1. A truck, initially at rest at a traffic light, speeds up with a constant acceleration $a = 0.4 \text{ m/s}^2$. A police car passes the same traffic light 12 s after the truck departed. If the police car is traveling at a constant speed of 30 m/s:

(a) How long does the police car need to overtake the truck?  
(b) How far from the traffic light will the police car overtake the truck?  

\[
\begin{align*}
\text{TRUCK: } \quad & x_f - x_0 = v_{0T}t + \frac{1}{2}a_Tt^2 \quad \Rightarrow \quad \boxed{x_f = \frac{1}{2}a_Tt^2} \quad (1) \\
\text{CAR: } \quad & x_f - x_0 = v_c \cdot (t-12) \quad \Rightarrow \quad \boxed{x_f = v_c \cdot (t-12)} \quad (2)
\end{align*}
\]

\[(1) = (2) \quad \Rightarrow \quad \frac{1}{2}a_Tt^2 = v_c (t-12) \quad \Rightarrow \quad \frac{1}{2}a_Tt^2 - v_c t + 12v_c = 0 \]

\[\Rightarrow \boxed{t = 13.15 \text{ s}}\]

\[t_{\text{police}} = 13.15 \text{ s} - 12 \text{ s} = \boxed{1.15 \text{ s}}\]

\[x_f = v_c (t-12) = (30 \text{ m/s}) \cdot (1.15 \text{ s}) = \boxed{34.5 \text{ m}}\]
2. (a) The movement of an object is described by the following equation:
\[ x(t) = -t^3 + 2t \] where \( t \) is in seconds and \( x \) in meters. Calculate:

(i) The average velocity from \( t = 1 \) s to \( t = 5 \) s. \( (5 \text{ points}) \)

\[
\frac{x(5) - x(1)}{5 - 1} = \frac{245m - 1m}{4s} = 61 \text{ m/s}
\]

\( x(5) = -5^3 + 250 = 245 \text{ m} \)

\( x(1) = -1+2 = 1 \text{ m} \)

(ii) The acceleration of the car at \( t = 2 \) s. \( (5 \text{ points}) \)

\[ v(t) = \frac{dx}{dt} = -1 + 6t^2 \quad \Rightarrow \quad a(t) = \frac{dv(t)}{dt} = 12t \]

\[ a(2) = 24 \text{ m/s}^2 \]

(b) A particle moves with constant speed around the circle below. When it is at point A its coordinates are \( x = -3 \text{ m}, y = 0 \text{ m} \) and its velocity is \( 6 \hat{j} \text{ m/s} \). Obtain its velocity and acceleration at point B. (Express your answer in terms of unit vectors). \( (10 \text{ points}) \)

\[ \vec{a}_B = \frac{v^2}{R} = \frac{36 \text{ m}^2/\text{s}^2}{3 \text{ m}} = 12 \text{ m/s}^2 \quad \text{centripetal} \]

\[ \vec{v}_A = 6 \hat{j} \text{ m/s} \]

\[ \vec{v}_B = 6 \hat{i} \text{ m/s} \]

\[ \vec{a}_B = -12 \hat{j} \text{ m/s}^2 \]

| (a)(i) | 6 \text{ m/s} | (a)(ii) | 34 \text{ m/s}^2 | (b)(i) | 6 \hat{i} \text{ m/s} | (b)(ii) | -12 \hat{j} \text{ m/s}^2 |
3. A hiker makes three consecutive displacements across a dense forest starting from his campsite. The first displacement is 5 km due North, the second one 3 km 30° South of East, and the third one 7 km 10° North of West. Find:

(a) How far from its original position will the hiker end?

(b) In which direction should he walk to go back to his campsite?

\[ \vec{d}_1 = 5 \hat{j} \text{ km} \]
\[ \vec{d}_2 = (3 \cos 30° \hat{i} - 3 \sin 30° \hat{j}) \text{ km} \]
\[ \vec{d}_2 = 2.60 \hat{j} - 1.5 \hat{i} \text{ km} \]
\[ \vec{d}_3 = (-7 \cos 10° \hat{i} + 7 \sin 10° \hat{j}) \text{ km} \]
\[ \vec{d}_3 = (-6.9 \hat{i} + 1.2 \hat{j}) \text{ km} \]

(a) \[ \vec{d}_T = \vec{d}_1 + \vec{d}_2 + \vec{d}_3 = (-4.3 \hat{i} + 4.7 \hat{j}) \text{ km} \]

\[ |\vec{d}_T| = \sqrt{4.3^2 + 4.7^2} = 6.37 \text{ km} \]

(b) \[ \tan \theta = \frac{\Delta y}{\Delta x} = \frac{4.7}{4.3} \Rightarrow \theta = 53.5° \]

Direction:

To go back to campsite \( \Rightarrow 53.5° \text{ South of East} \)

(a) 6.37 Km  (b) 53.5° South of East
4. A projectile fired into the air from ground level lands 40 m away from the launching position 5 s later. Neglecting air resistance, find:

(a) Direction of the initial velocity. (5 points)
(b) Magnitude of the initial velocity. (5 points)
(c) Maximum height reached by the projectile during its flight. (10 points)

\[ x_f - x_0 = 40 \text{ m} = V_0 \cos \theta \cdot t = V_{0x} \cdot t \Rightarrow V_{0x} = \frac{40 \text{ m}}{5 \text{ s}} = 8 \text{ m/s} \]

\[ y_f - y_0 = V_{0y} \cdot t - \frac{1}{2} g t^2 \Rightarrow 0 = V_{0y} \cdot (5 \text{ s}) - (4.9 \text{ m/s}^2) \cdot (25 \text{ s}^2) \Rightarrow V_{0y} = 24.5 \text{ m/s} \]

\[ |V_0| = \sqrt{V_{0x}^2 + V_{0y}^2} = \sqrt{(8 \text{ m/s})^2 + (24.5 \text{ m/s})^2} = 25.8 \text{ m/s} \]

\[ \tan \theta = \frac{V_{0y}}{V_{0x}} = \frac{24.5 \text{ m/s}}{8 \text{ m/s}} \Rightarrow \theta \approx 72^\circ \]

(c) \[ h_{\text{max}} = \frac{V_{0y} \cdot t_{\text{hmax}}}{2} \; \text{or} \; \frac{V_{0y}}{g} \Rightarrow t_{\text{hmax}} = \frac{V_{0y}}{g} = \frac{24.5 \text{ m/s}}{9.8 \text{ m/s}^2} = 2.5 \text{ s} \]

\[ h_{\text{max}} = V_{0y} \cdot t_{\text{hmax}} - \frac{1}{2} g t_{\text{hmax}}^2 = \left(24.5 \text{ m/s}\right) \left(2.5 \text{ s}\right) - \left(4.9 \text{ m/s}^2\right) \left(2.5 \text{ s}\right)^2 = h_{\text{max}} = 30.62 \text{ m} \]

(a) 72°, (b) 25.8 m/s, (c) 30.62 m
5. The two blocks in the diagram below are connected by a massless cord to a massless pulley. The masses of the blocks are: $M_1 = 2 \text{ kg}$, $M_2 = 5 \text{ kg}$. The coefficient of kinetic friction between $M_1$ and the incline plane is 0.1.

(a) Draw the force diagram. (4 points)
(b) Calculate the acceleration of the system. (8 points)
(c) Obtain the tension on the cord. (8 points)

\( M_2 \) \( \Rightarrow \)
\[
M_2 g - T = M_2 a
\]
\( M_1 \) \( \Rightarrow \)
\[
\begin{align*}
T - \mu_k N - M_1 g \sin 40^\circ &= M_1 a \\
N - M_1 g \cos 40^\circ &= 0 \\
\mu_k N &= \mu_k M_1 g \cos 40^\circ \\
\Rightarrow T - \mu_k M_1 g \cos 40^\circ - M_1 g \sin 40^\circ &= M_1 a
\end{align*}
\]
Adding (1) + (2)
\[
M_2 g - \mu_k M_1 g \cos 40^\circ - M_1 g \sin 40^\circ = (M_1 + M_2) a
\]
\[
\Rightarrow a = 4.98 \text{ m/s}^2
\]
\[
\begin{align*}
\text{(c)} \quad T &= M_2 (g - a) = 5 \text{ kg} \left( 9.8 \text{ m/s}^2 - 4.98 \text{ m/s}^2 \right) \\
&= 24 \text{ N}
\end{align*}
\]

(b) 4.98 m/s²  (c) T = 24 N