You may use any type of handheld calculator, however you are not allowed to store information on the calculator in advance of the exam. You should refer to the sheet provided which lists all formulae/constants/conversions you will need for the problems in this exam. You will need your TAMU ID to submit your exam; please have it out and ready to show the proctor when you go to drop it off.

This exam consists of two parts:
1. Four (4) short answer questions worth a total of 20%; and
2. Four (4) free-response problems worth a total of 80%;

All free-response problems require that your work be shown in a legible and logical manner; you will not get credit for simply writing down the answer, whether it is correct or not. You may receive partial credit on multiple choice answers if only some of your choices are correct, however you do not have to show your work in this case and there is no partial credit for work shown.

If you need extra space, feel free to use the room on the last sheet, but make sure you indicate that you have done so.
Short Answers: Please circle the letter representing the correct answer(s). You do not need to cross out or otherwise try to indicate incorrect answers.

1. [5 pts] Which of the following statements are true (there may be more than one)?
   
   (a) If no forces are acting on an object, the object could still be moving.
   (b) If an object isn’t moving, there cannot be any external forces acting on it.
   (c) If a single force is acting on an object, the object must be accelerating.
   (d) If an object accelerates, at least one force is acting on it.
   (e) If an object isn’t accelerating, there cannot be any external forces acting on it.
   (f) If the net force acting on an object is in the positive $\hat{x}$ direction, the object must be moving in the positive $\hat{x}$ direction.

2. [5 pts] At a certain instance of time, the acceleration and velocity vectors of an object are as shown below. Which statement most correctly describes the motion of this object at that time?

   (a) it is slowing down and turning upwards
   (b) it is slowing down and turning downwards
   (c) it is speeding up and turning upwards
   (d) it is speeding up and turning downwards
   (e) it is maintaining its speed but turning upwards
   (f) it is maintaining its speed but turning downwards

3. [5 pts] The graph in the figure to the right shows the $x$ component of the acceleration of a 2.4-kg object as a function of time. At which of the following times does the $x$ component of the net force on the object have its maximum magnitude?

   (a) 2.5 s
   (b) 3.0 s
   (c) 4.5 s
   (d) 5.0 s
   (e) 6.0 s

4. [5 pts]: A car is going around a circular track and is slowing down to stop. At some point while slowing down, the car is at point $P$ on the track moving counter-clockwise in the direction indicated by the arrow. The view of the picture is from above, or the “bird’s eye view.” In which direction is the acceleration of the car at point $P$?

   (a) Towards 1
   (b) Towards 4
   (c) Towards 3
   (d) Between 1 and 4
   (e) Between 3 and 4
Prob 1 [20 pts]: Three horizontal ropes pull on a large stone stuck in the ground, producing the vector forces $\vec{A}$, $\vec{B}$ and $\vec{C}$ as shown from the top view below.

(a) Find the magnitude and direction of the net force on the stone due to the three forces $\vec{A}$, $\vec{B}$ and $\vec{C}$.

\[
\begin{align*}
|\vec{B}| &= 80.0 \text{ N} \\
|\vec{C}| &= 40.0 \text{ N} \\
|\vec{A}| &= 100 \text{ N}
\end{align*}
\]

Ans: 

(b) Find the magnitude and direction of a fourth force on the stone that will make the sum of the four forces zero.

Ans: 

Prob 2 [20 pts]: You are told that the velocity of a plane is given by \( \vec{v}(t) = [3.60 \text{ m/s} + (0.0420 \text{ m/s}^3) t^2] \hat{i} - [(9.27 \text{ m/s}^2) t] \hat{j} \), where \( \hat{i} \) is the horizontal direction pointing north and \( \hat{j} \) is vertically upwards. You note that at a particular time, say \( t = 0 \), it is 7.00 km above the ground and 450.0 m south of you.

(a) Determine the horizontal and vertical components of the plane’s acceleration as a function of time.

\[ \hat{i} \text{- component: } \]

\[ \hat{j} \text{- component: } \]

(b) Determine the horizontal and vertical components of the plane’s position vector relative to you as a function of time.

\[ \hat{i} \text{- component: } \]

\[ \hat{j} \text{- component: } \]

(c) How long before the plane reaches ground level?

\[ \text{Time: } \]

(d) Do you think it lands softly or crashes? Briefly justify your answer.
Prob 3 [20 pts]: I took my nephews skating one day. Mel, whose mass at the time was $m_M$, grabbed a rope I was holding onto and Dario (whose mass was $m_D$) in turn held onto a 2nd rope so that we made a little “train”. The rope I pulled with was horizontal, while the rope between my nephews was at an angle as shown in the figure below. Assume the ropes are weightless, there is no friction between any of our skates with the ice, and that no one is lifted off the surface of the ice.

(a) Draw the free-body diagram for each nephew.
(b) What is the acceleration of the train in terms of $F$, $m_D$ and $m_M$?

Ans: ____________________________

(c) What is the tension in the rope between Mel and Dario in this case, in terms of $F$, $m_D$, $m_M$, and $\phi$?

Ans: ____________________________
Prob 4 [20 pts]: You are on top of the Northside Garage holding a water balloon and see me riding a motorcycle in your direction at a constant speed $v_{prof}$ as shown. Upset that I wouldn’t give you an extension on the homework, you plan to throw the balloon and hit me with it on the head. Ironically, you use the same physics I taught you to make sure I get soaked. Say that the height of my head above the pavement is $h$ and that you throw the balloon upwards with an initial speed $v_{ball}$ from a height $H$ above the pavement.

(a) In terms of $v_{ball}$, $H$, $h$ and $g$, how long does it take for the balloon to reach the height of the top of my head?

Ans: __________________________

(b) Find $D$, the horizontal distance away I should be when you throw the balloon up so that you will hit your target. Express your answer in terms of $v_{ball}$, $v_{prof}$, $H$, $h$ and $g$.

Ans: __________________________
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<thead>
<tr>
<th>Multiple choice</th>
<th>Problems</th>
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<tbody>
<tr>
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More Extra Space:
Equations of motion:

- Constant acceleration only:
  \[
  \vec{r}(t) = \vec{r}_o + \vec{v}_o t + \frac{1}{2} \vec{a} t^2 \\
  \vec{v}(t) = \vec{v}_o + \vec{a} t \\
  v_x^2 = v_{x,0}^2 + 2a_x (x - x_0) \\
  \text{and similarly for } y \text{ and } z \\
  \vec{r}(t) = \vec{r}_o + \frac{1}{2} (\vec{v}_o + \vec{v}(t)) t \\
  \text{always true:} \\
  \begin{align*}
  \langle \vec{v} \rangle &= \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} \\
  \langle \vec{a} \rangle &= \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} \\
  \vec{r}(t) &= \vec{r}_o + \int_0^t \vec{v}(t') \, dt' \\
  \vec{v}(t) &= \vec{v}_o + \int_0^t \vec{a}(t') \, dt'
  \end{align*}
  \]

Circular motion:

- |\vec{a}_{rad}| = \frac{v^2}{R} \\
  T = \frac{2\pi R}{v}

Relative velocity:

- \vec{v}_{A/C} = \vec{v}_{A/B} + \vec{v}_{B/C} \\
  \vec{v}_{A/B} = -\vec{v}_{B/A}

Constants/Conversions:

- \( g = 9.80 \text{ m/s}^2 = 32.15 \text{ ft/s}^2 \) (on Earth’s surface)

\[
\begin{align*}
1 \text{ km} &= 0.6214 \text{ mi} \\
1 \text{ mi} &= 1.609 \text{ km} \\
1 \text{ ft} &= 0.3048 \text{ m} \\
1 \text{ m} &= 3.281 \text{ ft} \\
1 \text{ hr} &= 3600 \text{ s} \\
1 \text{ s} &= 0.0002778 \text{ hr} \\
1 \text{ kg} &= 1 \text{ N} = 0.2248 \text{ lb} \\
1 \text{ lb} &= 4.448 \text{ N}
\end{align*}
\]

\[
\begin{align*}
10^{-9} & \quad \text{nano-} & 10^3 & \quad \text{kilo-} \\
10^{-6} & \quad \text{micro-} & 10^6 & \quad \text{mega-} \\
10^{-3} & \quad \text{milli-} & 10^9 & \quad \text{giga-} \\
10^{-2} & \quad \text{centi-} & & \\
\end{align*}
\]

Forces:

\[
\sum \vec{F} = m\vec{a}, \quad \vec{F}_B \text{ on } A = -\vec{F}_A \text{ on } B
\]