Problem 1: An object's speed is increased by a factor of three.

Part (a) How does the object's momentum change?
MultipleChoice :

1) It increases by a factor of more than three.
2) There is not enough information.
3) It increases by a factor of three.
4) The momentum does not change.
5) It decreases by a factor of three.
6) It decreases by a factor of more than three.

Part (b) How does the object's kinetic energy change?
MultipleChoice :

1) Doubled.
2) Halved.
3) There is not enough information to determine.
4) Increased by a factor of nine.

Problem 2: Two objects are dropped (with zero initial speed) from a height h.

If object A has twice the mass of object B, what can be said about the momentum of each just before they hit the ground? Ignore air resistance.
MultipleChoice :

1) object A has the same momentum as object B.
2) object A has half the momentum of object B.
3) object A has four times the momentum of object B.
4) object A has twice the momentum of object B.
5) object A has one fourth the momentum of object B.

Problem 3: Suppose a large ship has a momentum of ***1.25*** $\times 10^9$ kg·m/s.

Part (a) What is the mass of the large ship, in kilograms, if the ship is moving at a speed of ***47.5*** km/h?
Numeric : A numeric value is expected and not an expression.
m_s = _____

Part (b) How much larger is the ship's momentum than the momentum of a ***1075***-kg artillery shell fired at a speed of ***275*** m/s?
Numeric : A numeric value is expected and not an expression.
p_s/p_a = _____

Problem 4: A railway car with a mass of 2050 kg moves along horizontal tracks at a constant speed of 5.36 m/s. It rolls under a grain terminal, which dumps grain directly down into the freight car after which the car's speed decreases by 2.74 m/s.

What is the mass, in kilograms, of the grain dumped into the car?
Numeric : A numeric value is expected and not an expression.
m_{grain} = _____ kg

Problem 5: A baseball of mass m = ***0.47*** kg is dropped from a height h_1 = ***2.9*** m. It bounces from the concrete below and returns to a final height of h_2 = ***1.41*** m. Neglect air resistance.

Randomized Variables

m = ***0.47*** kg

h_1 = ***2.9*** m

h_2 = ***1.41*** m

Part (a) Select an expression for the impulse I that the baseball experiences when it bounces off the concrete.
SchematicChoice :

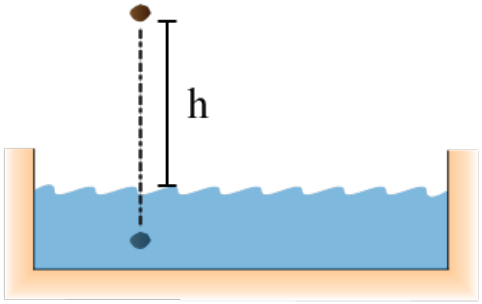
$I = m\left(\sqrt{2gh_1} - \sqrt{2gh_2}\right)$ $I = m\sqrt{2gh_2}$ $I = m\left(\sqrt{2gh_2} - \sqrt{2gh_1}\right)$

$I = m\left(\sqrt{2gh_2} + \sqrt{2gh_1}\right)$ $I = m\sqrt{2gh_1}$ $I = \sqrt{2gh_2} + \sqrt{2gh_1}$

Part (b) What is this impulse, in kilogram meters per second?
Numeric : A numeric value is expected and not an expression.
I = _____

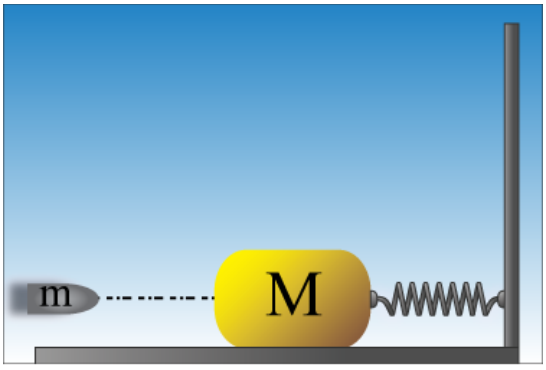
Part (c) If the baseball was in contact with the concrete for $t = 0.01$ s, what average force F_{ave} did the concrete exert on the baseball, in newtons?
Numeric : A numeric value is expected and not an expression.
$\boldsymbol{F_{ave}}$ = _____

Problem 6: A rock of mass m = ***1.2*** kg is dropped from a height of h = ***3.8*** m into a tank of water. At a time of t = ***1.61*** s after striking the surface of the water, the rock's velocity has decreased by 50%.



What is the magnitude of the average force the rock experiences, in newtons, during the time t?
Numeric : A numeric value is expected and not an expression.
$\boldsymbol{F_{ave}}$ = _____

Problem 7: A massless spring (with force constant k = ***187*** N/m) connects a wall and a block of wood. The system is initially at rest, with the spring unstretched. The block has mass M = ***52.3*** g and is able to move without friction on a table. A gun is positioned to fire a bullet of mass m = ***9.6*** g into the block along the spring axis. After the gun is fired, the bullet gets embedded in the block, and the spring is compressed a maximum distance d = ***0.81*** m.



Part (a) Find an equation for the speed of the bullet v, just before it hits the block, in terms of the variables given in the problem statement.
SchematicChoice :

$v = \frac{d}{M}\sqrt{k(M+m)}$ $v = \frac{m}{d}\sqrt{k(M+m)}$ $v = \frac{kd^2}{m}$

$$v = \frac{M}{d}\sqrt{k(M+m)} \qquad v = \frac{d}{m}\sqrt{k(M+m)} \qquad v = \frac{d}{m}\sqrt{(M+m)}$$

Part (b) In meters per second, what is the speed of the bullet v before it enters the block?
Numeric : A numeric value is expected and not an expression.
v = _____

Problem 8: A freight train is comprised of 15 cars each with a mass m. The train is moving at a constant velocity of V = 8.5 m/s through a train yard. To add another car to the train engineers will let the car roll down a hill of vertical height h = 8.75 m, until it strikes the train, coupling to it. The train and the new car are moving in the same direction before the collision.

Randomized Variables

V = 8.5 m/s
h = 8.75 m

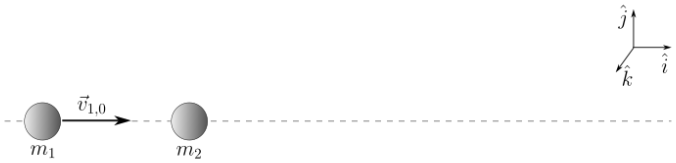
Part (a) Select an expression for the train's velocity V_f after it has coupled with the new car.
SchematicChoice :

$$V_f = \frac{15V + 2gh}{16} \qquad V_f = V + \sqrt{2gh} \qquad V_f = \frac{15V + \sqrt{gh}}{16}$$

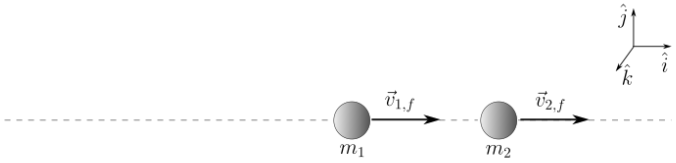
$$V_f = \frac{15V + \sqrt{2gh}}{16}$$

Part (b) What is V_f in m/s?
Numeric : A numeric value is expected and not an expression.
V_f = _____

Problem 9: The line which passes through the centers of two small masses, $m_1 = 101$ g and $m_2 = 918$ g, is parallel to the x axis. Initially mass m_2 is at rest, and mass m_1 is directed towards it with the velocity $\vec{v}_{1,0} = (2.03\ \text{m/s})\ \hat{i}$, as shown.



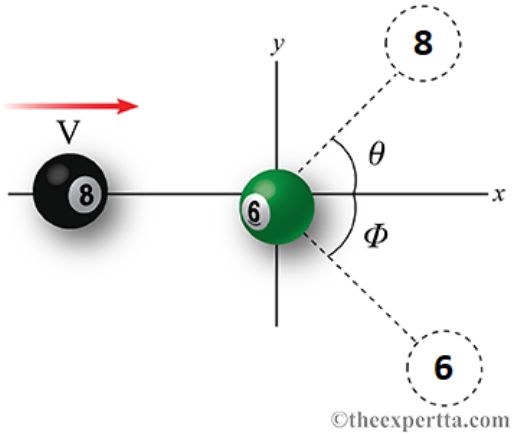
After colliding elastically, masses m_1 and m_2 are both moving parallel to the x axis with velocities $\vec{v}_{1,f} = v_{1,f}\ \hat{i}$ and $\vec{v}_{2,f} = v_{2,f}\ \hat{i}$, respectively, as shown in the second drawing. The proportionate lengths of the vectors may differ from what is shown.



Part (a) What is the x component, in meters per second, of the final velocity of mass m_1?
Numeric : A numeric value is expected and not an expression.
$v_{1,f}$ = _____ $\mathrm{m/s}$

Part (b) What is the x component, in meters per second, of the final velocity of mass m_2?
Numeric : A numeric value is expected and not an expression.
$v_{2,f}$ = _____ $\mathrm{m/s}$

Problem 10: The eight ball, which has a mass of $m = 0.500$ kg, is initially moving with a velocity $v = \left(4.26\ \mathrm{m/s}\right)\hat{i}$. The six ball has an identical mass and is initially at rest. After the two collide in an inelastic collision, the eight ball is deflected by an angle of $\theta = 24.2^\circ$, and the six ball is deflected by an angle of $\Phi = 25.3^\circ$, as shown in the figure.



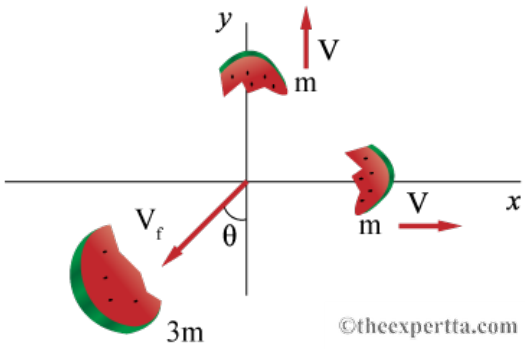
Part (a) Write an expression for the magnitude of six ball's velocity, in terms of the angles given in the problem and the magnitude of the eight ball's initial velocity, v.
Expression :
v_2 = _____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(Φ)**, **cos(θ)**, **cotan(θ)**, **l**, **sin(α)**, **sin(Φ)**, **sin(θ)**, **tan(θ)**, **w**, **α**, **β**, **θ**, **d**, **g**, **h**, **m**, **t**, **tan(Φ)**, **v**

Part (b) What is the magnitude, in meters per second, of the velocity of the six ball?
Numeric : A numeric value is expected and not an expression.
v_2 = _____ $\mathrm{m/s}$

Part (c) What is the magnitude, in meters per second, of the velocity of the eight ball after the collision?
Numeric : A numeric value is expected and not an expression.
v_1 = _____ $\mathrm{m/s}$

Problem 11: A watermelon is blown into three pieces by a large firecracker. Two pieces of equal mass m fly away perpendicular to one another, one in the x direction another in the y direction. Both of these pieces fly away with a speed of $V =$ ***23*** m/s. The third piece has three times the mass of the other two pieces.



Randomized Variables

$V =$ ***23*** m/s

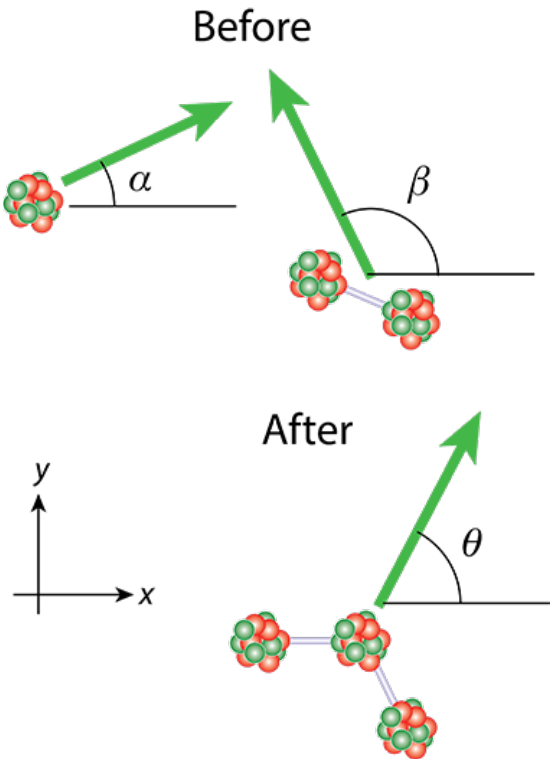
Part (a) Write an expression for the speed of the larger piece, that is in terms of only the variable V.
Expression :
$V_f =$ _____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(θ), **n**, **sin(θ)**, **β**, **θ**, **a**, **d**, **g**, **h**, **i**, **j**, **k**, **m**, **t**, **V**

Part (b) What is the numeric value for the speed of the larger piece, in meters per second?
Numeric : A numeric value is expected and not an expression.
$V_f =$ _____

Part (c) At what angle does the largest piece travel with respect to the -y axis, in degrees?
Numeric : A numeric value is expected and not an expression.
$\theta =$ _____

Problem 12: An oxygen atom (mass 16 u) is moving with speed $v_1 =$ ***1110*** m/s at an angle of $\alpha =$ ***29.6***°. An oxygen molecule (mass 32 u) is moving with speed $v_2 =$ ***550*** m/s at an angle of $\beta =$ ***104***°. A collision forms an ozone molecule (mass 48 u) which moves with velocity $\vec{v}$ at angle θ. All angles are measured from positive x, as shown in the diagram.



Part (a) Write an expression for the x component of the velocity of the ozone molecule.
Expression :
$v_x =$ _____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(β)**, **cos(φ)**, **cos(θ)**, **sin(α)**, **sin(β)**, **sin(φ)**, **sin(θ)**, **γ**, **θ**, **g**, **m**, **n**, $\mathbf{v_1}$, $\mathbf{v_2}$

Part (b) Write an expression for the y component of the velocity of the ozone molecule.
Expression :
v_y = _____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(β)**, **cos(φ)**, **cos(θ)**, **sin(α)**, **sin(β)**, **sin(φ)**, **sin(θ)**, **γ**, **θ**, **g**, **m**, **n**, $\mathbf{v_1}$, $\mathbf{v_2}$

Part (c) What is the speed, in meters per second, of the ozone molecule?
Numeric : A numeric value is expected and not an expression.
v = _____ m/s

Part (d) What is the angle, in degrees, between the velocity vector of the ozone molecule and the positive x axis?
Numeric : A numeric value is expected and not an expression.
θ = _____ °

Problem 13: Rockets achieve high speeds by using the momentum from their exhaust. The exhaust is a small amount of mass moving backwards at some velocity -**v**, so the rocket gains forward velocity to conserve momentum.

Can the speed of the rocket exceed the exhaust velocity of the fuel?
MultipleChoice :

1) Yes. The rocket continually gains speed as long as the fuel is available.
2) There is not enough information here to answer.
3) No. The rocket can only push away from the gas particles as quickly as the gas particles exit the rocket.

Problem 14: Antiballistic missiles (ABMs) are designed to have very large accelerations so that they may intercept fast-moving incoming missiles in the short time available.

What is the takeoff acceleration, in meters per square second, of a ***12000***-kg ABM that expels 196 kg of gas per second at an exhaust speed of ***2.25*** × 10^3 m/s?
Numeric : A numeric value is expected and not an expression.
a = _____

Problem 15: Suppose a space probe of mass m_1 = ***4150*** kg expels m_2 = ***3400*** kg of its mass at a constant rate with an exhaust speed of v_{ex} = ***2.2*** × 10^3 m/s.

Part (a) What is the increase in speed, of the space probe, in terms of the variables given in the introduction? You may assume the gravitational force is negligible at the probe's location.
SchematicChoice :

$\Delta v = v_{ex} \ln\left(\frac{m_1 - m_2}{m_1}\right) + v_0$ $\Delta v = v_{ex} \ln\left(\frac{m_1}{m_2}\right)$ $\Delta v = v_{ex} \ln\left(\frac{m_1}{m_1 - m_2}\right) + v_0$

$\Delta v = v_{ex} \ln\left(\frac{m_1}{m_1 - m_2}\right)$ $\Delta v = v_{ex} \ln\left(\frac{m_1 - m_2}{m_1}\right)$ $\Delta v = v_{ex} \ln\left(\frac{m_2}{m_1}\right)$

Part (b) Calculate the increase in speed, in meters per second, of the space probe.
Numeric : A numeric value is expected and not an expression.
Δ*v* = _____

Problem 16: A rocket fires its thrusters in deep space. From rest, it reaches a speed of 73.4 m/s in 8.18 s. The speed of the exhaust, relative to the rocket, is 1580 m/s and the mass of fuel burned is 195 kg.

What was the initial mass, in kilograms, of the rocket?
Numeric : A numeric value is expected and not an expression.
m_0 = _____ kg