Use $|g| = 9.8 \text{ m/s}^2$ unless otherwise stated in problem.

Some useful conversion factors:

1 inch = 2.54 cm  
1 yd = 3 ft  
1 ft = 12 inch

Vectors: for $\theta$ measured from the +x axis:  

\[ A_x = |\vec{A}| \cos \theta; \quad A_y = |\vec{A}| \sin \theta; \quad |\vec{A}| = \sqrt{A_x^2 + A_y^2} \]

\[ \theta = \tan^{-1} \frac{A_x}{A_y}; \quad \vec{C} = \vec{A} + \vec{B} \Rightarrow C_x = A_x + B_x, \quad C_y = A_y + B_y \]

One-dimensional motion:  
\[ \Delta x = x - x_0 = v_o t + \frac{1}{2} a t^2; \quad v^2 = v_o^2 + 2a\Delta x; \quad v = v_o + at; \]

Projectile motion:  
\[ v_{ox} = v_o \cos \theta; \quad v_{oy} = v_o \sin \theta; \quad x = v_{ox} t; \quad v_x = v_{ox} \]
\[ \Delta y = y - y_0 = v_{oy} t - \frac{1}{2} g t^2; \quad v_y = v_{oy} - gt; \quad v_y^2 = v_{oy}^2 - 2g\Delta y \]

---

FORCE AND MOTION  

| $F_{net} = ma$ | $F_g = mg$ | $f_{s,\text{max}} = \mu_s N$ | $f_k = \mu_k N$ |
---|---|---|---|

Uniform circular motion:  
\[ \text{centripetal acceleration: } a = \frac{v^2}{r}; \quad \text{centripetal force: } F = \frac{mv^2}{r} \]
As a student at NJIT I (sign)_____________________________, will conduct myself in a professional manner and will comply with the provisions of the NJIT Academic Honor Code. I also understand that I must subscribe to the following pledge on major work submitted for credit as described in the NJIT Academic Honor code: On my honor, I pledge that I have not violated the provisions of the NJIT Academic Honor Code.

The exam is closed book and closed notes. You are required to show all of your work. NO WORK MEANS NO CREDIT even if you answer is correct. Your work must be legible. If the grader can not follow and understand your work, it is wrong.

1. **(2 Points)** If we know an object is moving at constant velocity, we may assume:
   a. the net force acting on the object is zero.
   b. there are no forces acting on the object.
   c. the object is accelerating.
   d. the object is losing mass.

2. **(2 Points)** If the only forces action on a 2.0 kg mass are $\vec{F}_1 = (3\hat{x} - 8\hat{y})$ N and $\vec{F}_1 = (5\hat{x} + 3\hat{y})$ N what is the magnitude of the acceleration?

3. **(2 Points)** A roller-coaster car has a mass of 500 kg when fully loaded with passengers. The car passes over a hill of radius 15 m. At the top of the hill, the car has a speed of 8.0 m/s. What is the magnitude of the force of the track on the car at the top of the hill?

4. **(2 Points)** An airplane travels 80 m/s as it makes a horizontal circular turn which has a 800m radius. What is the magnitude of the resultant force on the 75-kg pilot of this airplane?

5. **(3 Points)** In the figure below if $M = 2.0$ kg, what is the tension in string 1?
6. (7 Points) A force $F$ of 14 N is applied to two boxes shown in the figure below (on a frictionless surface). For this problem $m_1=3$ kg and $m_2=6$ kg.

![Diagram of two boxes with forces and masses](image)

a. Draw a free body for each mass.

b. What is the acceleration of the boxes?

c. What is the magnitude of the force of box 2 on box 1?

d. What is the NET force of box 1 on box 2?

e. Based on the result of (d), one can use this net force to calculate the acceleration of $m_2$ using $F_{net} = m_2a_2$. Using the net force on box 2 (your answer to part (d) ), calculate the acceleration $a_2$ of box 2 and compare it to the result of (b). EXPLICITLY STATE which acceleration is bigger or smaller. HINT: Do you EXPECT the accelerations to be different?
7. (7 points). A 10 kg mass is tied to a cable 0.24 meters in length and the mass rotates (in a horizontal plane) from a fixed support making an angle of $15^\circ$ relative to vertical as seen in the figure below.

![Diagram of a mass on a cable](image)

a. Draw a free body diagram for the mass.

b. Determine the tension in the cable.

c. Determine the velocity of the mass (in the horizontal circle).

d. How does the velocity change if the mass is 20 kg instead of 10 kg?
8. **(15 Points)** Three masses $m_1$, $m_2$, and $m_3$ are attached using strings and a pulley as shown in the figure below. The plane is inclined at an angle $\theta$. Consider the case where the masses $m_2$ and $m_3$ are accelerating while mass $m_1$ is held fixed by the lower cable. The friction coefficients are given in the figure.

![Diagram of masses and pulley on an inclined plane](image)

a. Draw the free-body diagrams for the three masses showing all forces acting on each mass.

b. Write down all components of Newton’s equation (ie. $\sum \vec{F} = m\vec{a}$) for mass $m_1$ based on the diagrams in (a). Keep in mind that $m_1$ is FIXED.

c. Write down all components of Newton’s equation (ie. $\sum \vec{F} = m\vec{a}$) for mass $m_2$ based on the diagrams in (a). Keep in mind that $m_2$ is accelerating.

d. Write down all components of Newton’s equation (ie. $\sum \vec{F} = m\vec{a}$) for mass $m_3$ based on the diagrams in (a). Keep in mind that $m_3$ is accelerating.
e. Using the equations from parts (b), (c), and (d), find the accelerations of \( m_2 \) and of \( m_3 \) in terms of the masses, the gravitational acceleration \( g \), angle of incline \( \theta \), and the coefficients of friction \( \mu_1 \) and \( \mu_2 \). Your answer should ONLY depend on these values.

f. As a short hand notation, going forward in the problem you can refer to this complicated formula for the acceleration as \( a_3 \). In terms of \( a_3 \), the masses, the gravitational acceleration \( g \) and angle of incline \( \theta \), and the coefficients of friction, find the tension in the string which is connected to mass \( m_3 \).

g. What is the DIRECTION of the frictional force which acts on mass \( m_1 \)?

h. In terms of the masses, the gravitational acceleration \( g \), the angle of incline \( \theta \), and the coefficients of friction, find the MAGNITUDE of the friction force which acts on mass \( m_1 \).