You must answer all three questions, and show all your work in order to receive full credit. Partial credit will be given. The test is closed book, but a formula sheet is provided on the last page. Start each question on a new page, and remember that your answers must indicate the units and directions of vectors where appropriate. You have 75 min to complete the test. Good Luck!

1. An airplane releases a food package while traveling at a constant horizontal speed of 100 m/s. The package is released from rest relative to the airplane, when the airplane is 1,500 m above the ground. Neglect air resistance.

(10 pts) A. At what time, \( t \), does the package hit the ground?

(10 pts) B. What is the distance between the package and the airplane at the time the package hits the ground?

(10 pts) C. What is the velocity (magnitude and direction) of the package when it hits the ground?

2. Consider a "train" consisting of three cars and an engine joined by ropes. The mass of each of the cars and the engine is 1000 kg (\( m_1 = m_2 = m_3 = m_4 = 1000 \) kg). The train is moving with a constant velocity of 10 m/s, as shown in the diagram. The coefficients of static and kinetic friction for the cars and the train on the ground are equal, \( \mu_k = \mu_s = 0.5 \).

(10 pts) A. What force must be supplied by the train engine to move at that velocity?

(10 pts) B. What is the tension in the rope joining \( m_1 \) and \( m_2 \), \( T_{12} \)?

(10 pts) C. How much work is done by the train engine as it travels 100 m?

(10 pts) D. How much power does the train engine supply to move the train?
3. Two skaters, each of mass 50 kg, are joined by a 1 m rope, and are rotating around each other. They have a speed such that they complete one revolution in 3 seconds. You may assume that the ice provides a frictionless surface.

(10 pts) A. What is the tangential speed of each skater?

(10 pts) B. What is the tension in the string?

(10 pts) C. How much work is done by the tension that acts on skater 1 in one revolution?
\[ R = \sum F = 0 \text{ (equilibrium)} \]
\[ \sum F_x = 0 \]
\[ \sum F_y = 0 \]
\[ \sum F_z = 0 \]

\[ F_x \leq \mu_s N \quad F_k = \mu_k N \]

\[ \bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} \]
\[ v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \]

\[ \bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t} \]
\[ a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \]

\[ v = v_0 + at \quad x = x_0 + v_0 t + \frac{1}{2}at^2 \]
\[ v^2 = v_0^2 + 2a(x - x_0) \]
\[ F = ma \quad \sum F = ma_\perp \]
\[ \Sigma F_x = ma_x \quad \Sigma F_y = ma_y \quad \Sigma F_z = ma_z \]

\[ w = mg \]
\[ x = (v_0 \cos \theta_0) t \]
\[ v_x = v_0 \cos \theta_0 \]
\[ y = (v_0 \sin \theta_0) t \]
\[ v_y = v_0 \sin \theta_0 - gt \]

\[ a_\perp = v^2/R \quad F_\perp = ma_\perp \]
\[ v_{AE} = v_{AF} + v_{FE} \]
\[ W = F \cdot s = (F \cos \theta) s \]
\[ K = \frac{1}{2}mv^2 \quad W = K_2 - K_1 = \Delta K \]
\[ U(\text{gravitational}) = mgy \]
\[ U(\text{gravitational}) = -Gmm_E/r \]
\[ U(\text{elastic}) = \frac{1}{2}kx^2 \]
\[ W' = (\frac{1}{2}mv_x^2 + mgy_2) - (\frac{1}{2}mv_1^2 + mgy_1) = (K_2 + U_2) - (K_1 + U_1) = E_2 - E_1 = \Delta E \]
\[ W' = (\frac{1}{2}mv_x^2 + \frac{1}{2}kx_2^2) - (\frac{1}{2}mv_1^2 + \frac{1}{2}kx_1^2) = (K_2 + U_2) - (K_1 + U_1) = E_2 - E_1 = \Delta E \]
\[ P = \Delta W/\Delta t \quad P = \lim_{\Delta t \to 0} \Delta W/\Delta t \]

\[ g = 9.8(\text{m/s}^2) \]
\[ G = 6.67 \times 10^{-11}(\text{N} \cdot \text{m}^2/\text{kg}^2) \]
\[ m_E = 5.98 \times 10^{24}(\text{kg}) \]
\[ r_e = 6.38 \times 10^6(\text{m}) \]

1 N = 1 kg·m/s² 1 J = 1N·m 1 W = 1 J/s

\[ ax^2 + bx + c = 0 \Rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]