1. (20 points) Fill in the letter or letters that correspond to the terms that best fit the description given below. Note that in some cases more than one letter can be used—in those instances list all of the letters that apply. Letters may be used more than once.

A. acceleration due to gravity  B. speed  C. displacement  
D. acceleration  E. instantaneous velocity  F. average speed  
G. centripetal acceleration  H. net force  I. momentum  
J. centripetal force  
K. Newton’s first law of motion  
L. Newton’s second law of motion  
M. Newton’s third law of motion  

H, J quantity (ies) that could have units of Newtons  
A, D, G quantity (ies) that could have units of m/s²  
M observation that involves forces on two different bodies  
A, C, D, E, G, H, I, J list all vector quantities above  
B, F list all scalar quantities above  
J a force always pointing toward the inside of a circle  
H Newton’s second law states that the acceleration of an object is directly proportional to this quantity

2. (10 points) Make the following conversions. Show your work to the right for ones which necessitate the doing of calculations.

a. 1.56 mm = \( 0.00156 \) m  
b. 0.00563 kg = \( 5630 \) mg  
c. 6.0 L = \( \frac{16}{1} \) gal \( \frac{6.0L}{1} \times \frac{1qt}{0.946L} \times \frac{1gal}{4qt} = 1.6 \) gal  
d. 150.0 g mercury = \( \frac{11.02 \text{ mL mercury}}{13.6g} \) mL mercury (density of mercury = 13.6 g/mL)  
\( \frac{150.0g}{1} \times \frac{1 \text{ mL mercury}}{13.6g} = 11.02 \text{ mL mercury} \)  
e. 55.0 cm = \( 550 \) mm
3. (10 points) Consider a 30-minute trip taken according to the following diagram. Each side of each square represents one mile.

![Diagram of a 30-minute trip]

a. What is the distance traveled during this trip?
   **31 miles**

b. What is the average speed achieved during this trip?
   \[
   \text{average speed} = \frac{31 \text{ miles}}{30 \text{ minutes}} = 1.0 \text{ miles/minute} = 60.0 \text{ miles/hour}
   \]

c. What is displacement of this trip?
   **5 miles east**

d. What is the average velocity of this trip?
   \[
   \text{average velocity} = \frac{5 \text{ miles east}}{30 \text{ minutes}} = 0.167 \text{ miles east/minute} = 0.333 \text{ miles east/hour}
   \]

e. Is it possible to tell if there was acceleration during this trip? Explain your answer.
   *There had to have been acceleration during the trip because the object changed direction along the route.*

4. (6 points)
   a. A car is being accelerated at a rate of 2.0 m/s$^2$ to the east. If the car’s initial velocity is 15 m/s to the east, what is its velocity after 10.0 s of the acceleration? *The acceleration is 2.0 m/s$^2$ to the east and this is applied for 10.0 s. Therefore the car has accelerated 2.0 m/s$^2$ east \(10.0 \text{ s} = 20.0 \text{ m/s east} \). If the initial velocity was 15 m/s to the east, the final velocity is 15 m/s east + 20.0 m/s east = 35.0 m/s east.*

   b. Another car is also being accelerated at a rate of 2.0 m/s$^2$ to the east. If this car’s initial velocity is 15 m/s to the west, what is its velocity after 10.0 s of the acceleration? *The change in velocity is the same as that above, 20.0 m/s to the east. This is added to 15 m/s to the west, giving a final velocity of 5.0 m/s to the east.*
5. (10 points) A ball is thrown straight up into the air with an initial speed of 12.0 m/s.

a. How long will it take the ball to reach its maximum height?
   At the top, the velocity of the ball is 0 m/s since it is turning around. Using
   \[ v_f = v_0 + at \]
   \[ 0 \text{ m/s} = 12.0 \text{ m/s} + (-9.8 \text{ m/s}^2) t \Rightarrow -12.0 \text{ m/s} = -9.8 \text{ m/s}^2 t \Rightarrow t = \frac{-12.0 \text{ m/s}}{-9.8 \text{ m/s}^2} = 1.2 \text{ s} \]

b. How high will the ball be at its maximum height?
   Using \( d = \frac{1}{2} at^2 \):
   \[ d = \frac{1}{2} (9.8 \text{ m/s}^2) (1.2 \text{ s})^2 = 7.3 \text{ m} \]

c. How long will the ball be in the air before it returns to the hand of the person that tossed it up?
   \text{Twice the answer to a } = 2 \times 1.2 \text{ s} = 2.4 \text{ s} \]

d. Rather than being thrown straight up, the ball is now thrown with an initial upward speed of 12.0 m/s and a horizontal speed of 20.0 m/s. How far would the ball travel horizontally during this trip, assuming it is returning to the same height that it departed at?
   \text{Time of travel } = 2.4 \text{ s. The speed in the horizontal direction is 20.0 m/s with no acceleration. So, the distance traveled is } 2.4 \text{ s } \times 20.0 \text{ m/s } = 48 \text{ m} \]

e. Which, if any, of your answers to parts a through d would change if the mass of the ball is doubled? Explain your reasoning.
   \text{None of the answers are changed. Notice the mass of the ball wasn’t even given and you are still able to work out the solution.} \]

6. (10 points) Consider the following diagram.

```
20 N
  30 kg
---
5 N
```

a. State the net force on the box.
   \text{Net force } = 20 \text{ N to the right } + 5 \text{ N to the left } = 15 \text{ N to the right}.

b. Find the acceleration of the box.
   \[ F = ma \Rightarrow 15 \text{ N right } = 30 \text{ kg } \times a \Rightarrow a = \frac{15 \text{ N right}}{30 \text{ kg}} = 0.5 \text{ m/s}^2 \text{ right} \]

c. If one is told the box is initially moving at a speed of 5.0 m/s to the left, what would its velocity be after 10.0 s?
   \[ v_f = v_0 + at = 5.0 \text{ m/s left } + (-0.5 \text{ m/s}^2)(10.0 \text{ s}) = 0 \text{ m/s} \]

d. If the mass of the box is doubled, what would happen to the value of its acceleration – by what factor would it increase, decrease, or would it stay the
same?

*The acceleration would be cut in half.*

7. (9 points) State for each of the following changes in conditions by what factor the gravitational force would change. Be specific – doubled, tripled, cut in half, cut to one-third, etc.

Equation to consider: \( F = G \frac{m_1 m_2}{r^2} \)

a. Both masses are tripled and the distance between them is doubled.

*The tripling of masses causes the force to increase by a factor of \( 3^2 = 9 \), while the doubling of the radius causes the force to be reduced by \( 2^2 = 4 \), for a total increase of \( \frac{9}{4} \) the original force.*

b. One mass is tripled, the other is cut to one-third of its initial value, and the distance between the two objects is doubled.

*One mass is tripled, the other cut to one-third so the next effect is \( 3 \times \frac{1}{3} \), or basically no change due to that part. If the distance is doubled, the force is reduced by a factor of \( 2^2 = 4 \), for a total force reduction to \( \frac{1}{4} \) of its original value.*

c. Both masses are doubled and the distance between them is cut in half.

*Doubling both masses causes the force to increase by a factor of \( 2^2 = 4 \). Cutting the distance in half causes the force to increase by \( 2^2 = 4 \). So, overall, the effect is an increase in the force by a factor of \( 4 \times 4 = 16 \).*

8. (10 points)

a. Two blocks, one 15-kg and the other 10-kg, are separated by a compressed spring and held together by a string. The string is cut, and the 15-kg block on the left moves to the left at a speed of 5.0 m/s. How fast does the other block move off to the right?

*Conservation of momentum:*

\[
\text{Total momentum before collision} = \text{Total momentum after collision}
\]

\[
\text{Momentum of 15-kg block before} + \text{Momentum of 10-kg block before} = \text{Momentum of 15-kg block after} + \text{Momentum of 15-kg block after}
\]

Let’s say moving to the left is the negative direction:

\[
15-\text{kg} \ (0 \text{ m/s}) + 10-\text{kg} \ (0 \text{ m/s}) = 15-\text{kg} \ (-5.0 \text{ m/s}) + 10.0-\text{kg} \ \nu_{10\text{kg}}
\]

\[
0 = -75.0 \text{ kgm/s} + 10.0-\text{kg} \ \nu_{10\text{kg}}
\]

\[
\nu_{10\text{kg}} = 75.0 \text{ kgm/s} / 10.0 \text{ kg} = 7.5 \text{ m/s right}
\]

b. Find the kinetic energy of each block after the string is cut.

\[
\text{KE} = \frac{1}{2} m v^2
\]

For the 15-kg block: \( \text{KE} = \frac{1}{2} (15-\text{kg})(5.0 \text{ m/s})^2 = 188 \text{ J} \)

For the 10-kg block: \( \text{KE} = \frac{1}{2} (10-\text{kg})(7.5 \text{ m/s})^2 = 281 \text{ J} \)
Equations and constants that may be helpful:

\[
d = \frac{1}{2}at^2
\]

\[
a = 9.8 \text{ m/s}^2 = 32 \text{ ft/s}^2
\]

\[
\nu = \frac{d}{t}
\]

\[
G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2
\]

\[
\rho = \frac{m}{V}
\]

1 inch = 2.54 cm

\[
a = \frac{\Delta v}{t} = \frac{v_f - v_o}{t}
\]

or \( v_f = v_o + at \)

\[
a_c = \frac{v^2}{r}
\]

1 lb = 453.6 g

1 qt = 0.946 L

\[
F = \frac{Gm_1m_2}{r^2}
\]

p = mv

L = mHV Hr

J = rF

F = ma