Problem 1: Given Newton’s First Law of Motion, what do we reasonably expect an object to do given the following scenarios?

Part (a) An object sits at rest with no unbalanced forces acting upon it. What do we expect this object to do?
MultipleChoice :

1) The object will remain at rest.
2) The object will begin to move with a changing velocity .
3) The object will begin to move at a constant velocity.
4) None of these answers.

Part (b) An object is traveling with a constant velocity with no unbalanced forces acting upon it. What do we expect this object to do?
MultipleChoice :

1) The object will speed up.
2) The object will remain at the same speed, traveling in the same direction.
3) The object will slow down and eventually come to rest.
4) The object will remain at the same speed but change direction.
5) The object will begin to spin as it slows down.
6) None of these answers.

Part (c) An object sits at rest with an unbalanced force acting upon it. What should we not expect this object to do? Asking another way, which of the following choices could not be an outcome?
MultipleChoice :

1) The object will remain at rest.
2) None of these answers.
3) The object will begin to move with a changing velocity.
4) The object will begin to move and then move with a constant velocity.

Problem 2: For this problem, assume that Earth is an inertial reference frame. (Strictly speaking, Earth cannot be an inertial reference frame because of its rotation and movement in its orbit about the Sun, but for most purposes it can be thought of as an inertial reference frame.)

Which of the following objects are also inertial reference frames? Check all that apply.
MultipleSelect :

1) A car that is at rest, but just starting to move forward
2) An elevator moving upward at constant speed
3) A baseball dropped from the top of a building
4) A car moving in a straight line at constant speed
5) A car that is moving at constant speed, but turning off the highway

Problem 3: A firefighter, whose mass (including clothing and equipment) is m =*89* kg, hears the alarm and slides down the pole with a constant downward acceleration of magnitude a =*4.92* $\mathrm{m/s^2}$.

Part (a) What is the direction of the force exerted on the firefighter by the pole?
MultipleChoice :

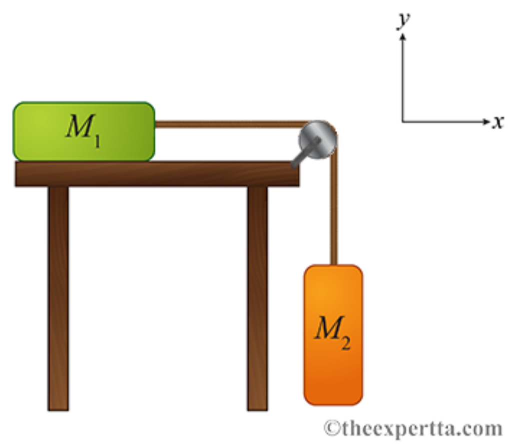
1) Upward
2) Downward

Part (b) Write an expression for the magnitude of the force, F, exerted on the firefighter by the pole. Answer in terms of the variables from the problem statement as well as g for the acceleration due to gravity.
Expression :
F = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **θ**, **a**, **b**, **c**, **d**, **g**, **h**, **j**, **k**, **m**, **n**, **P**, **S**

Part (c) What is the magnitude, in newtons, of the force F?
Numeric : A numeric value is expected and not an expression.
F = ____

Problem 4: Two blocks of unequal mass are tied together with a massless string that does not stretch and connected via a frictionless and massless pulley. Mass one, M_1, rests on a frictionless table top. Mass two, M_2, is released and both blocks begin to move.



The blocks accelerate at the same rate since they are connected. What is the acceleration? (Choose the correct answer.)
MultipleChoice :

1) Cannot be Determined.
2) $g/2$
3) A value between zero and g.
4) Zero
5) g
6) A value greater than g.

Problem 5: A block is placed on a smooth horizontal surface, and it accelerates due to the application of a horizontally directed force.

The acceleration is observed for four different trials where the mass and the force are varied. Rank the four trials according to the magnitude of the acceleration, from smallest to largest by dragging them to the area provided.
DragNDrop :
= ____

Problem 6: A high-performance dragster with a mass of m = ***1371*** kg can accelerate at a rate of a = ***26.5*** m/s^2.

Randomized Variables

m = ***1371*** kg
a = ***26.5*** m/s^2

Part (a) Write an expression for the magnitude of the net force, F_{NET}, that propels the dragster forward in terms of the variables provided.
Expression :
F_{NET} = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, θ, a, d, g, h, i, j, k, l, m, P, S, t, w

Part (b) If the track has length L and the dragster starts from rest, select the correct symbolic equation for how fast v_f the dragster is traveling when it finishes the run. (Assume that it accelerates at the same rate along the full length of the track.)
SchematicChoice :

$$V_f = \sqrt{2L} \qquad V_f = \sqrt{2a} \qquad V_f = \sqrt{2aL}$$

$$V_f = aL \qquad V_f = \sqrt{aL} \qquad V_f = 2aL$$

Part (c) If the track is L=400 m long, what is the numerical value of the dragster's final speed, v_f in m/s?
Numeric : A numeric value is expected and not an expression.
v_f = ____

Problem 7: A bullet with a mass of m = ***15*** g is fired out of a gun that has length L = ***0.96*** m. The bullet spends t = ***0.17*** s in the barrel.

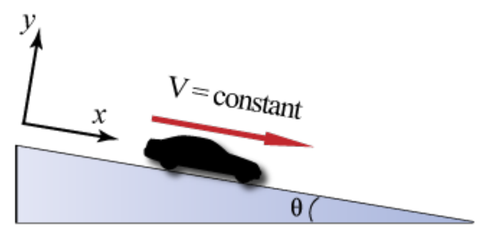
Part (a) Write an expression, in terms of the given quantities, for the magnitude of the bullet's acceleration, a, as it travels through the gun's barrel. You may assume the acceleration is constant throughout the motion.
Expression :
a = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, b, d, g, h, j, k, L, m, P, S, t

Part (b) Calculate the numerical value for the magnitude of the bullet's acceleration, a in m/s^2.
Numeric : A numeric value is expected and not an expression.
a = ____

Part (c) What is the numerical value of the net force F_{NET} in newtons acting on the bullet?
Numeric : A numeric value is expected and not an expression.
F_{NET} = ____

Problem 8: A toy car rolls down a ramp at a constant velocity. The car's mass is m = ***1.1*** kg and the ramp makes an angle of θ = ***13*** degrees with respect to the horizontal. Assume the rolling resistance is negligible.



Part (a) What is the magnitude of the car's acceleration, a in m/s^2?
Numeric : A numeric value is expected and not an expression.
a = ____

Part (b) What is the numeric value for the sum of the forces in the x-direction, ΣF_x, in Newtons?
Numeric : A numeric value is expected and not an expression.
ΣF_x = ____

Part (c) Assuming the car experiences only air resistance in opposition to its motion, with magnitude F_r. Write an expression for the sum of the forces in the x-direction using the acceleration due to gravity, g, and the variables provided.
Expression :
ΣF_x = ____

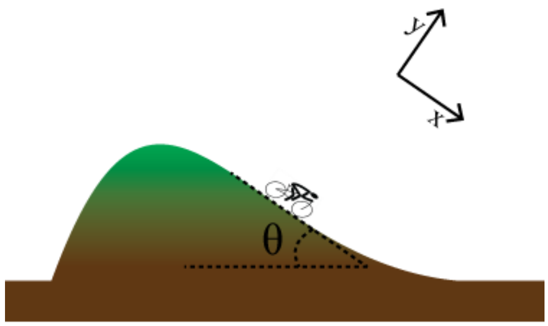
Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), α, β, θ, d, F_r, g, h, m, t

Part (d) What is the magnitude of the force caused by air resistance, F_r in Newtons? (Maintain the assumption that the car's velocity is constant.)
Numeric : A numeric value is expected and not an expression.
F_r = ____

Problem 9: A bicycle and rider with mass m rolls down a hill at constant velocity under the influence of gravity with negligible rolling resistance. The hill makes an angle of θ = *17* degrees with respect to the horizontal. The force of air resistance, termed "drag", has a magnitude of F_d = *54* N. Assume that the x-direction is parallel to the slope of the hill and the y-direction is perpendicular to the hill as shown.

Randomized Variables

$\theta = 17°$
$F_d = 54$ N



Part (a) What is the sum of the forces in the y direction, ΣF_y in Newtons?
Numeric : A numeric value is expected and not an expression.
ΣF_y = ____

Part (b) Input an expression for the sum of the forces in the x-direction, ΣF_x, in terms of the quantities given and variables available in the palette.
Expression :
ΣF_x = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), cos(φ), cos(θ), sin(α), sin(φ), sin(θ), α, β, θ, d, F_d, g, h, m, t

Part (c) Using the information above, what is the total mass of the bike and rider m in kg?
Numeric : A numeric value is expected and not an expression.
m = ____

Problem 10: A car with mass m drives on a straight-line track. Starting with speed v, it comes to rest over a distance d.

Write an expression for the magnitude of the net force on the car.
Expression :
F_{net} = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, γ, θ, b, c, d, g, h, j, k, m, n, P, S, v

Problem 11: A *85*-kg astronaut takes off from the Earth, eventually reaching the limits of our solar system, far from the reaches of gravity.

Part (a) What is her mass, in kilograms, so far from Earth?
Numeric : A numeric value is expected and not an expression.
m = ____ kg

Part (b) What is her weight, in newtons, so far from Earth?
Numeric : A numeric value is expected and not an expression.
w = ____ N

Problem 12: Suppose the mass of a fully loaded module in which astronauts take off from the Moon is *12500* kg. The thrust of its engines is *32000* N.

Randomized Variables

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m = *12500* kg
f = *32000* N

Calculate the magnitude of its acceleration in a vertical takeoff from the Moon in meters per square second, assuming the acceleration due to gravity on the Moon is 1.67 m/s^2.
Numeric : A numeric value is expected and not an expression.
a = ____

Problem 13: A car and a dump truck are involved in an accident and crash into each other.

Assuming the only force acting is the force of collision, which one experiences the most force during the crash - the car or the dump truck?
MultipleChoice :

1) They experience the same size force.
2) The car.
3) It depends on which one is moving faster.
4) It depends on the angle of their collision.
5) The dump truck.

Problem 14: A car and a dump truck are involved in an accident and crash into each other.

Which one will have the greatest magnitude of acceleration during the crash? (Assume the dump truck has a mass that is 4 times larger than the car, and the only forces in the problem are those between the two vehicles.)
MultipleChoice :

1) They experience the same acceleration.
2) The car.
3) It depends on the angle of their collision.
4) The dump truck.
5) It depends on which one is moving faster.

Problem 15: A ***1100*** kg artillery shell is fired from a battleship. While it is in the barrel of the gun, it experiences an acceleration of ***2.9*** $\times 10^4$ m/s^2.

Randomized Variables

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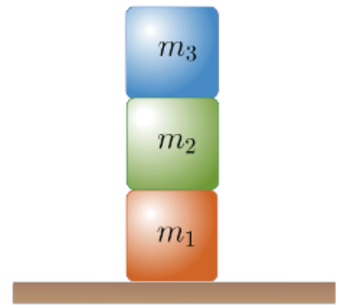
m = ***1100*** kg
a = ***2.9*** $\times 10^4$ m/s^2

Part (a) What net force is exerted on the artillery shell before it leaves the barrel of the gun (in Newtons)?
Numeric : A numeric value is expected and not an expression.
F_{net} = ____

Part (b) What is the magnitude of the force exerted on the ship by the artillery shell in Newtons?
Numeric : A numeric value is expected and not an expression.
$|F_{ship}|$ = ____

Problem 16: Three objects are stacked on the floor. From the bottom of the stack to the top, their masses are m_1, m_2, and m_3, respectively, as shown on the diagram. When referring to the various forces, the subscripts $i = 1, 2, 3$ of the objects will be used, and f will be used to indicate the floor.



- Weights, *if required*, will be denoted with the corresponding subscript of the object as $\vec{F}_{g,i}$, for $i = 1, 2, 3$.
- The normal force exerted by object a on object b, *if required*, will be denoted as $\vec{F}_{n,a\to b}$ for $i = 1, 2, 3, \text{f}$, but $a \neq b$.
- The force of kinetic friction exerted by object a on object b, *if required*, will be denoted as $\vec{F}_{k,a\to b}$ for $i = 1, 2, 3, \text{f}$, but $a \neq b$.
- The force of static friction exerted by object a on object b, *if required*, will be denoted as $\vec{F}_{s,a\to b}$ for $i = 1, 2, 3, \text{f}$, but $a \neq b$.

Part (a) Please utilize the interface below to devise your free body diagram for the object that is on the top of the stack. Assume, for the moment, that the object is in equilibrium. See the problem statement with regard to notation.
FBD :
Force Labels: Fg,1, Fg,2, Fg,3, Fn,2→3, Fn,1→3, Fn,f→3, Fk,2→3, Fs,2→3, v, a
Angle Labels: 0, 45, 90, 135, 180, 225, 270, 315, θ

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Part (b) Please utilize the interface below to devise your free body diagram for the object that is in the center of the stack. Assume, for the moment, that the object is in equilibrium. See the problem statement with regard to notation.
FBD :
Force Labels: Fg,1, Fg,2, Fg,3, Fn,1→2, Fn,3→2, Fn,f→2, Fs,1→2, Fk,1→2, Fs,3→2, Fk,3→2, v, a
Angle Labels: 0, 45, 90, 135, 180, 225, 270, 315, θ

Part (c) Please utilize the interface below to devise your free body diagram for the object that is on the bottom of the stack. Assume, for the moment, that the object is in equilibrium. See the problem statement with regard to notation.
FBD :
Force Labels: Fg,1, Fg,2, Fg,3, Fn,3→1, Fn,2→1, Fn,f→1, Fk,2→1, Fs,2→1, Fk,f→1, Fs,f→1, v, a
Angle Labels: 0, 45, 90, 135, 180, 225, 270, 315, θ

Part (d) The floor discussed in the problem statement is the floor of an elevator. When the elevator accelerates, all of the objects have a common acceleration in the vertical direction. Input an expression for the net force on the top-most object to complete the expression of Newton's Second Law with the upward direction being taken as the positive y direction.
Expression :
$m_3 a_y$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
μ_k, μ_s, $F_{n,1\to3}$, $F_{n,2\to3}$, $F_{n,f\to3}$, g, m_1, m_2, m_3, x, y, z

Part (e) The floor discussed in the problem statement is the floor of an elevator. When the elevator accelerates, all of the objects have a common acceleration in the vertical direction. Input an expression for the net force on the middle object to complete the expression of Newton's Second Law with the upward direction being taken as the positive y direction.
Expression :
$m_2 a_y$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
μ_k, μ_s, $F_{n,1\to2}$, $F_{n,3\to2}$, $F_{n,f\to2}$, g, m_1, m_2, m_3, x, y, z

Part (f) The floor discussed in the problem statement is the floor of an elevator. When the elevator accelerates, all of the objects have a common acceleration in the vertical direction. Input an expression for the net force on the bottom-most object to complete the expression of Newton's Second Law with the upward direction being taken as the positive y direction.
Expression :
$m_1 a_y$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.

μ$_k$, μ$_s$, $F_{n,2\to1}$, $F_{n,3\to1}$, $F_{n,f\to1}$, g, m_1, m_2, m_3, x, y, z

Part (g) Input an expression for the magnitude of the force of the bottom-most object on the center object valid for any value of the vertical acceleration, a_y, using only the parameters provided in the palette.
Expression :
$F_{n,1\to2}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
μ$_k$, μ$_s$, a_y, g, m_1, m_2, m_3, x, y

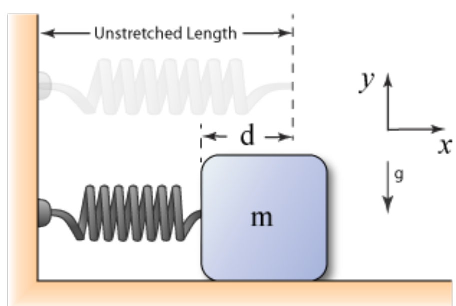
Part (h) Input an expression for the magnitude of the force of the floor on the bottom-most object valid for any value of the vertical acceleration, a_y, using only the parameters provided in the palette.
Expression :
$F_{n,f\to1}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
μ$_k$, μ$_s$, a_y, g, m_1, m_2, m_3, x, y

Part (i) In an earlier step, an FBD was created for the bottom-most object under the assumption of equilibrium. Which statement best describes the modifications necessary if that FBD is redrawn under the assumption $a_y < 0$?
MultipleChoice :

1) The weight vector labeled $F_{g,1}$ would be unchanged. The normal-force vector labeled $F_{n,2\to1}$ would become shorter, but the normal-force vector labeled $F_{n,f\to1}$ would become shorter by a greater amount.
2) The weight vector labeled $F_{g,1}$ would be unchanged. The normal-force vector labeled $F_{n,2\to1}$ would become longer, but the normal-force vector labeled $F_{n,f\to1}$ would become shorter.
3) The weight vector labeled $F_{g,1}$ would be unchanged. The normal-force vector labeled $F_{n,f\to1}$ would become shorter, but the normal-force vector labeled $F_{n,2\to1}$ would become shorter by a greater amount.
4) The weight vector labeled $F_{g,1}$ would change length, becoming shorter, but the normal-force vectors would be unchanged.
5) The weight vector labeled $F_{g,1}$ and the normal-force vector labeled $F_{n,2\to1}$ would be unchanged, but the normal-force vector labeled $F_{n,f\to1}$ would become shorter.
6) Because things feel partially weightless in the elevator, all three vectors would be shorter.
7) The diagram requires no changes because all of the forces remain the same.

Problem 17: A spring with a spring constant of k = ***184*** N/m is initially compressed by a block a distance d = ***0.23*** m. The block is on a horizontal surface with coefficient of kinetic friction μ_k, static friction μ_s, and has a mass of m = ***8*** kg.



Part (a) Assuming the block is released from the initial position and begins to move to the right, please use the interactive area below to draw the Free Body Diagram for the block. Use *Fsp* as the spring force. If necessary, use *Fs* for the force of static friction and *Fk* as the force of kinetic friction.
FBD :
Force Labels: Fn, Fg, Fsp, Fk, Fs, a, v
Angle Labels: 45, 0, 90, 135, 180, 225, 270, 315, θ

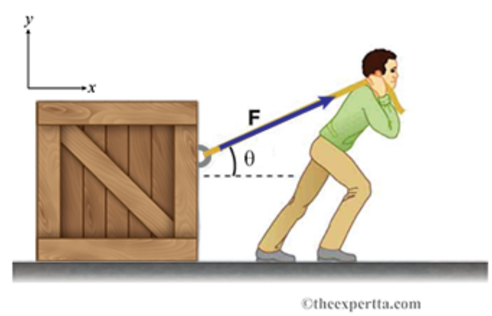
Part (b) Assuming the block is released from the initial position and begins to move to the right, input an expression for the sum of the forces in the x-direction in the configuration shown above, using the variables provided.
Expression :
ΣF_x = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, μ$_k$, θ, a, d, g, h, i, j, k, m, P, S, t

Part (c) How large would the coefficient of static friction μ_s need to be to keep the block from moving?
Numeric : A numeric value is expected and not an expression.
μ_s = ____

Part (d) Assuming the block has just begun to move and the coefficient of kinetic friction is μ_k = 0.2, what is the block's acceleration in meters per square second?
Numeric : A numeric value is expected and not an expression.
a = ____

Problem 18: A crate sits on a rough surface. Using a rope, a man applies a force to the crate, as shown in the figure. The force is not enough to move the crate, however, and it remains stationary. Use f to represent the force of friction.



Please use the interactive area below to draw the Free Body Diagram for the crate.
FBD :
Force Labels: F, f, Fn, Fg, a, v
Angle Labels: 45, 0, 90, 135, 180, 225, 270, 315, θ

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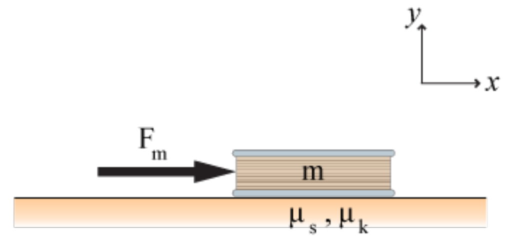
Problem 19: A horizontal force, $F_{\rm m}$, is applied to a book that is on a rough horizontal tabletop. As a result the book is accelerating to the right. If necessary, use $F_{\rm s}$ for the force of static friction and $F_{\rm k}$ as the force of kinetic friction.



Please use the interactive area below to draw the Free Body Diagram for the book.

FBD :

Force Labels: Fn, Fg, Fm, Fk, a, v, Fs

Angle Labels: 45, 0, 90, 135, 180, 225, 270, 315, θ