Problem 1: Multiple Choice [20 pts]

a) [5 pts] If the velocity of Bob relative to Faye is \( \overrightarrow{v_{Bob}} \), and the velocity of Ryan relative to Faye is \( \overrightarrow{v_{Ryan}} \), then what is the velocity of Bob relative to Ryan?

A. \( \overrightarrow{v_{Bob}} \)
B. \( \overrightarrow{v_{Ryan}} \)
C. \( \overrightarrow{v_{Bob} + \overrightarrow{v_{Ryan}}} \)
D. \( \overrightarrow{v_{Bob} - \overrightarrow{v_{Ryan}}} \)

b) [5 pts] A car undergoes constant acceleration starting from rest. After a time \( t \), the car has moved a distance \( d \). How long did it take to cover the first \( \frac{d}{2} \) of the trip?

A. \( \frac{t}{4} \)
B. \( \frac{t}{2} \)
C. \( \frac{t}{\sqrt{2}} \)
D. \( \frac{3t}{4} \)

c) [5 pts] The speed of sound in air can depend on the air pressure, \( P \), and on the density of the air, \( \rho \). \( P \) is measured in N/m\(^2\), and \( \rho \) is measured in kg/m\(^3\). Which of the following could be the expression for the speed of sound?

(a) \( \rho P^2 \)
(b) \( \frac{\rho}{P} \)
(c) \( \sqrt{\rho P} \)
(d) \( \frac{P}{\sqrt{\rho}} \)
(e) \( \frac{P^2}{\rho} \)
d) [5 pts] Two children, A (60 kg) and B (45 kg) are seated on two adjacent skateboards that can roll without friction on a horizontal surface. They start out stationary, face-to-face, and then push on each other and roll off in opposite directions: A to the left, and B to the right. Consider the system consisting of both children plus both skateboards. After they push apart, which way does the system’s center of mass move?

   (a) To the left, towards A  
   (b) To the right, towards B  
   (c) It depends on who pushes harder  
   (d) It depends on the final speeds of the two students  
   (e) The center of mass does not move at all

Problem 2: Mountain Driving [15 pts]

You are driving your car (mass $m$) with a constant speed $v$ down a long hill that makes an angle $\theta$ from the horizontal. You slam on your brakes, and your tires skid against the pavement with a coefficient of kinetic friction $\mu_k$. (You may ignore air resistance for this problem.)

   a) [5 pts] Draw a clear free-body diagram for your car while it is skidding straight down the hill.

   b) [15 pts] Derive an expression for the distance $d$ required to stop your car, in terms of the mass $m$, the initial speed $v$, the angle $\theta$, and the coefficient of kinetic friction $\mu_k$. 

Problem 3: Stephanie saves the day [30 pts]

Stephanie Smith, the human cannonball, is in a wheeled cannon mass $m_1$ hurtling towards the edge cliff at speed $v_i$. Just before it reaches the edge, the cannon fires Stephanie (who has mass $m_2$) horizontally forward. As a result, the cannon comes to a stop at the edge of the cliff. Stephanie lands on the ground (miraculously unhurt) at a horizontal distance $d$ from the edge of the cliff, which is a height $h$ above the ground.

a) [20 pts] Determine $m_1$, the mass of the cannon. You may neglect friction between the cannon and the ground, and air drag on Stephanie. Express your answer in terms of $m_2$, $v_i$, $d$, $h$, and $g$. 
Problem 2: Stephanie saves the day (cont.)
b) [10 pts] Consider the cannon and Stephanie taken together as a system. At the instant that Stephanie lands, what is the $x$-coordinate of the system’s center of mass? Let $x = 0$ at the base of the cliff, and express your answer in terms of $v_i$, $g$, and $h$. ($Hint$: we do not want your answer to contain $d$, $m_1$, or $m_2$.)