statements about the book include which of the following? Select two answers.

(A) The book has a greater mass than the feather and experiences less air resistance.
(B) The book has a greater mass than the feather and experiences a greater net force.
(C) The book has a greater cross-sectional area than the feather and experiences less air resistance.
(D) The book has a greater cross-sectional area than the feather and experiences more air resistance.

Answers: B & D

The force of air resistance on the book is greater than the force of air resistance on the feather due to the larger cross-sectional area of the book (the book moves through more air). However, the book also experiences a larger downward force due to gravity due to its larger mass. Even though the force of air resistance is greater for the book, the proportion of the force of air resistance to the force of gravity on the book is smaller than that for the feather. The book has a larger net force on it, and also a larger proportion of force to mass, resulting in a larger downward acceleration.

EK: 3.A.3 A force exerted on an object is always due to the interaction of that object with another object. 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

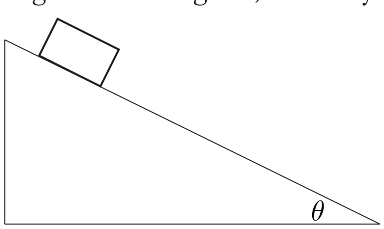
SP: 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models. 1.2 The student can describe representations and models of natural or man–made phenomena and systems in the domain.

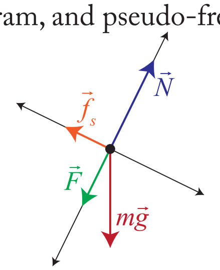
LO: 3.A.3.1 The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

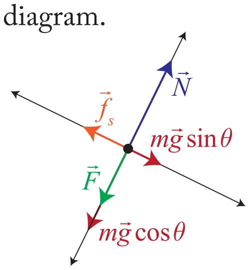
4. A force F is applied perpendicular to the top of a box of mass m sitting on an incline of angle θ. What is the magnitude of F such that the normal force of the incline on the box is equal to the weight of the box?

(A) mgcosθ
(B) mg(1-cosθ)
(C) mg(1-sinθ)
(D) mg(1+sinθ)

Answer: (B) mg(1-cosθ)
Begin with a diagram, free body diagram, and pseudo-free body diagram.







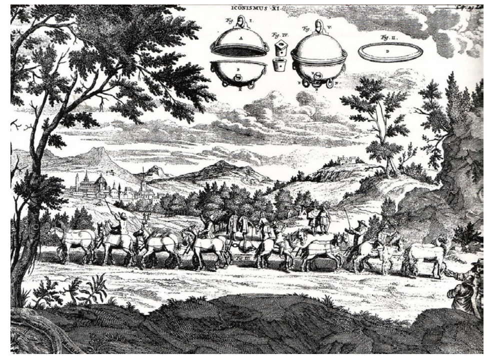
Writing a Newton's 2nd Law equation in the y-direction provides the appropriate relationship to solve for the applied force.

$$N - F - mg\cos\theta = 0 \rightarrow F = N - mg\cos\theta \xrightarrow{N=mg} F = mg - mg\cos\theta = mg(1-\cos\theta)$$

EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.B.1.3 The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.



5. In 1654 in Magdeburg, Germany, scientist Otto von Guericke demonstrated the concept of atmospheric pressure by placing two sealed iron hemispheres together and using a vacuum pump to create a partial vacuum inside the spheres. He then attached a team of 15 horses to each of the hemispheres, and had the horses attempt to pull the spheres apart. All 30 horses were not able to separate the spheres.

Suppose von Guericke had instead attached both teams (all 30 horses) to one of the hemispheres and attached the remaining hemisphere to a tree. How would the tension in the spheres change?

(A) The tension in the spheres would be reduced by half.
(B) The tension in the spheres would remain the same.
(C) The tension in the spheres would double.
(D) The tension in the spheres would quadruple.

Answer: (C) The tension in the spheres would double.

When each team of horses is pulling on the spheres, the tension from each team is the same, with each team pulling in opposite directions. Whatever force one team pulls with, the other team must pull back with an equal magnitude force, otherwise the sphere would accelerate. This is the same as the force that would be exerted if one side of the sphere was held motionless while one team of horses pulls on a hemisphere. By attaching both teams (all 30 horses) to the same hemisphere, and fixing the opposing hemisphere in place, double the force of one team is obtained between the hemispheres.

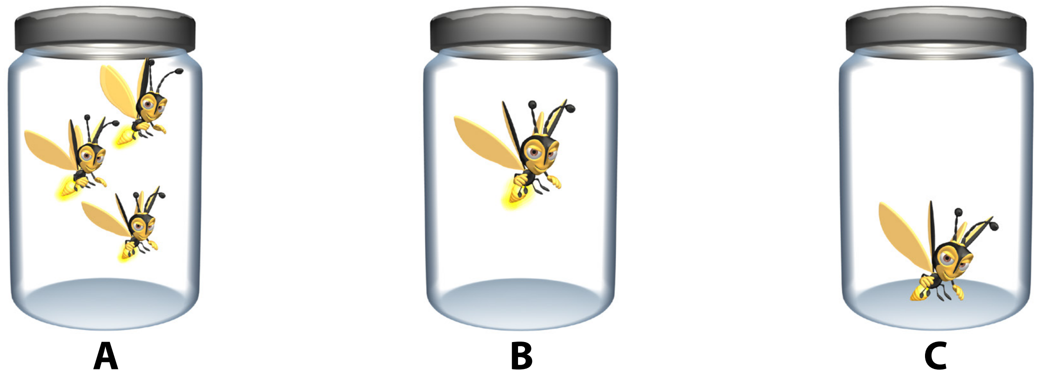
EK: 3.A.3 A force exerted on an object is always due to the interaction of that object with another object. 3.A.4 If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

SP: 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models. 7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

LO: 3.A.3.1 The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. 3.A.4.2 The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

AP1 Dynamics

6. Identical fireflies are placed in closed jars in three different configurations as shown below. In configuration A, three fireflies are hovering inside the jar. In configuration B, one firefly is hovering inside the jar. In configuration C, one firefly is sitting at rest on the bottom of the jar. Each jar is placed upon a scale and measured. Rank the weight of each jar according to the scale reading from heaviest to lightest. If jars have the same scale reading, rank them equally.



Answer: A, B=C

Whether the fireflies are in flight or sitting on the bottom of the jar, they provide the same weight to the scale (if they are flying in the jar, the force their wings provide on the air pushing down is equal to the force of the air pushing them up. This same air pushes down on the bottom of the jar by Newton's 3rd Law, making their weights equivalent whether flying or resting. Therefore, the only factor in determining the weight is the number of fireflies in the jar.

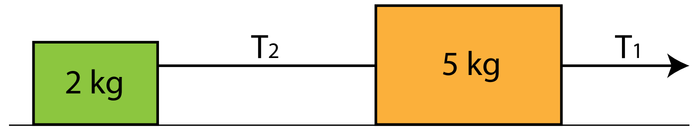
EK: 3.A.4 If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. 4.A.3 Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 3.A.4.2 The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. 4.A.3.2 The student is able to use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system.

 Difficulty: 2

7. The system shown at right is accelerated by applying a tension T_1 to the right-most cable. Assuming the system is frictionless, the tension in the cable between the blocks, T_2, is



(A) $2T_1/7$
(B) $2T_1/5$
(C) $5T_1/7$
(D) $7T_1/5$

Answer: (A) $2T_1/7$

Analyzing the system as a whole, $T_1=7a$, therefore $a=T_1/7$

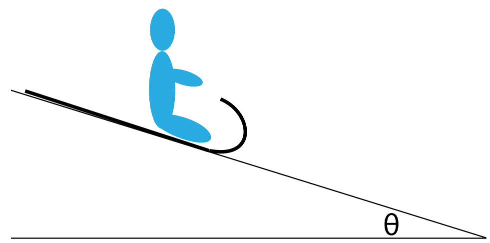
Looking at just the 2-kg block, $T_2=2a$. Substituting in the acceleration of the system (since both blocks must have the same acceleration), you find $T_2=2T_1/7$

EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

8. Jane rides a sled down a slope of angle θ at constant speed v. Determine the coefficient of kinetic friction between the sled and the slope. Neglect air resistance.



(A) μ=gsinθ
(B) μ=mgcosθ
(C) μ=tanθ
(D) μ=gcosθ

Answer: (C) μ=tanθ

Utilizing a free body diagram (and pseudo-free body diagram to bring the weight vector into components that line up with the axes, you find that F_f=mgsinθ and N=mgcosθ. Putting these together to to determine the coefficient of friction:

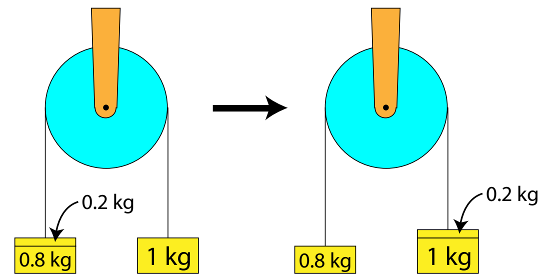
$$\mu = \frac{F_f}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta$$

EK: 3.A.2 Forces are described by vectors. 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

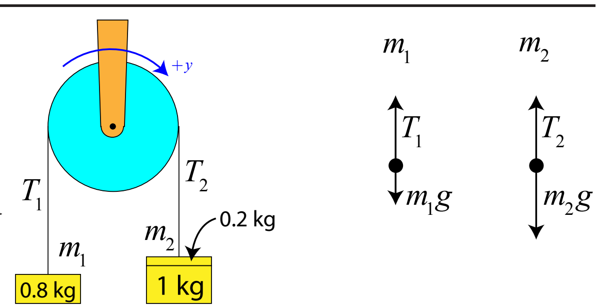
SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.A.2.1 The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 3.B.1.3 The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

9. Masses are hung on a light string attached to an ideal massless pulley as shown in the diagram at right. The total mass hanging from the left string is equal to that on the right. At time t=0, the 0.2-kg mass is moved from the left to the right side of the pulley. How far does each mass move in one second?



Answer: $\Delta y = 1$ m



First draw a free body diagram for the two masses.

Next you can write out Newton's 2nd Law equations for the two objects, keeping in mind the y-axis we have chosen curving around the pulley.

$T_1 - m_1g = m_1a$

$m_2g - T_2 = m_2a$

Combining these equations and recognizing $T_1=T_2$ because this is an ideal, massless pulley, you can then solve for the acceleration of the system.

$$m_2g - m_1g = (m_1 + m_2)a \rightarrow a = g\left(\frac{m_2 - m_1}{m_1 + m_2}\right) = 2\,\tfrac{m}{s^2}$$

With the acceleration known, you can solve for the distance traveled using kinematic equations.

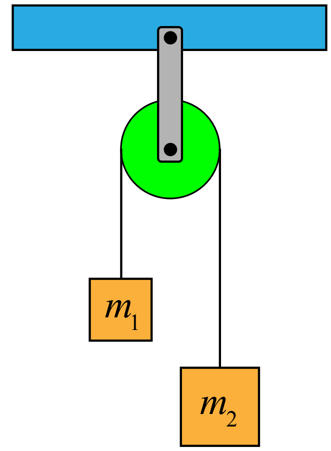
$$\Delta y = v_0t + \tfrac{1}{2}a_yt^2 \rightarrow \Delta y = \tfrac{1}{2}(2\,\tfrac{m}{s^2})(1s)^2 = 1m$$

EK: 3.A.1 An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration. 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.A.1.1 The student is able to express the motion of an object using narrative, mathematical, and graphical representations. 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

10. The Atwood machine shown to the right consists of a massless, frictionless pulley, and a massless string. If m_1 = 3 kg and m_2 = 5 kg, find the force of tension in the string.



Answer: F_T=37.5 N

First step is to solve for the acceleration of the masses by using Newton's second law. The 5 kg mass is accelerating downward and the 3 kg mass is accelerating upward. Assume g = 10 m/s^2

$$\sum F = ma$$
$$m_2 g - m_1 g = (m_1 + m_2)a$$
$$50N - 30N = (8kg)a$$
$$a = 2.5 \,{}^{m}\!/\!{}_{s^2}$$

Second step is to isolate the 5 kg mass to find the tension in the string. Again use Newton's second law.

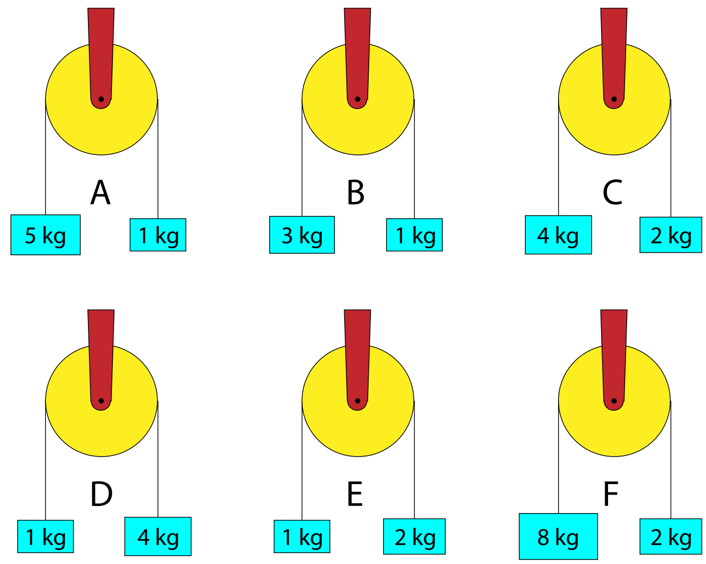
$$\sum F = ma$$
$$-F_T + m_2 g = m_2 a$$
$$-F_T + 50N = (5kg)(2.5 \,{}^{m}\!/\!{}_{s^2})$$
$$F_T = 37.5N$$

EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

11. Two masses are hung from a light string over an ideal frictionless massless pulley. The masses are shown in various scenarios in the diagram at right. Rank the acceleration of the masses from greatest to least.



Answer: A > D=F > B > C=E

A simple analysis of the Atwood Machines shows that the acceleration of the system is equal to the net force divided by the sum of the masses. Summarizing in table form:

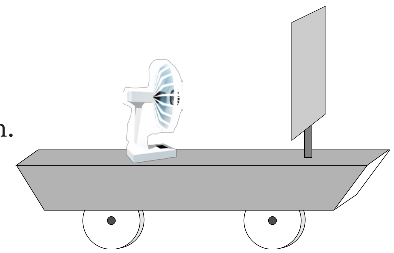
Scenario	m_1 (kg)	m_2 (kg)	F_{net} (N)	a (m/s^2)
A	5	1	40	6.67
B	3	1	20	5
C	4	2	20	3.33
D	1	4	30	6
E	1	2	10	3.33
F	8	2	60	6

EK: 3.A.4 If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 3.A.4.3 The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

12. Students build a wind-powered vehicle as shown in the diagram at right. A fan attached to the vehicle is powered by a battery located inside the vehicle, striking a completely rigid, perfectly flat sail. Describe the motion of the vehicle when the fan is powered on. Justify your answer in a clear, coherent, paragraph-length explanation.



Answer: The vehicle remains at rest.

Students may approach their justification in multiple ways. An example of a strong answer could include references to all three of Newton's Laws (i.e. the vehicle will remain at rest because it is not acted upon by an outside force. You can observe this as the spinning fan imparts a force on the air molecules, which, by Newton's 3rd Law, apply an opposing force on the fan blades. The air molecules impact the sail, imparting a force on the sail, while the sail imparts an opposing force back on the air molecules. Because both the fan and the sail are part of the same object, the opposing forces on the sail and fan blades balance each other out, resulting in no net force. According to Newton's 2nd Law, if there is no net force, there is no acceleration, therefore the vehicle remains at rest.

Other possible explanations include, but are not limited to, a dynamics analysis looking at the vehicle from a systems perspective, as well as a momentum analysis.

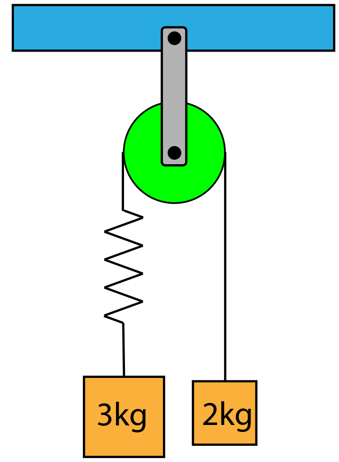
EK: 3.A.4 If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction. 4.A.3 Forces that systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.

SP: 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models. 7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

LO: 3.A.4.1 The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. 4.A.3.2 The student is able to use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system.

AP1 Dynamics

13. The Atwood machine shown to the right consists of a massless, frictionless pulley, a massless string, and a massless spring. The spring has a spring constant of 200 N/m. How far will the spring stretch when the masses are released?



Answer: x = 0.12m

First step is to solve for the acceleration of the masses by using Newton's second law. The 3-kg mass is accelerating downward (negative direction) and the 2-kg mass is accelerating upward (positive direction). Assume g = 10 m/s^2.

$$\sum F = ma$$
$$-30N + 20N = (5kg)a$$
$$a = -2\, {}^{m}\!/_{s^2}$$

Second step is to isolate the 3-kg mass to find the tension acting on the spring. Again use Newton's second law.

$$\sum F = ma$$
$$F_T - 30N = (3kg)(-2\, {}^{m}\!/_{s^2})$$
$$F_T = 24N$$

Third step is to use Hooke's Law to solve for the stretch of the spring.

$$F = kx$$
$$24N = (200\, {}^{N}\!/_{m})x$$
$$x = 0.12m$$

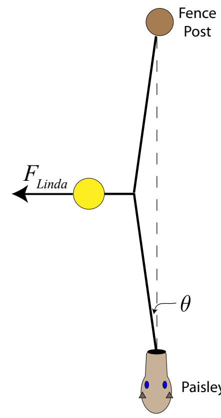
EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

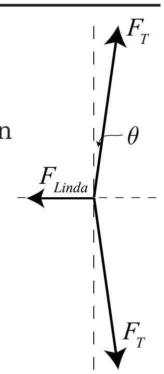
14. Paisley the horse gets stuck in the mud. Her rider, Linda, ties a rope around Paisley and pulls with a force of 500 newtons, but isn't strong enough to get Paisley out of the mud.

In a flash of inspiration, Linda thinks back to her physics classes and ties one end of the rope to Paisley, and the other end to a nearby fence post. She then applies the same force of 500 newtons to the middle of the rope at an angle of $\theta=6°$, just barely freeing Paisley from the mud, as shown in the diagram at right.



Determine the minimum amount of tension the rope must support.

Answer: 2400 N



A free body diagram showing all the forces on the rope is quite helpful in this situation. Note that the tension in the portion of rope connected to the fence post must be the same as the tension in the portion of rope connected to Paisley.

$$F_{net_X} = 2F_T \sin\theta - F_{Linda} = 0 \rightarrow F_T = \frac{F_{Linda}}{2\sin\theta} = \frac{500N}{2\sin(6°)} = 2400N$$

EK: 3.A.2 Forces are described by vectors. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

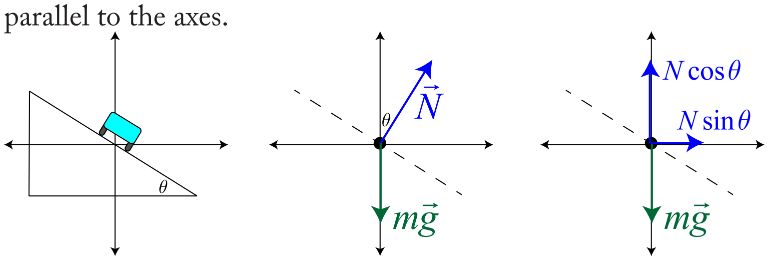
SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.A.2.1 The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

15. Curves can be banked at just the right angle that vehicles traveling a specific speed can stay on the road with no friction required. Given a radius for the curve and a specific velocity, at what angle should the bank of the curve be built?

Answer: $\theta = \tan^{-1}\left(\frac{v^2}{gr}\right)$

First draw a free body diagram for the car on the banked curve, then a pseudo-FBD, showing all forces lining up parallel to the axes.



Then, write out Newton's 2nd Law equations for both the x- and y-directions.

$$F_{net_X} = F_{net_C} = N\sin\theta = \frac{mv^2}{r}$$

$$F_{net_Y} = N\cos\theta - mg = 0 \rightarrow N = \frac{mg}{\cos\theta}$$

Finally, combining the results of these two equations, solve for the angle θ.

$$N\sin\theta = \frac{mv^2}{r} \xrightarrow{N=\frac{mg}{\cos\theta}} \frac{mg\sin\theta}{\cos\theta} = \frac{mv^2}{r} \rightarrow g\tan\theta = \frac{v^2}{r} \rightarrow \theta = \tan^{-1}\left(\frac{v^2}{gr}\right)$$

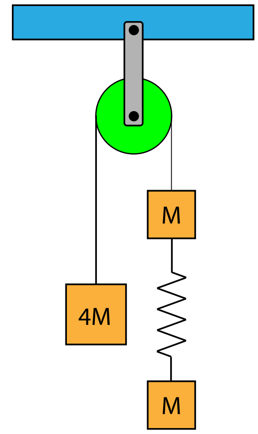
EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. 3.B.1.3 The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

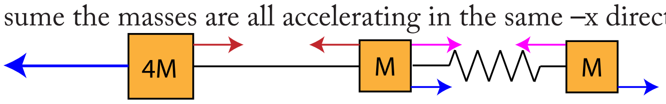
AP1 Dynamics

16. The Atwood machine shown to the right consists of a massless, frictionless pulley, a massless string, and a massless spring. The spring has a spring constant of 100 N/m. Calculate the stretch of the spring in terms of M.



Answer: x = (0.133M) m

First Step is to solve for the acceleration of the masses by using Newton's second law. The 4m mass is accelerating downward and the other 2 masses are accelerating upward. We can put these masses on the horizontal axis and assume the masses are all accelerating in the same –x direction.



This new horizontal system can be analyzed using Newton's second law. Assume g = 10 N/kg

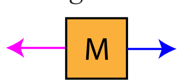
Analyzing forces from right to left:

$$\sum F = Ma$$

$$-4Mg + F_T - F_T + Mg + F_s - F_s + Mg = (6M)a$$

$$a = -3.3\,{}^{m}\!/\!_{s^2}$$

Second Step is to isolate the mass on the right end to find the force acting from the spring. Again use Newton's second law. Assume g = 10 N/kg



$$\sum F = Ma$$

$$Mg - F_s = Ma$$

$$F_s = Mg - Ma = (13.3M)\,{}^{m}\!/\!_{s^2}$$

Third Step is to use Hooke's Law to solve for the stretch of the spring.

$$F_s = kx$$

$$(13.3M)\,{}^{m}\!/\!_{s^2} = (100\,{}^{N}\!/\!_{m})x$$

$$x = (0.133M)m$$

EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

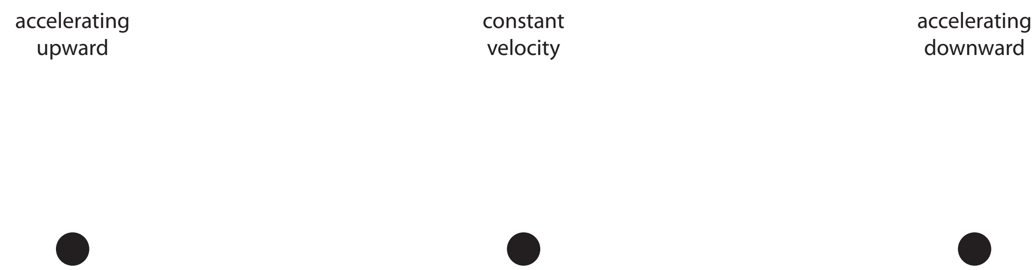
SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

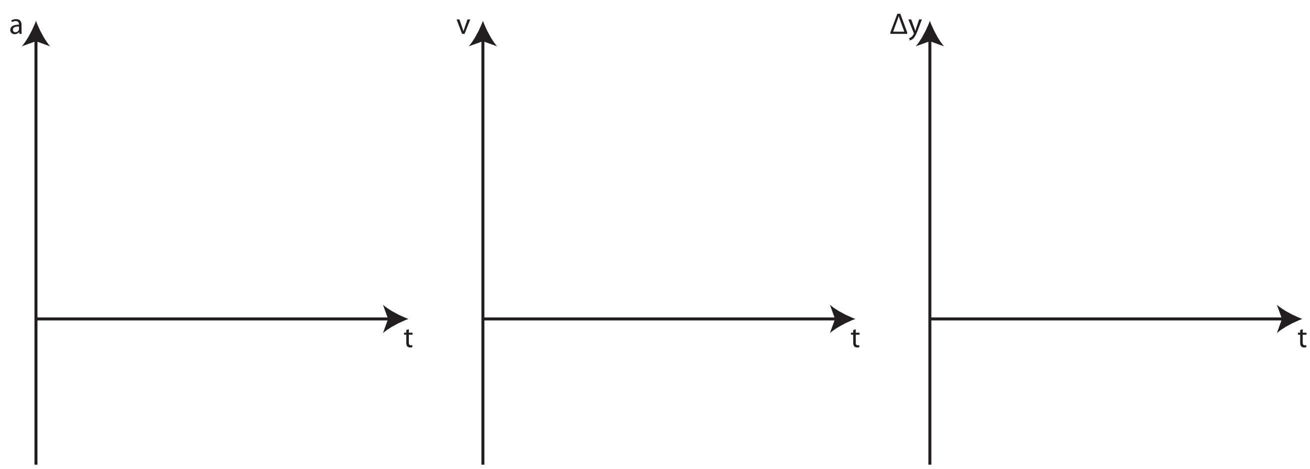
17. A student, standing on a scale in an elevator at rest, sees that the scale reads 840 N. As the elevator rises, the scale reading increases to 945 N for 2 seconds, then returns to 840 N for 10 seconds. When the elevator slows to a stop at the 10th floor, the scale reading drops to 735 N for 2 seconds while coming to a stop.

(a) Explain why the apparent weight of the student increased at the beginning of the motion.

(b) Draw the free body diagram for the student while the student is accelerating upward, then moving at a constant velocity, and finally accelerating downward at the end. Draw the length of the force vectors to show when forces are balanced or unbalanced.



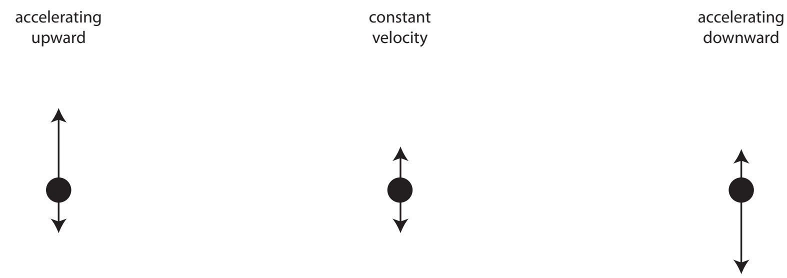
(c) Sketch acceleration vs. time, velocity vs. time, and displacement vs. time graphs of the student during the elevator ride.



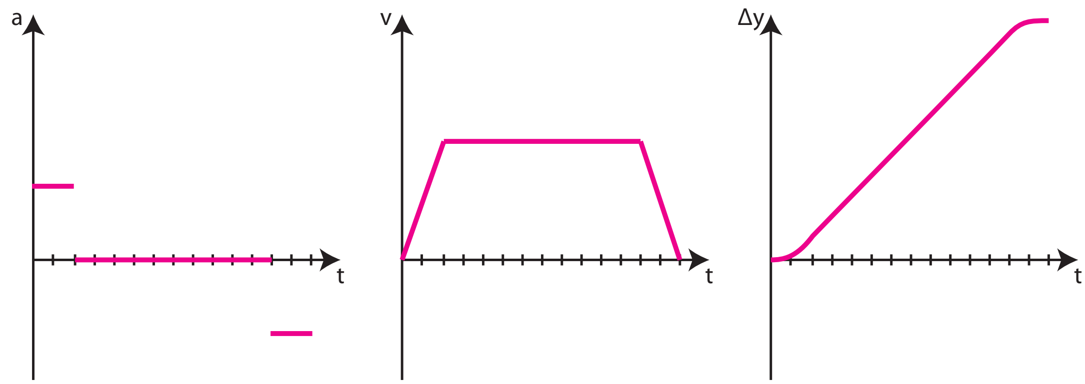
Answer:

(a) The student's mass has inertia and wants to stay at rest. In order to accelerate her mass, an unbalanced force must be applied. The reading on the scale shows not only the force of her normal weight, but has an additional unbalanced force causing her mass to accelerate.

(b)



(c)

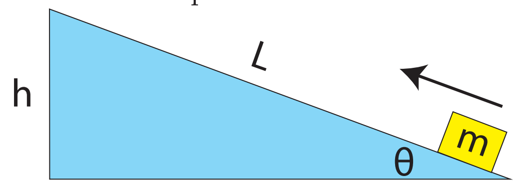


EK: 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

LO: 3.B.1.1 The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

18. A block of mass m, is pushed up an incline with an initial speed of v_0. The incline has a height of h and the length of the ramp is L. The coefficient of kinetic friction between the incline and block is μ_k and the coefficient of static friction is μ_s. The block does not leave the ramp.



Answer the following questions using the variables listed above and fundamental constants.

(a) What is the angle of the ramp in terms of h and L?
(b) What is the minimum angle of the ramp such that the block slides back down the ramp after sliding up? (Hint: the answer is not in terms of h and L.)
(c) Assume the distance the block travels down the ramp is the same distance the block traveled up the ramp. Does it take more time for the block to travel up or down the ramp? Explain your answer.

Answer:

(a) $\theta = \sin^{-1}(h / L)$

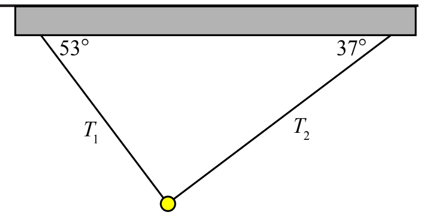
(b) When the block slows to a stop, the component of the weight along the incline has to be slightly larger than the force of friction in order to start back down the incline, therefore $F_f < mg\sin\theta$. Then, use utilizing the equation for the force of friction and the static coefficient of friction since the block stops at the top of its path, $F_f = \mu_s F_N = \mu_s mg\cos\theta$. Then, set the two force of friction equations equal to each other and solve for the angle θ. $\mu_s mg\cos\theta = mg\sin\theta$, therefore $\theta = \tan^{-1}(\mu_s)$.

(c) It takes more time for the block to travel down the ramp since it is moving at a slower speed on the way down due to the force of friction acting as a nonconservative force. This work the friction does on the block decreases the kinetic energy of the block so the longer the block slides on the ramp the more energy that is being removed from the ramp block system.

EK: 3.A.2 Forces are described by vectors. 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

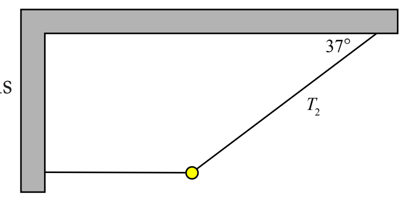
SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.A.2.1 The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 3.B.1.3 The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.



19. A ball of mass 0.5 kg is suspended by two strings as shown in the diagram at right.
    (a) Determine the weight of the ball.
    (b) In the space below, draw and clearly label all the forces (not components) acting on the ball.

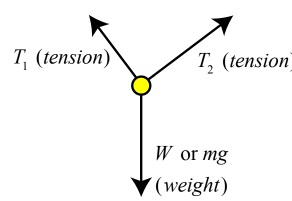
    (c) Determine the magnitude of each of the forces labeled in your diagram from part (b).



The left-hand string is now attached to a wall at a right angle as shown.
    (d) Indicate whether T_2 is now greater than, equal to, or less than the value reported in part (c). Justify your answer qualitatively, without using equations or calculations.
    (e) Determine the new vertical component of T_2 without using equations or calculations. Justify your answer qualitatively.

Answer:
(a) $W = mg = (0.5kg)(9.8 \, {}^{m}\!/\!_{s^2}) = 4.9N$

(b)



(c) Since the ball is in equilibrium, the sum of all the forces is zero. The force vectors may be resolved along axes coinciding with the strings or along horizontal and vertical axes. Substitution of the appropriate trigonometric functions into either pair of the equations gives T_1 = 3.9 N and T_2 = 3.0 N.
(d) T_2 is now greater than it was previously. Previously, a portion of T_1 supported the vertical weight of the ball, whereas in the new configuration the entire weight of the ball is supported by the vertical component of T_2.
(e) The vertical component of T_2 is 4.9 N, equal to the weight of the ball (see part (d)).

EK: 3.A.2 Forces are described by vectors. 3.B.1 If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. 3.B.2 Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 3.A.2.1 The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. 3.B.1.3 The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. 3.B.2.1 The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.