1. a) (9 points) As their booster rockets separate, Space Shuttle astronauts typically feel accelerations up to $3g$, where $g = 9.80 \text{ m/s}^2$. In their training, astronauts ride in a device where the astronaut is fastened securely at the end of a mechanical arm that then turns at constant speed in a horizontal circle. Determine the rotation rate, in revolutions per second, required to give an astronaut a centripetal acceleration of $3.00g$ while in circular motion with radius $9.45 \text{ m}$.

b) (8 points) The consumption of natural gas by a company satisfies the empirical equation $V = 1.49t + 0.00735t^2$, where $V$ is the volume in millions of cubic feet and $t$ the time in months. Express this equation in units of cubic feet and seconds. Assign proper units to the coefficients. Assume a month is equal to $30.0$ days. Round coefficients to three significant figures. Give your answer in scientific notation if necessary.

c) (8 points) The position of a particle moving under uniform acceleration is some function of time, $t$, and the acceleration, $a$. Suppose we write this position $s = ka^mt^n$, where $k$ is a dimensionless constant. Use dimensional analysis to find the values of $m$ and $n$. Can this analysis give the value of $k$?
2. a) A particle starts from rest and accelerates as shown in the Figure. Determine
   (i) (4 points) the particle's speed at \( t = 10.0 \) s and at \( t = 20.0 \) s,
   (ii) (8 points) the distance traveled in the first 20.0 s.

b) An object moves along the \( x \) axis according to the equation \( x(t) = (3.00t^2 - 2.00t + 3.00) \) m. Determine
   i) (3 points) the average speed between \( t = 2.00 \) s and \( t = 3.00 \) s.
   ii) (4 points) the instantaneous speed at \( t = 2.00 \) s and at \( t = 3.00 \) s.
   iii) (3 points) the average acceleration between \( t = 2.00 \) s and \( t = 3.00 \) s.
   iv) (3 points) the instantaneous acceleration at \( t = 2.00 \) s
3. a) Consider the displacement vectors $\vec{A} = (3\hat{i} - 3\hat{j})$ m, $\vec{B} = (\hat{i} - 4\hat{j})$ m, and $\vec{C} = (-2\hat{i} + 5\hat{j})$ m. Use the component method to determine

(i) (5 points) the magnitude of the vector $\vec{D} = \vec{A} + \vec{B} + \vec{C}$

(j) (9 points) the magnitude and direction of $\vec{D} = -\vec{A} - \vec{B} + \vec{C}$

b) (11 points) The pilot of an airplane notes that the compass indicates a heading due west. The airplane's speed relative to the air is 150 km/h. If there is a wind of 30.0 km/h toward the north, find the velocity of the airplane relative to the ground and the direction the plane is heading relative to the air.

For full credit be sure to sketch a properly labeled diagram showing the relationship between the velocity vectors $\vec{V}_{PG}$, $\vec{V}_{PA}$ and $\vec{V}_{AG}$ where P, G and A denote the Plane, Ground and Air respectively.
4. A basketball player who is 2.00 m tall is standing on the floor 10.0 m from the basket.

The basket height is 3.05 m.

a) (15 points) If he shoots the ball at a 40.0° angle with the horizontal, at what initial speed must he throw so that it goes through the hoop without striking the backboard?

b) (4 points) If the shot clock shows 6.00 s when the ball leaves his hands, what does it read when the ball passes through the hoop?

c) (6 points) At the peak height of the trajectory, how high is the basketball above the floor?