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 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, no external forces are 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, no external forces are 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]: You set the cruise control of your truck to a certain speed and take a turn, during which time the speed of the truck is constant. Which of the following are true during the turn (there may be more than one)?
   (a) the total acceleration of the truck is outwards away from the center
   (b) the net force on the truck pushes out away from the center
   (c) the total acceleration of the truck is towards the center
   (d) the net force on the truck is towards the center
   (e) the total acceleration of the truck is towards the center and a little forward, depending on the speed of the truck
   (f) the net force on the truck is towards the center and a little forward, depending on the speed of the truck
   (g) the total acceleration of the truck is zero
   (h) the net force on the truck is zero
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 $\vec{C}$.

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

Ans: 

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

Ans: 

(c) How long before the plane “lands”?

Ans: 

(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 on to 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) Since both nephews are connected by the rope, they will have the same acceleration due to my pulling them; what is this acceleration, in terms of $F$, $m_D$ and $m_M$? (Hint: since there is no friction, you don’t care about the normal force of the ice on my nephews).

(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: ________________________________

Ans: ________________________________
Prob 4 [20 pts]: You are on top of North Side garage holding a water balloon and see me riding my motorcycle in your direction at a constant speed \( v_{\text{prof}} \) 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 \( v_{\text{ball}} \) from a height \( H \) above the pavement.

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

Ans: 

(b) In terms of \( v_{\text{ball}}, v_{\text{prof}}, H, h \) and \( g \), find the horizontal distance away I should be when you throw the balloon up so that you will hit your target.

Ans: 

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<th>Multiple choice</th>
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General math:

\[ \log (x/y) = \log (x) - \log (y) \]
\[ \log (xy) = \log (x) + \log (y) \]
\[ \log (x^n) = n \log (x) \]

\[ h_x = h \cos \theta = h \sin \phi \]
\[ h_o = h \sin \theta = h \cos \phi \]

\[ h^2 = h_x^2 + h_o^2 \quad \tan \theta = \frac{h_o}{h_x} \]

\[ \vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k} \]
\[ \vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z = AB \cos \theta = A || B = AB \parallel \]
\[ \vec{A} \times \vec{B} = (A_y B_z - A_z B_y) \hat{i} + (A_z B_x - A_x B_z) \hat{j} + (A_x B_y - A_y B_x) \hat{k} \]

\[ = AB \sin \theta = A \perp B = AB \perp \]

If \( f(t) = at^n \), then

\[
\int_{t_1}^{t_2} f(t) \, dt = \left( \frac{a}{n+1} \right) (t^{n+1}_2 - t^{n+1}_1) \quad \text{(for } n \neq -1) \\
\int f(t) \, dt = \frac{a}{n+1} t^{n+1} + C \quad \text{(for } n \neq -1) 
\]

Equations of motion:

\[
\vec{r}(t) = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2} \vec{a} t^2 \\
\vec{v}(t) = \vec{v}_0 + \vec{a} t \\
v_x^2 = v_{x,0}^2 + 2a_x(x - x_0) \\
\text{(and similarly for } y \text{ and } z) \\
\vec{r}(t) = \vec{r}_0 + \frac{1}{2} (\vec{v}_0 + \vec{v}(t)) t
\]

always true:

\[
\langle \vec{v} \rangle = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} \quad \vec{v} = \frac{d\vec{r}}{dt} \\
\langle \vec{a} \rangle = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} \quad \vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \\
\vec{r}(t) = \vec{r}_0 + \int_0^t \vec{v}(t') \, dt' \\
\vec{v}(t) = \vec{v}_0 + \int_0^t \vec{a}(t') \, dt'
\]

Circular motion:

\[
|\vec{a}_\text{rad}| = \frac{v^2}{R} \quad T = \frac{2\pi R}{v}
\]

Relative velocity:

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

Constants/Conversions:

\[
g = 9.80 \text{ m/s}^2 = 32.15 \text{ ft/s}^2 \text{ (on Earth's surface)}
\]

1 km = 0.6214 mi 
1 mi = 1.609 km

1 ft = 0.3048 m 
1 m = 3.281 ft

1 hr = 3600 s 
1 s = 0.0002778 hr

1 kg \( \text{m/s}^2 = 1 \text{ N = 0.2248 lb} \)
1 lb = 4.448 N

\[
10^{-9} \quad \text{nano-} \\
10^{-6} \quad \text{micro-} \\
10^{-3} \quad \text{milli-} \\
10^{-2} \quad \text{centi-}
\]

\[
10^3 \quad \text{kilo-} \\
10^6 \quad \text{mega-} \\
10^9 \quad \text{giga-}
\]

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