Problem 1 (30 points)

1. You heat a sample of air to twice its original temperature in a constant-volume container. The pressure of air is increased since the average translational kinetic energy of the molecules is increased. The work done by air during the process is
   A. equal to pressure difference (Δp) times volume (V), thus proportional to Δp.
   B. equal to pressure times volume, thus increased by ΔT using pV = nRT.
   C. unchanged.
   D. logarithmically increased.

2. You compress a sample of air slowly to half its original volume, keeping its temperature constant. The internal energy of the gas
   A. decreases to half its original value.
   B. remains unchanged.
   C. increases to twice its original value

3. Dr. Kamon gave an analogy of First law of Thermodynamics (\( Q = ΔU + W \)) in class. That is:
   A. First law of Banking
   B. First law of Newton’s mechanics
   C. First law of Heat flow
   D. First law of Paycheck
   E. First law of Saving and Loan
   F. First law of Energy Conservation (\( E = K + U \))

4. When ice melts at 0°C, its volume decreases. Compared to the amount of heat added, the change in internal energy is
   A. greater
   B. less
   C. the same.

5. The formula \( ΔU = nC_vΔT \) for the change in the internal energy of a fixed amount of an ideal gas is valid
   A. only for constant-volume processes.
   B. only for adiabatic processes.
   C. only for isobaric processes.
   D. for any process involving that fixed amount of the gas.

6. One-third of a mole of He gas is taken along the path a→b→c. Assume that the gas may be treated as ideal. How much heat (\( Q \)) is transferred into or out of the gas?
   - \( Q = (+3000) \) J [make sure to have a proper sign on the numerical value]
   - The heat is transferred “into” or “out of” of the gas [choose one].

![Diagram with pressure-volume graph]
Problem 2 (30 points)

A tennis ball on Mars, where the magnitude of the acceleration due to gravity is 3.71 m/s² and air resistance is negligible, is thrown directly upward and return to the same level 8.60 s later.

(a) (10 pts) How high above its original point did the ball go?
(b) (10 pts) How fast was it moving just after being hit?
(c) (10 pts) Sketch clear graphs of the ball’s vertical position, vertical velocity, and vertical acceleration as function of time while it is in the air.

\[
y = y_0 + V_{0y}t + \frac{1}{2}a_yt^2 \quad \Rightarrow \text{Consider } B \rightarrow C
\]

\[
0 = y_B + 0 + \frac{1}{2}(-3.71)(4.30)^2
\]
\[
y_B = 34.3 \quad \Rightarrow y_B = 34.3 \text{ m}
\]

\[
V_B = V_A + a_yt \quad \Rightarrow \text{Consider } A \rightarrow B
\]
\[
0 = V_A + (-3.71)(4.30) \quad \Rightarrow V_A = 15.958
\]
\[
= 16.0 \text{ m/s}
\]
Problem 3 (35 points)

A 125N box rests on the horizontal floor. You push on the box with 60.0 N at 30.0° below the horizontal. The coefficient of static friction between the box and the horizontal floor is 0.800.

(a) (10 pts) Make a free-body diagram of the box.
(b) (10 pts) What is the normal force on the box?
(c) (10 pts) What is the largest the friction force could be?
(d) (5 pts) You now replace your push with a pull at 30.0° above the horizontal, and gradually increase the pull until you observe the box just begins to move. Find the magnitude of pull on the box in the case.

(b) \[ \vec{F} = m \vec{a} \]

Rest = 3

\[ \begin{align*}
\begin{align*}
\mu \cos 30^\circ - f &= 0 \quad (1) \\
n - F \sin 30^\circ - W &= 0 \quad (2)
\end{align*}
\end{align*} \]

\[ n = (60.0) \sin 30^\circ + 125 = 155 \text{ N} \]

\[ f = (60.0) \cos 30^\circ = 51.96 \approx 52.0 \text{ N} \]

(c) \[ f_s^{\text{max}} = \mu_s n = (0.8)(155) = 124 \text{ N} \]

\[ \mu \cos 30^\circ - f_s^{\text{max}} = 0 \quad (3) \]

\[ n + F \sin 30^\circ - W = 0 \quad (4) \]

\[ n = W - F \sin 30^\circ \]

\[ F(\cos 30^\circ + \mu_s \sin 30^\circ) = \mu_s W \]

\[ F = 79.0 \text{ N} \]
Problem 4 (35 points)

A uniform solid ball of mass \( m = 0.500 \) kg and radius \( R = 0.0200 \) m is rolling down without slipping on an inclined plane. It has a linear velocity \( v_0 = 0.800 \) m/s when it is at a height \( h = 0.400 \) m.

(a) (10 pts) Calculate the velocity of the ball when it reaches the floor.
(b) (10 pts) Knowing that the plane is inclined by an angle \( \theta = 30.0^\circ \), find the linear acceleration of the ball on the inclined plane.
(c) (5 pts) How the answers to (a) and (b) change if the radius \( R \) of the ball is two times larger.
(d) (10 pts) When the ball reaches the floor it makes a completely inelastic collision with a block of mass \( M = 2.00 \) kg, what is the velocity after the collision?

**Energy Conservation**

\[
\frac{1}{2} m v_0^2 + \frac{1}{2} I \omega_0^2 + mgh = \frac{1}{2} m v_B^2 + \frac{1}{2} I \omega_B^2
\]

\[
I = \frac{2}{5} mR^2 \quad \omega_0 = \frac{v_0}{R}
\]

\[
\frac{7}{10} m v_0^2 + mgh = \frac{7}{10} m v_B^2 \quad \text{(1)}
\]

\( \therefore v_B = 2.50 \text{ m/s} \)

**Force Balance**

\[
F_x = m a_x \Rightarrow m g \sin \theta - f = m a_x
\]

\[
f = I \alpha \Rightarrow f R = \frac{2}{5} m R^2 \frac{a_x}{R}
\]

\( \therefore m g \sin \theta = \frac{2}{5} m a_x = m a_x \)

\( \therefore a_x = \frac{5}{7} g \sin 30^\circ = 3.50 \text{ m/s}^2 \)

\( \therefore \text{ No change} \)

**Momentum Conservation**

\[
m v_B = (m + M) v_C
\]

\( \therefore v_C = \frac{m}{m + M} v_B = 0.500 \text{ m/s} \)
Problem 5 (35 points)

A large wooden turntable in the shape of a flat disk has a radius of 5.00 m and a total mass of 320 kg. The turntable is initially rotating at 3.00 rad/s about a vertical axis through its center. Suddenly, a 80.0 kg parachutist makes a soft landing on the turntable at a point on its outer edge. Find the angular speed of the turntable after the parachutist lands. Assume that the parachutist is a particle.

\[
\frac{1}{2} (320)(5.00)^2 + (80.0)(5.00)^2 = 12,000 = 6,000 \omega_f
\]

\[
\omega_f = \frac{2.00 \text{ rad/s}}{5}
\]

\[
\text{Angular momentum conservation}
\]

\[
\frac{1}{2} (620)(5.00)^2 = 4000 \text{ Kg.m}^2
\]

Correct Setting: 2.0

\[
\frac{1}{2} (320)(5.00)^2 + (80.0)(5.00)^2
\]

\[
= 12,000 = 6,000 \omega_f
\]

\[
\omega_f = \frac{2.00 \text{ rad/s}}{5}
\]
Problem 6 (35 points)

The graph shown below closely approximates the displacement $x$ of a tuning fork as a function of time $t$ as it is playing a single note. What are (a) the amplitude, (b) period, (c) frequency, and (d) angular frequency of this fork’s motion?

$A = 0.4 \text{ mm}$

$T = 2 \text{ ms}$

$f = \frac{1}{T} = 500 \text{ Hz}$

$\omega = \frac{2\pi}{T} = 3.14 \times 10^3 \text{ rad/s}$