(1) (a) $x_{cm} = \frac{1}{M}(m_1x_1 + m_2x_2 + m_3x_3) = \frac{(4.1\,kg)(-2m) + (8.2\,kg)(4m) + (4.1\,kg)(1m)}{4.1\,kg + 8.2\,kg + 4.1\,kg}$

$= 1.8\,m$

$y_{cm} = \frac{1}{M}(m_1y_1 + m_2y_2 + m_3y_3) = \frac{(4.1\,kg)(3m) + (8.2\,kg)(2m) + (4.1\,kg)(-2m)}{4.1\,kg + 8.2\,kg + 4.1\,kg}$

$= 1.3\,m$

(b)(i) m_1: $F_1 = \langle -6, 0 \rangle N$ $\quad \frac{\Delta v_1}{\Delta t} = \frac{F_1}{m} = \frac{\langle -6, 0 \rangle N}{4.1\,kg} = \langle -1.46, 0 \rangle \frac{m}{s^2}$

$x_{1f} = x_{1i} + \frac{1}{2}\left(\frac{F_1}{m}\right)t^2 = -6.56\,m$ $\quad y_{1f} = 3\,m$

m_2: $F_2 = \langle 12\cos 45°, 12\sin 45° \rangle = \langle 8.48, 8.48 \rangle N$

$x_{2f} = x_{2i} + \frac{1}{2}\left(\frac{F_{2x}}{m}\right)t^2 = 4\,m + \frac{1}{2}\left(\frac{8.48N}{8.2kg}\right)(2.55)^2 = 7.23\,m$

$y_{2f} = y_{2i} + \frac{1}{2}\left(\frac{F_{2y}}{m}\right)t^2 = 2m + \frac{1}{2}\left(\frac{8.48N}{8.2kg}\right)(2.55)^2 = 5.23\,m$

m_3: $F_3 = \langle 14, 0 \rangle N$

$x_{3f} = x_{3i} + \frac{1}{2}\left(\frac{F_{3x}}{m}\right)(t^2) = 1 + \frac{1}{2}\left(\frac{14}{4.1}\right)(2.5)^2 = 10.67\,m$

$y_{3f} = -2\,m$

$x_{cm} = \frac{(4.1)(-6.57m) + (8.2kg)(7.23m) + (4.1kg)(10.67m)}{4.1\,kg + 8.2\,kg + 4.1\,kg} = 4.9\,m$

$y_{cm} = \frac{(4.1kg)(3m) + (8.2kg)(5.23m) + (4.1kg)(-2m)}{16.4kg} = 2.9\,m$

(ii) $\vec{F}_{net} = \langle -6, 0, 0 \rangle + \langle 12\cos 45°, 12\sin 45°, 0 \rangle + \langle 14, 0, 0 \rangle$

$= \langle 16.5, 8.5 \rangle N$

$$\frac{\Delta \vec{V}_{cm}}{\Delta t} = \frac{\vec{F}_{ext}}{M} = \frac{\langle 16.5, 8.5, 0\rangle N}{16.4\,kg} = \langle 1.007, 0.517, 0\rangle$$

$$\Delta \vec{V}_{cm} = \langle 2.51, 1.29, 0\rangle \text{ m/s}$$

$$\vec{V}_{i,cm} = 0 \Rightarrow \vec{V}_{f,cm} = \langle 2.51, 1.29, 0\rangle \text{ m/s}$$

$$\vec{V}_{cm,Avg} = \frac{1}{2}(\vec{V}_i + \vec{V}_f) = \langle 1.26, 0.65, 0\rangle \text{ m/s}$$

$$\vec{r}_f = \vec{r}_i + \vec{V}_{avg}\,\Delta t = \langle 1.8, 1.3, 0\rangle m + \langle 3.1, 1.6, 0\rangle m/s$$

$$= \langle 4.9, 2.9, 0\rangle m$$

(2) (a) $x = v_{0x} t = (v_0 \cos\theta) t$

$$= (12.4 m/s)(\cos 54°)(1.42 s) = 10.35 m$$

$$y = v_{0y} t + \frac{1}{2}\frac{F}{m} t^2 = (12.4 m/s)(\sin 54°)(1.42 s) + \frac{1}{2}\left(9.80 \frac{N}{kg}\right)(1.42 s)^2$$

$$= 4.36 m$$

(b) $\vec{r}_{cm} = \langle 10.35 m, 4.36 m, 0\rangle$

(c) $x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} \Rightarrow x_2 = \frac{M x_{cm} - m_1 x_1}{m_2}$

$$= \frac{(9.6 kg)(10.35 m) - (6.5 kg)(13.6 m)}{3.1 kg} = 3.5 m$$

$$y_2 = \frac{M y_{cm} - m_1 y_1}{m_2} = \frac{(9.6 kg)(4.36 m) - (6.5 kg)(5.9 m)}{3.1 kg}$$

$$= 1.1 m$$