1. (20 points) Express the following in SI units, with appropriate notation, rounding, and significant figures. (1 cm = 0.01000 m; 1 in = 2.5400 cm; 1 km = 1000 m; 1 ft = 0.3048 m)

(a) \( \frac{(4.32 \times 10^{-3} \text{ cm}^2)(1.8 \times 10^9 \text{s}^{-2})}{4900 \text{ in}} = ? \)

\[
\begin{align*}
\text{(4.32 \times 10^{-3} \text{ cm}^2) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^2 \left( 1.8 \times 10^9 \text{s}^{-2} \right) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right) =} \\
4900 \text{ in} & \quad 2.54 \text{ cm} \\
\text{1 in} & \quad 1 \text{ in}
\end{align*}
\]

\[
\frac{\text{4.32} \times 10^{-7} \text{ m}^2 \left( 1.8 \times 10^9 \text{s}^{-2} \right)}{124.5 \text{ m}} = 6.2 \text{ m/s}^2
\]

(b) 21.00 ft + 8.2 m + 0.321 km = ?

\[
\begin{align*}
21.00 \text{ ft} & \quad \frac{0.3048 \text{ m}}{1 \text{ ft}} + 8.2 \text{ m} + 0.321 \text{ km} \quad \frac{1000 \text{ m}}{1 \text{ km}} \\
& \quad 6.401 \text{ m} + 8.2 \text{ m} + 321 \text{ m}
\end{align*}
\]

\[
= 336 \text{ m}
\]
2. **(25 points)** From the right figure depicting the position of an object in a one-dimensional motion along the x-axis, determine the quantities in (a) and (b). Use two significant figures for your answers. Do not forget units and signs.

(a) The average velocity for the interval between \( t = 2 \, \text{s} \) and \( t = 7 \, \text{s} \).

\[
\bar{v} = \frac{2.0 - (-3.0)}{7.0 - 2.0} = 1.0 \, \text{m/s}
\]

(b) The instantaneous velocities at \( t = 2 \, \text{s} \) and \( t = 7 \, \text{s} \).

\[
v_{t=2} = \frac{-2 - (-4)}{3 - 1} = 1.0 \, \text{m/s}
\]

\[
v_{t=7} = \frac{0 - 4}{8 - 6} = -2.0 \, \text{m/s}
\]

(c) The average acceleration for the interval between \( t=2 \, \text{s} \) and \( t=7 \, \text{s} \).

\[
\bar{a} = \frac{v_{t=7} - v_{t=2}}{7 - 2} = \frac{-2.0 - 1.0}{5.0} = -0.60 \, \text{m/s}^2
\]
3. **(20 points)** A model rocket is launched from rest at an angle of 53.0° above the horizontal. The rocket moves for 140 m along its initial line of motion with an acceleration of 35.0 m/s². At this time, its engine fails and the rocket proceeds to move as a projectile. (a) Find the velocity of the rocket at the moment when its engine fails. (b) Find the rocket’s horizontal range, namely, the distance from the rocket’s launching point to its crash site.

\[ V^2 - V_0^2 = 2 a x ]

Here, \( V_0 = 0 \), \( a = 35.0 \text{ m/s}^2 \), \( x = 140 \text{ m} \)

\[ V = \sqrt{2 a x} = \sqrt{2 \times 35.0 \times 140} = 99.0 \text{ m/s} \]

(b) \[ d_1 = 140 \cos 53.0° = 84.3 \text{ m} \quad \text{and} \quad h = 140 \sin 53.0° = 112 \text{ m} \]

\[ \{ \begin{align*}
    d_2 &= V \cos 53.0° \cdot t \\
    -h &= V \sin 53.0° \cdot t - \frac{1}{2} g t^2
\end{align*} \]

In equation (2), \(-112 = 99.0 \times \sin 53.0° \cdot t - \frac{1}{2} \times 9.80 \times t^2\)

Solve it, \( t = 17.5 \text{ s} \)

Then \( d_2 = 99.0 \times \cos 53.0° \times 17.5 = 1042 \text{ m} \)

and the whole range is \( d_1 + d_2 = 84.3 + 1042 = 1126 \text{ m} \)
4. (20 points) A truck on a straight road starts from rest and accelerates at $1.0 \text{ m/s}^2$ until it reaches a speed of $20 \text{ m/s}$. Then the truck travels for 10 s at constant speed until the brakes are applied, stopping the truck in a uniform manner in an additional 7.0 s. What is the average velocity of the truck during the motion described?

During acceleration:

$$t_1 = \frac{20}{1.0} = 20 \text{ s}$$

$$d_1 = \frac{v^2 - u^2}{2a} = \frac{20^2 - 0^2}{2 \times 1.0} = 200 \text{ m}$$

During motion of constant speed:

$$t_2 = 10 \text{ s}$$

$$d_2 = vt_2 = 20 \times 10 = 200 \text{ m}$$

During deceleration:

$$t_3 = 7.0 \text{ s}$$

$$d_3 = \frac{1}{2} (v+0) t_3 = \frac{1}{2} (20+0) \times 7.0 = 70 \text{ m}$$

The total displacement is

$$d = d_1 + d_2 + d_3 = 200 + 200 + 70 = 470 \text{ m}$$

The total time is

$$t = t_1 + t_2 + t_3 = 20 + 10 + 7.0 = 37 \text{ s}$$

Then, the average velocity is

$$\bar{v} = \frac{d}{t} = \frac{470}{37} = 12.7 \text{ m/s}$$
5. **(15 points)** (a) A B express train and a Q local train are both running towards Manhattan on two rail tracks side by side. The B train has a speed of 35 mi/h and the Q train 18 mi/h. The front end of the B train is 1.2 miles behind the rear end of the Q train. How long does it take for the front end of B train to catch up with the rear end of Q train? (b) Now a Coney Island bound Q train (also 18 mi/h) is passing this B train in the opposite direction. Assuming the length of Q train is 150 m, how long is the passing period? (that is, the time duration between the two moments when the B train operator meets the front end and the rear end of the passing Q train) 

(1 mile = 1609 m, 1 h = 3600 s)

\[ \begin{align*}
\text{(a)} & \\
\vec{V}_B &= 35 \text{ m/s} \\
\vec{V}_Q &= 18 \text{ m/s} \\
d &= 1.2 \text{ mi} = 1.9 \times 10^3 \text{ m} \\
\vert \vec{V}_{BE} \vert &= 35 \text{ m/s} = 16 \text{ m/s} \\
\vert \vec{V}_{QE} \vert &= 18 \text{ m/s} = 8.0 \text{ m/s} \\
t &= \frac{d}{\vert \vec{V}_{BE} - \vec{V}_{QE} \vert} = \frac{1.9 \times 10^3}{16 - 8.0} = 2.4 \times 10^2 = 4.0 \text{ min} \\
\end{align*} \]

\[ \begin{align*}
\text{(b)} & \\
\vec{L} &= 150 \text{ m} \\
\vec{V}_B &\rightarrow \\
\vec{V}_Q &\rightarrow \\
t &= \frac{L}{\vert \vec{V}_{QB} \vert} = \frac{L}{\vert \vec{V}_{QE} - \vec{V}_{BE} \vert} = \frac{150}{-8.0 - 16} = 6.3 \text{ s} \end{align*} \]