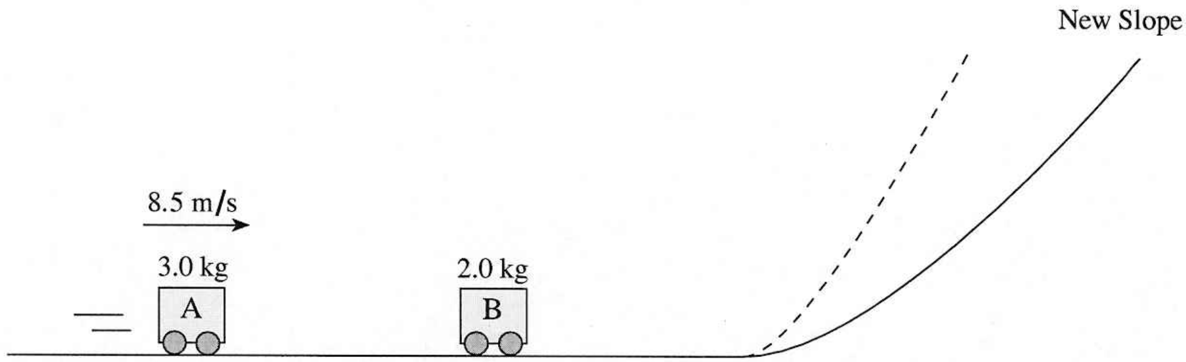
b) The steepness of the slope is decreased as shown below.



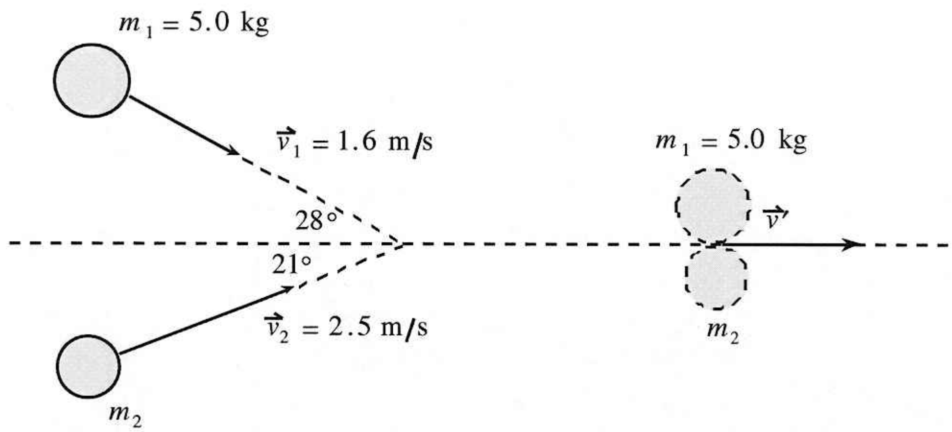
With this decreased slope, the combined cars will reach (check one response) **(1 mark)**

- ☐ a lesser height.
- ☑ the same height.
- ☐ a greater height.

c) Using principles of physics, explain your answer to b). **(3 marks)**

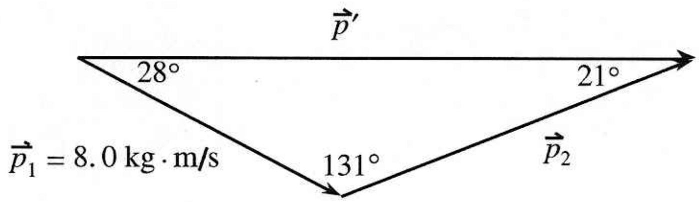
The steepness of the slope does not matter. All of the cars kinetic energy will be transferred to gravitational potential energy. Since the original kinetic energy of the cars has not changed, they must have the same potential. Therefore, they go to the same vertical height.

4. A 5.0 kg object travelling at 1.6 m/s collides with an object of unknown mass m_2 travelling at 2.5 m/s. The two objects stick together and move towards the right as shown in the diagram.



Find the mass of object m_2. **(7 marks)**

$p_1 = m_1 v_1 = 5.0(1.6) = 8.0 \text{ kg}\cdot\text{m/s}$ ← **1 mark**



← **3 marks**

$$\frac{p_2}{\sin 28°} = \frac{8.0}{\sin 21°}$$ ← **1 mark**

$p_2 = 10.5 \text{ kg}\cdot\text{m/s}$ ← **1 mark**

$$m_2 = \frac{10.5}{2.5} = 4.19 \text{ kg}$$ ← **1 mark**

OR the Component Method

$\tau_{cc} = -5(1.6)\sin 28°$ ← **2 marks**

$\tau_c = m(2.5)\sin 21°$ ← **2 marks**

$\Sigma\, \tau_y = 0 \quad \therefore m(2.5)(\sin 21°) + -5(1.6)\sin 28° = 0$ ← **1 mark**

$m = 4.2$ kg ← **2 marks**

Alternate Solution:

$4.145 \text{ kgm/s} + P_{Ax} = 7.7 \text{ kgm/s}$ ← **2 marks**

$P_{Ax} = 3.56 \text{ kgm/s}$ ← **½ mark**

$-2.80 + P_{Ay} = 0$ ← **2 marks**

$P_{Ay} = 2.80 \text{ kgm/s}$ ← **½ mark**

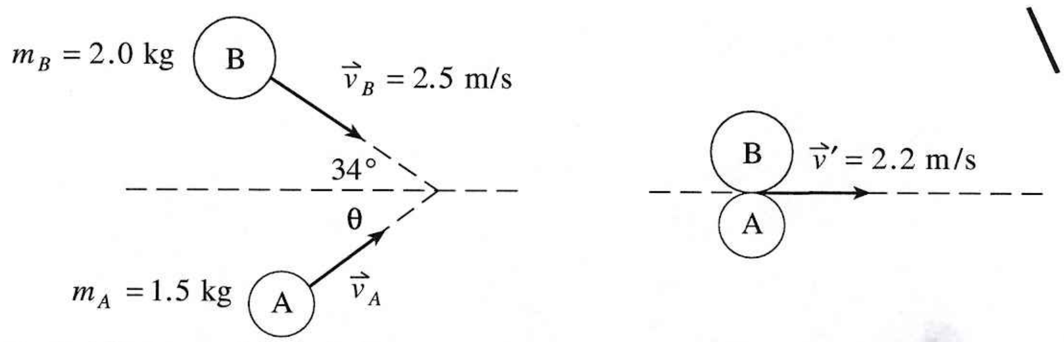
$P_A = 4.52 \text{ kgm/s}$ ← **½ mark**

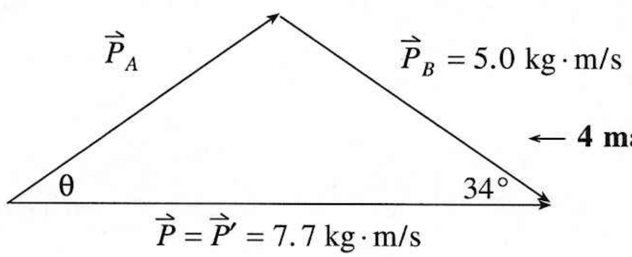
$v_A = 3.0 \text{ m/s}$ ← **½ mark**

$\tan\theta = \frac{2.80}{3.56}$ ← **½ mark**

$\theta = 38°$ ← **½ mark**

5. Two air pucks approach each other, stick together and then travel due east as shown below. Find the initial velocity (magnitude and direction) of puck **A**. **(7 marks)**





← **4 marks**

Momentum is conserved.	← **1 mark**
Momentum is a vector.	← **1 mark**
Calculating P_B and P'.	← **1 mark**
Correct triangle.	← **1 mark**

$P_A^2 = 7.7^2 + 5.0^2 - 2(7.7)(5.0)\cos 34°$ ← **1 mark**

$P_A = 4.52$ kg·m/s ← **½ mark**

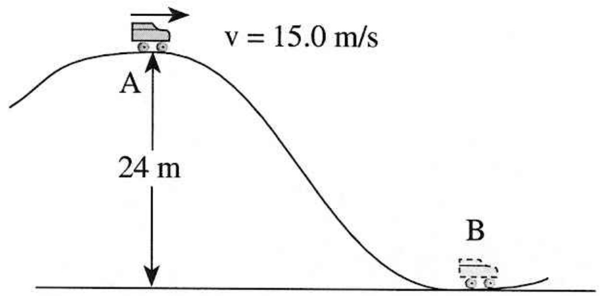
$v_A = \frac{4.52}{1.5} = 3.0$ m/s ← **½ mark**

$\frac{\sin\theta}{5.0} = \frac{\sin 34°}{4.52}$ ← **½ mark**

$\theta = 38°$ ← **½ mark**

or 38° N of E

6. A 150 kg roller coaster car passes the crest of a hill at 15.0 m/s.



a) What is the speed of the car at point **B** at the bottom of the hill? (Neglect friction.) **(5 marks)**

$$E_A = E_B$$

$$E_{k_A} + E_{p_A} = E_{k_B} + E_{p_B} \qquad \leftarrow \textbf{2 marks}$$

$$\frac{1}{2}mv_A^2 + mgh_A = \frac{1}{2}mv_B^2 + 0 \qquad \leftarrow \textbf{1 mark}$$

$$\frac{1}{2}v_A^2 + gh_A = \frac{1}{2}v_B^2 \qquad \leftarrow \textbf{1 mark}$$

$$v_B^2 = 2gh_A + v_A^2$$

$$= 2 \cdot 9.8\ \text{m/s}^2 \cdot 24\ \text{m} + (15\ \text{m/s})^2$$

$$\therefore v_B = 26\ \text{m/s} \qquad \leftarrow \textbf{1 mark}$$

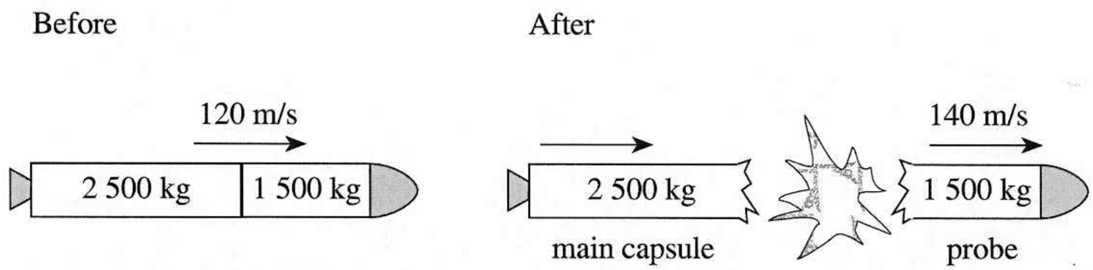
b) i) If the mass of the roller coaster car is increased by adding a passenger, how will the speed at **B** now compare to your answer for part a)? (Circle one) **(1 mark)**

A. equal to
B. less than
C. greater than

ii) Explain your answer using principles of physics. **(3 marks)**

The speed will be the same as in a). This is a direct transfer of potential energy to kinetic energy. Both potential energy and kinetic energy have the mass term in them. If you increase the mass, both potential energy and kinetic energy increase by the same amount.

7. A 4 000 kg space vehicle consists of a 2 500 kg main capsule and a 1 500 kg probe. The space vehicle is travelling at 120 m/s when an explosion occurs between the capsule and the probe. As a result, the probe moves forward at 140 m/s, as shown in the diagram below.



a) (i) What is the speed of the main capsule after the explosion? **(3 marks)**

$$\left.\begin{aligned} m_1v_1 + m_2v_2 &= m_1v_1' + m_2v_2' \\ (m_1 + m_2)v &= m_1v_1' + m_2v_2' \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$(4\,000)(120) = (1\,500)(140) + (2\,500)v_2' \quad \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} 270\,000 &= 2\,500v_2' \\ v_2' &= 108 \text{ m/s} \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$\therefore \text{speed} = 1.1 \times 10^2 \text{ m/s}$$

(ii) What is the magnitude of the impulse given to the probe? **(2 marks)**

$$\Delta p = mv_f - mv_0 \quad \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} F\Delta t &= \Delta p \\ &= 1\,500(140) - 1\,500(120) \\ &= 3.0 \times 10^4 \text{ N} \cdot \text{s} \end{aligned}\right\} \quad \leftarrow \textbf{1 mark}$$

b) Define *impulse* and briefly explain why the impulse on the probe is equal in magnitude to the impulse on the main capsule.

Impulse is a force acting for a given time interval, or a change in momentum. **(1 mark)**

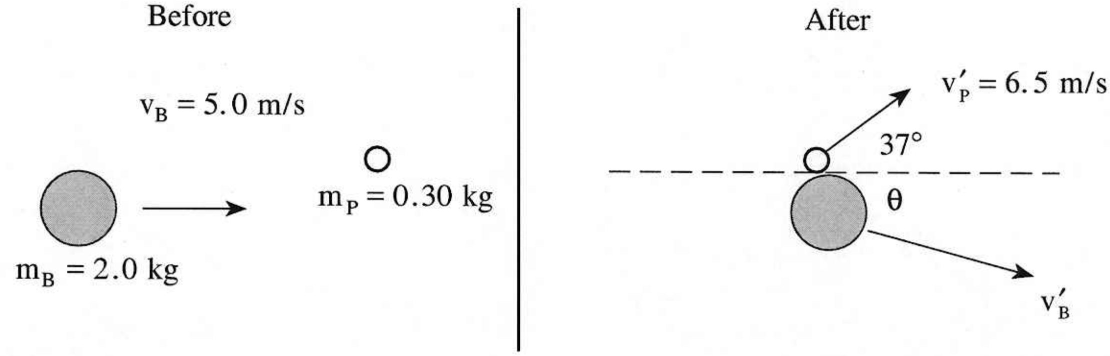
(i) Newton's Third Law states that for every force there is an equal and opposite reacting force. As the time of the explosion is equal for both the probe and the capsule, the impulse ($F\Delta t$) must be equal and opposite also.

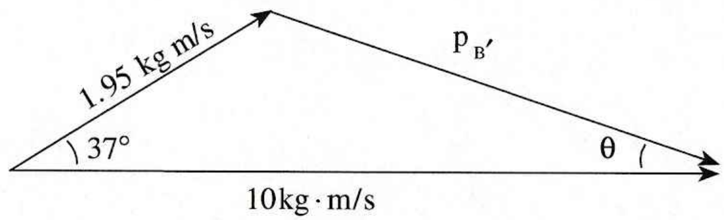
OR

(ii) Impulse is equal to a change in momentum. As momentum is conserved, the momentum gained by the probe must equal the momentum lost by the capsule

3 marks

8. A 2.0 kg bowling ball travelling 5.0 m/s collides with a stationary 0.30 kg bowling pin. After the collision, the pin moves at a speed of 6.5 m/s in the direction shown in the diagram. What is the velocity (magnitude and direction) of the bowling ball after the collision? **(7 marks)**





1 mark for diagram

$$p_B = (2.0)(5.0)$$

1 mark $= 10 \text{ kg}\cdot\text{m/s}$

$$p'_P = (0.30)(6.5)$$

1 mark $= 1.95 \text{ kg}\cdot\text{m/s}$

$$p'^2_B = (10)^2 + (1.95)^2 - (2)(10)(1.95)\cos 37$$

$$= 72.66$$

$\therefore p'_B = 8.52 \text{ kg}\cdot\text{m/s}$ **2 marks**

$$\therefore v'_B = \frac{8.52 \text{ kg}\cdot\text{m/s}}{2.0 \text{ kg}}$$

$$= 4.26 \text{ m/s}$$

$= 4.3$ m/s **1 mark**

$$\frac{\sin\theta}{1.95} = \frac{\sin 37}{8.52}$$

$\theta = 7.9°$ **1 mark**

Component Solution

Before: x	Before: y	After: x	After: y
$p_x = 2 \times 5 = 10$ **1 mark**	0	$p_{Px} = .3 \times 6.5 \times \cos 37$ $= 1.557$ **1 mark** $\therefore p_{Bx} = 10 - 1.557$ $= 8.443$ **1 mark**	$p_{Py} = .3 \times 6.5 \times \sin 37$ $= 1.174$ $\therefore p_{By} = 1.174$ (down) **1 mark**

$$\therefore p_B^2 = (8.443)^2 + (1.174)^2$$

$$p_B = 8.52$$ **1 mark**

$$\tan \theta = \frac{1.174}{8.443}$$

$$\theta = 7.92°$$ **1 mark**

$$v_B = \frac{p_B}{m_B}$$

$$= 4.26$$ **1 mark**

9. A 5.20 kg block sliding at 9.40 m/s across a horizontal frictionless surface collides head on with a stationary 8.60 kg block. The 5.20 kg block rebounds at 1.80 m/s. How much kinetic energy is lost during this collision? **(7 marks)**

$$\left.\begin{aligned} m_1v_1 + m_2v_2 &= m_1v_1' + m_2v_2' \\ (5.20)(9.40) &= (5.20)(-1.80) + (8.60)v_2' \\ v_2' &= 6.77 \text{ m/s} \end{aligned}\right\}$$ **4 marks**

$$\left.\begin{aligned} E_k(\text{before}) &= \frac{1}{2}m_1v_1^2 = 229.7 \text{ J} \\ E_k(\text{after}) &= \frac{1}{2}m_1v_1^{2\prime} + \frac{1}{2}m_2v_2^{2\prime} \\ &= 8.424 + 197.2 \\ &= 205.6 \text{ J} \\ \text{LOST} &= 24.12 \text{ J} \\ \Delta E &= 24.1 \text{ J} \end{aligned}\right\}$$ **3 marks**