Collaboration is not allowed. Allowed on your desk are: up to ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating/graphing scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

1. (3 points) A real object dropped from a very high height is not always in free-fall due to air resistance. At the instant the object is released it accelerates with magnitude g, but this instantaneously decreases as the object gains speed. The faster the object falls the greater the resistive force from the air becomes. At a certain speed, called terminal velocity, the object is in equilibrium. Draw a free-body diagram (FBD) for the object, for three different times of its motion; right after it is released \((t_0)\), a time \((t)\) between \(t_0\) and terminal velocity, and once it's reached terminal velocity \((t_{term})\). Properly label each force in the FBDs.

2. (4 points) A 20.0-kg package is dropped from a high tower and is “tracked” by a radar system. At one point the radar tracking indicates that its acceleration is 7.0 m/s\(^2\) downward. Determine the force of air resistance on the package at this point.

\[
\sum F = m\bar{a} \Rightarrow m\bar{g} - F_r = m\bar{a} \
\]

\[
F_r = m(g - \bar{a}) \\
F_r = 56 \text{ N}
\]
For questions 3 through 7 circle all correct answers (a given problem may have more than one correct answer). Each correctly circled answer will receive 2 points and each incorrect circled answer will lose 1 point - no partial credit is available for these problems. The minimum score you will receive on any particular problem is zero. There are a total of 8 correct answers in this section.

3. A boy and a girl of equal mass are riding on a merry-go-round which is turning at a constant rate. The boy is near the outer rim and the girl is closer to the center of rotation. Which of the following statements are true?
   (a) Both the boy and the girl have the same non-zero tangential acceleration.
   (b) The boy has a larger radial acceleration than the girl.
   (c) The girl has a larger net force acting on her than the boy.
   (d) The girl has a smaller net force acting on her than the boy.
   (e) The boy has a larger angular speed than the girl.

4. A small plane climbs with a constant velocity of 250 m/s at an angle of 28° with respect to the horizontal. Which statement is true concerning the magnitude of the net force on the plane?
   (a) It is equal to the weight of the plane.
   (b) It is equal to the magnitude of the force of air resistance.
   (c) It is less than the weight of the plane but greater than zero.
   (d) It is equal to the component of the weight of the plane in the direction of motion.
   (e) It is zero.

5. A small block is on top of a large block which is on top of a table. There is no friction between the large block and the table but all other surfaces have friction. A finger is pushing lightly down and to the right on the top of the small block. Which of the following statements are necessarily false?
   (a) The top block is moving to the left.
   (b) The top and bottom block are moving in the opposite direction.
   (c) The direction of the friction from the top block on the bottom block is to the left.
   (d) The direction of the friction from the top block on the finger is to the left.
   (e) The table must have a force pointing to the left to keep it from accelerating.
   (f) The net force in the vertical direction on the table is zero.

6. A spaceship, at rest relative to the Earth, falls from a height 2r above the surface of the earth. Which of the following statements regarding the positions A, B, and C during the ship's fall are true. Assume air resistance is negligible.
   (a) The acceleration due to gravity at all three locations is equal.
   (b) The acceleration due to gravity increases as the ship falls.
   (c) The acceleration due to gravity decreases as the ship falls.
   (d) The force of gravity on the ship at point C is twice as large as at point B.
   (e) The force of gravity on the ship at point C is nine times larger than at point A.

7. The figure shows the velocity versus time curve for a car traveling along a straight line. Which of the following statements is false?
   (a) No net force acts on the car during interval B.
   (b) Net forces act on the car during intervals A and C.
   (c) The magnitude of the net force acting during interval A is less than that during C.
   (d) Equal and opposite forces may be acting on the car during interval B.
   (e) The car is traveling in the positive direction at point C.
8. (10 points) A certain crane can provide a maximum lifting force of 25,000 N. It hoists a 2000-kg load starting at ground level by applying the maximum force for a 2 second interval; then, it applies just sufficient force to keep the load moving upward at constant speed. How long does it take to raise the load from ground level to a height of 30 m²?

Two stages: stage 1 w/ \( \Sigma F \neq 0 \), stage 2 w/ \( \Sigma F = 0 \)

**Stage 1**

\[
\begin{align*}
\Sigma F &= F_{g0} - (\text{load}) \\
\Sigma F &= F_{\text{max}} - mg = ma_1 \\
a_1 &= \frac{2.7 \, \text{m/s}^2}{2} \\
V_{f1} &= 5.4 \, \text{m/s} \\
\Delta y_1 &= 5.4 \, \text{m} \\
\Delta t_1 &= 2 \, \text{s} \\
\end{align*}
\]

**Stage 2**

\[
\begin{align*}
\Sigma F &= 0 \\
V_{i2} &= \frac{V_{f1}}{2} = \frac{5.4}{2} \, \text{m/s} \\
a_2 &= 0 \\
\Delta y_2 &= \Delta y_1 = 24.6 \, \text{m} \\
\Delta t_2 &= 4.56 \, \text{s} \\
\end{align*}
\]

\[
\begin{align*}
\Delta t_{\text{tot}} &= \Delta t_1 + \Delta t_2 = 6.56 \, \text{s}
\end{align*}
\]
9. (10 points) Take the earth to be a perfect sphere of diameter 1.274 x 10^7 m. (a) At the north pole an object's apparent weight (normal force) is equal to its actual weight (gravitational force). Why? (b) If an object has an apparent weight of 100 N while on a scale at the north pole, will its apparent weight increase, decrease, or stay the same at the equator? Explain. (c) Will the objects mass at the equator be less than, greater than, or equal to the object's mass at the north pole? (d) What will the object's apparent weight be at the equator?

(a) 
\[ F_{BD\,(North)} \]
\[ \Sigma F_r = mg - F^N = m\frac{V^2}{r} \]
\[ \text{w/ } V = 0, \quad F^N = mg \quad m = \frac{F^N}{g} = 10.2 \text{ kg} \]

(b) As \( V \uparrow \), \( F^N \downarrow \) so it will decrease

(c) Same mass is independent of location

(d) 
\[ F_{BD\,(equator)} \]
\[ \Sigma F_r = mg - F^N = m\frac{v_o^2}{r} \]
\[ F^N = m(g - \frac{v_o^2}{r}) \]

Need to find \( V \)
\[ V = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{T} \quad \text{radius of Earth} = \frac{r}{2} \]
\[ T = 1 \text{ day} = 86,400 \text{s} \]

So \[ F^N = mg - \frac{4\pi^2 r^2}{T^2} \frac{1}{\text{kg}} = 99.7 \text{ N} \]
10. (10 points) Two identical, perfectly smooth 71.2-N bowling balls, 21.7 cm in diameter are hung together from the same hook in the ceiling by means of two thin, light wires, as show in the figure. Find (a) the tension in each wire and (b) the force the balls exert on each other.

\[ \theta = 25^\circ, \quad M = \frac{71.2 \text{ N}}{9.8 \text{ m/s}^2} = 7.26 \text{ kg} \]

\[ \Sigma F_x = F_T \sin \theta - F_{21}^n = ma_x^0 \]
\[ \Sigma F_y = F_T \cos \theta - mg = ma_y^0 \]

\[ a) \quad F_T = \frac{mg}{\cos \theta} = 78.6 \text{ N} \]
\[ b) \quad F_{21}^n = |F_T\sin \theta| = 33.2 \text{ N} \]
11. (15 points) A square block (1) sits atop a triangular wedge (2). Connected to the square block via a massless rope, through a massless, frictionless pulley, is a hexagonal block (3). The hexagonal and triangular block have a mass $m$, while the square block has a mass $3m$. A force $F_a$ is applied horizontally to the triangular wedge, causing the entire setup to accelerate to the left (see the figure below). While accelerating to the left the square block does not slide relative to the triangular wedge and the string connected to hexagonal block makes an angle $\theta$ with respect to the horizontal. The coefficient of kinetic friction ($\mu_k$) between the triangular wedge and the ground is 0.1. No friction is present between any other surfaces. (a) Draw a free-body diagram for the square, wedge, and hexagonal mass separately. Scale each force relative to each other. (b) Identify all Newton's third law force pairs. (c) When analyzing this system what coordinate system orientation would best be suited? Explain. (d) Create a set of Newton's 2nd law equations for each mass, being sure to identify any quantities that are zero. (you do not have to solve for anything) (e) Identify any constraints these objects may have with respect to each other.

\[
\begin{align*}
\mathbf{FBD(1)} & \quad \mathbf{FBD(2)} & \quad \mathbf{FBD(3)} \\
F_{21}'' & \quad \Sigma \mathbf{F} = 0 & \quad \Sigma \mathbf{F} = 0 \\
F_{21} & \quad \Sigma \mathbf{F} = 0 & \quad \Sigma \mathbf{F} = 0 \\
3mg & \quad \Sigma \mathbf{F} = 0 & \quad \Sigma \mathbf{F} = 0 \\
\end{align*}
\]

b) \[ \overrightarrow{F}_{21}'' = -\overrightarrow{F}_{12}'' \]
Tension aren't technically $F_P$'s but \[ |\overrightarrow{F}_{21}''| = |\overrightarrow{F}_{12}''| \]

c) $\mathbf{a} \leftarrow \mathbf{\hat{u}}$ Since all three objects accelerate to the left, lining up the coordinate system in that direction is ideal.

d) \[
\begin{align*}
\Sigma \mathbf{F}_x & = F_{21}' \sin \phi - F_{21}' \cos \phi - F_{12}'' \sin \phi - F_{12}'' \cos \phi = 3m \mathbf{a}_{1x} \\
\Sigma \mathbf{F}_y & = F_{21}' \cos \phi + F_{12}'' \sin \phi - 3mg = 3m \mathbf{a}_{1y} \\
\Sigma \mathbf{F}_z & = \mathbf{a}_{1z} \quad \Sigma \mathbf{F}_a = F_{12}'' \cos \phi - F_{12}'' \sin \phi = m \mathbf{a}_{1z} \\
\end{align*}
\]
e) \[ \overrightarrow{\mathbf{a}}_1 = \overrightarrow{\mathbf{a}}_2 = \overrightarrow{\mathbf{a}}_3 = \overrightarrow{\mathbf{a}}_1 \]
\[ F_p, F'_p, |F_{31}'| = |F_{12}''| \]