2022 MIDTERM 2 EXAM

1. Two forces, of magnitudes $F1 = 60.0$ N and $F2 = 35.0$ N, act in opposite directions on a block, which sits atop a frictionless surface, as shown in the figure. Initially, the center of the block is at position $xi = −2.15$ cm. At some later time, the block has moved to the right, and its center is at a new position, $xf = 4.25$ cm. Determine the change in the kinetic energy of the block as it moves from $xi = −2.15$ cm to $xf = 4.25$ cm.

2. A crate on a motorized cart starts from rest and moves with a constant eastward acceleration a = 2.80 m/s^2 A worker assists the cart by pushing on the crate with a force that is eastward and has magnitude that depends on time according to F(t) = (5.40 N/s)t. What is the instantaneous power supplied by the force at t = 6.00 s?

3. Suppose that the coefficient of kinetic friction between Zak's feet and the floor, while wearing socks, is 0.250. Knowing this, Zak decides to get a running start and then slide across the floor. If Zak's speed is 3.50 m/s when he starts to slide, what distance will he slide before stopping?

4. A force parallel to x-axis acts on a particle moving along the x-axis. This force produces potential energy U(x) given by U(x) = αx4, where α = 0.630 J/m4. What is the force when the particle is at x = −0.750 m?

5. While a roofer is working on the roof that slants 36.0° above the horizontal, he accidentally nudges his 85.0 N toolbox, causing it to start sliding downward from rest. If it starts 4.05 m from the lower edge of the roof, how fast will the toolbox be moving just as it reaches the edge of the roof if the kinetic friction force on it is 22.0 N?

6. On a frictionless horizontal air table, puck A (with mass 249 g) is moving toward puck B (with mass 371 g), which is initially at rest. After the collision, puck A has velocity 0.120 m/s to the left, and puck B has velocity 0.650 m/s to the right. Calculate the change in the total kinetic energy of the system that occurs during the collision.

7. Starting at t = 0, a horizontal net external force F=....is applied to a box that has an initial momentum p=…. What is the momentum of the box at t = 2.00 s?

8. A uniform cube with mass 0.500 kg and volume 0.027 m^3 is sitting on the floor. A uniform sphere with radius 0.300 m and mass 0.800 kg sits on top of the cube. How far is the center of mass of the two-object system above the floor?

9. A rocket is fired in deep space, where gravity is negligible. In the first second it ejects 1 150 of its mass as exhaust gas and has an acceleration of 14.9 m/s^2. What is the speed of the exhaust gas relative to the rocket?

10. A machine part is initially rotating at 0.500 rad/s. Its rotation speeds up with constant angular acceleration 2.50 rad/s^2. Through what angle has the machine part rotated when its angular speed equals 3.55 rad/s?

11. Consider a cube of mass m with edges of length a. The moment of inertia IIcccc of the cube about an axis through its center of mass and perpendicular to one of its faces is given by I=.... Find the moment of inertia about an axis p through one of the edges of the cube.

12. The rotor (flywheel) of a toy gyroscope has mass 0.140 kg. Its moment of inertia about its axis is 1.05 × 10-4 kg · m^2. The mass of the frame is 25.0 g. The gyroscope is supported on a single pivot with its center of mass a horizontal distance 4.00 cm from the pivot. The gyroscope is precessing in a horizontal plane at the rate of one revolution in 2.20 s. What is the angular speed at which the rotor is spinning about its axis?

13. A diver comes off a board with arms straight up and legs straight down, giving her a moment of inertia about her rotation axis of 18 kg · m^2. She then tucks into a small ball, decreasing this moment of inertia to 3.6 kg · m^2. While tucked, she makes two complete revolutions in 1.0 s. If she had not tucked at all, how many revolutions would she have made in the 1.8 s from board to water?

14. Two balls of the same radius and same mass roll down an incline plane, starting from rest. One ball is hollow, and the other is solid. What is the ratio thollow/tsolid of the time intervals the two balls require to reach the bottom?

1. Chapter 6

$F_1 = 60N$ $F_2 = 35N$

$X_i = -2.15cm$ $X_f = 4.25cm$ $X_{total} = 6.4cm$

Change in kinetic energy = W_{Total}

$W = F \times d$

$W_1 = 60 \cdot 0.064 = 3.84J$

$W_2 = -35 \cdot 0.064 = 2.24J$

Individual Work

$W_{Total} = F_{total} \cdot d$

$W_{Total} = (F_1 - F_2) \cdot 0.064$

$W_{Total} = (60 - 35) \cdot 0.064$

$W_{Total} = 1.6J$ $\boxed{B)}$

2. Chapter 6

$a = 2.80 m/s^2$ $F(t) = (5.40 N/s)t$

$P @ t=6 = ?$

Instantaneous Power → $P = V \cdot \vec{F}$

Average Power → $P = \frac{\Delta W}{\Delta t} = \frac{dW}{dt}$

$V(t) = \int a(t) = \int 2.80 = 2.80(t)$

$P = 2.80(t) \cdot 5.40(t)$

$P = 15.12(t)^2$

$P(6) = 15.12(6)^2$

$P = 544.32 \ W$ $\boxed{E)}$

$P = 544 \ W$

3. Chapter 6/7

$\mu_K = 0.250$ $V = 3.50 m/s$

$d = ?$

$K_E = \frac{1}{2}mv^2$

$\vec{F_K} = K_E$

$\mu_K \vec{F_N} = \frac{1}{2}mv^2$

$\mu_K \cdot mg \cdot d = \frac{1}{2}mv^2$

$d = \frac{mv^2}{2 \cdot \mu_K \cdot m \cdot g}$

$d = \frac{v^2}{2\mu_K g}$

$d = \frac{3.50^2}{2(0.250)(9.81)}$

$d = 2.49745158$

$d = 2.50m$ $\boxed{A)}$

OR

Frictional Acceleration:

$a = \mu_K g$

$a = 0.250(9.81)$

$a = 2.4525 \ m/s^2$

$V_f^2 = V_i^2 + 2ad$

$d = \frac{V_f^2}{2a}$

$d = \frac{(3.50)^2}{2(2.4525)}$

$d =$

4. Chapter 7

$U(x) = \alpha x^4$ $\alpha = 0.630 J/m^4$

$\vec{F} @ x = -0.750m?$

$\vec{F} = -\frac{dU}{dx}$

$\vec{F} = -4\alpha x^3$

$\vec{F}(-0.750) = -4(0.630)(-0.750)^3$

$\vec{F}(-0.750) = 1.063125 \ N$

$\vec{F} = (1.06N)\uparrow$ $\boxed{D)}$

5. Chapter 7

$\theta = 36^\circ$ $\quad m_{Toolbox} = 85N$

$d_{initial} = 4.05m$ $\quad F_K = 22.0N$

$V_f = ?$

Step 1: Potential Energy

$U_{toolbox} = mgd \cdot \sin\theta$ $\quad$ *Mass is in Newtons, so we don't multiply by gravity.

$U_{toolbox} = 85(4.05) \cdot \sin 36^\circ$

$U_{toolbox} = 202.3450731 J$

Step 2: Find the work done:

$W = \vec{F} \cdot d$

$W = \vec{F_k} \cdot d$

$W = 22 \cdot 4.05$

$W = 89.1 J$

Step 3: Kinetic Energy

$K_E = \frac{1}{2}\left(\frac{m}{g}\right)v^2$ $\quad$ * $\frac{m}{g}$ so we can convert Newtons to kg

$K_E = \frac{1}{2}\left(\frac{85}{9.81}\right)v^2$

Step 4: Apply Conservation of Energy

$U_{toolbox} = W + K_E$

$202.3450731J = 89.1J + \frac{1}{2}\left(\frac{85}{9.81}\right)v^2$

$v = \sqrt{\frac{2(202.3450731 - 89.1)9.81}{85}}$ $\quad$ * $V = \sqrt{\frac{2(U_{toolbox} - W)g}{m}}$

$V = 5.11269278$

$V = 5.11 \text{ m/s}$ $\boxed{C)}$

6. Chapter 8

$m_A = 249g$ (0.249kg) $\quad m_B = 371g$ (0.371kg)

$V_{fA} = 0.120 \text{m/s [left]}$ $\quad V_{iB} = 0$

$V_{fB} = 0.650 \text{m/s [right]}$

$\Delta E_K = ?$

Step 1: Conservation of momentum

$p = p'$

$m_1V_{1i} + m_2V_{2i} = m_1V_{1f} + m_2V_{2f}$

$0.249V_{1i} + 0.371(0) = 0.249(-0.120) + 0.371(0.650)$

$0.249V_{1i} = 0.21127$

$V_{1i} = 0.8484738956 \text{ m/s}$

Step 2: Conservation/Change in Kinetic Energy

$K_{Ei} = K_{Ef}$

$\frac{1}{2}mv_{1i}^2 + \frac{1}{2}mv_{2i}^2 = \frac{1}{2}mv_{1f}^2 + \frac{1}{2}mv_{2f}^2$

$\frac{1}{2}(0.249)(0.8484738956)^2 = \frac{1}{2}(0.249)(-0.120)^2 + \frac{1}{2}(0.371)(0.650)^2$

$0.08962853996 = 0.08016655$

$\Delta K_E = K_{Ef} - K_{Ei}$

$\Delta K_E = 0.08016655 - 0.08962853996$

$\Delta K_E = -9.46198996 \times 10^{-3} J$

$\Delta K_E = -9.46 \times 10^{-3} J$ $\boxed{E)}$

7. Chapter 8

$\vec{F} = 0.280t\hat{i} - 0.450t^2\hat{j}$

$P_i = -3\hat{i} + 4\hat{j}$

$p @ t = 2 = ?$

Impulse momentum theorem:

$\vec{J} = P_2 - P_1 = \Delta P$ $\quad$ * $\vec{J} = \int_{t_1}^{t_2} \vec{F}$

So, $\vec{J} = \int 0.280t\hat{i} - 0.450t^2\hat{j}$

$\vec{J} = 0.140t^2\hat{i} - 0.150t^3\hat{j}$

$\vec{J}(2) = 0.140(2)^2\hat{i} - 0.150(2)^3\hat{j}$

$\vec{J}(2) = 0.560\hat{i} - 1.20\hat{j}$

$\vec{J} = P_2 - P_1$

$P_2 = \vec{J} + P_1$

$P_2 = (0.560\hat{i} - 1.20\hat{j}) + (-3\hat{i} + 4\hat{j})$

$P_2 = (0.560\hat{i} - 3\hat{i}) + (4\hat{j} - 1.20\hat{j})$

$P_2 = \left(-2.44\frac{kg}{ms}\right)\hat{i} + \left(2.8\frac{kg}{ms}\right)\hat{j}$ $\boxed{B)}$

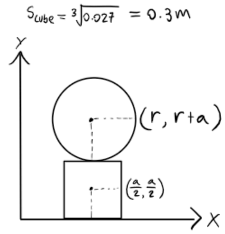
8. Chapter 8

$m_{cube} = 0.500kg$ $\quad V = 0.027m^3$

$m_{sphere} = 0.800kg$ $\quad r = 0.300m$

One side of the cube:

$S_{cube} = \sqrt[3]{0.027} = 0.3m$



Center of mass above the floor, so find y-component:

$Y_{cm} = \frac{m_1r_1 + m_2r_2}{m_1 + m_2}$

$Y_{cm} = \frac{0.500\left(\frac{a}{2}\right) + 0.800(r+a)}{0.500 + 0.800}$

$Y_{cm} = \frac{0.500\left(\frac{0.3}{2}\right) + 0.800(0.3+0.3)}{0.500 + 0.800}$

$Y_{cm} = 0.42692307 \text{ cm}$

$Y_{cm} = 0.427 \text{cm}$ $\boxed{A)}$

9. Chapter 8.

$t = \frac{1}{150}$ $a = 14.9 m/s^2$

Step 1: Equation for thrust force:

$$F_t = \frac{-\Delta(mV_{gas})}{\Delta t}$$

$$F_t = V_{gas} \cdot \frac{-\Delta m}{\Delta t} \qquad * -\frac{\Delta m}{\Delta t} = -\frac{m}{150} \nearrow$$

mass decreasing With time

Step 2: Equation taking into account decreasing weight:

$$F_{net} = F_t - W$$

Gravity is negligible, so,

$$F_{net} = F_t$$

Step 3: Calculate speed of gas relative to the rocket

$$F_{net} = m_r a_r$$

Next, substitute values

$$F_{net} = F_t$$

$$m_r a_r = V_{gas} \cdot \frac{-m}{\Delta t}$$

$$m_r a_r = V_{gas} \cdot -\left(\frac{-m_r}{150}\right)$$

$$a_r = V_{gas} \cdot \frac{1}{150}$$

$$V_{gas} = 150 a_r$$

$$V_{gas} = 150(14.9 m/s)$$

$$V_{gas} = 2235 m/s$$

$$V_{gas} = 2.235 km/s$$

$$V_{gas} = 2.24 km/s \quad \boxed{D)}$$

10. Chapter 9

$\omega_1 = 0.500 rad/s$

$\omega_2 = 3.55 rad/s$

$\alpha = 2.50 rad/s^2$

Using Angular kinematics:

$$\omega_2^2 - \omega_1^2 = 2\alpha(\theta_2 - \theta_1)$$

$$(\theta_2 - \theta_1) = \frac{\omega_2^2 - \omega_1^2}{2\alpha}$$

$$(\theta_2 - \theta_1) = \frac{(3.55)^2 - (0.500)^2}{2(2.50)}$$

$$(\theta_2 - \theta_1) = 2.4705$$

$$(\theta_2 - \theta_1) = 2.4705 \cdot \frac{180}{\pi}$$

$$(\theta_2 - \theta_1) = 141.5492233$$

$$(\theta_2 - \theta_1) = 142^\circ \quad \boxed{C)}$$

11. Chapter 9

Using the Parallel axis theorem:

$$I_p = I_{cm} + Md^2$$

$$I_p = \frac{1}{6}ma^2 + m \cdot 2a^2 \qquad * d = \frac{a}{\sqrt{2}}$$

$$I_p = \frac{1}{6}ma^2 + m\left(\frac{a}{\sqrt{2}}\right)^2$$

$$I_p = \frac{1}{6}ma^2 + \frac{1}{2}ma^2$$

$$I_p = \frac{4}{6}ma^2$$

$$I_p = \frac{2}{3}ma^2 \quad \boxed{E)}$$

13. Chapter 10

$\boxed{D)}$

12. Chapter 10

$I = 1.05 \times 10^{-4}\ kg \cdot m^2$

$m = 0.140 kg$ $M = 25g\ (0.025 kg)$

$r = 4cm\ (0.04m)$

$\omega_I = \frac{2\pi}{T} = \frac{2\pi}{2.20}$

$\omega_I = 2.855993321$

$\omega = \frac{(m+M)gr}{I\omega_I}$

$\omega = \frac{(0.140+0.025) \cdot 9.8 \cdot 0.04}{1.05 \times 10^{-4} \cdot 2.855993321}$

$\omega = 215.6867789$

$\omega = 215.6867789 \cdot \frac{60}{2\pi}$

$\omega = 2059.657021 \frac{rev}{min}$

$\omega = 2060 \frac{rev}{min}$ $\boxed{B)}$

13. Chapter 10

$I_i = 18 kg \cdot m^2$

$I_f = 3.6 kg \cdot m^2$ $T = 1.0 s$

$T_2 = 1.8 s$

Using the conservation of angular momentum:

$I_i \omega_i = I_f \omega_f$

$\omega_f = \frac{\Delta\theta_2}{T_1}$

$\omega_f = \frac{2 \cdot 2\pi}{1}$

$\omega_f = 12.56637061$

$\omega_i = \frac{I_f \omega_f}{I_i}$

$\omega_i = \frac{3.6 \cdot 12.56637061}{18}$

$\omega_i = 2.513274122$

So, $\omega_i = \frac{\Delta\theta_1}{T_2}$

$\Delta\theta_1 = \omega_i T_2$

$\Delta\theta_1 = 2.513274122 \cdot 1.8$

$\Delta\theta_1 = 4.52389342$

$\Delta\theta_1 = \frac{4.52389342}{2\pi}$

$\Delta\theta_1 = 0.7199999998$

$\Delta\theta_1 = 0.72$ $\boxed{D)}$

14. Chapter 9/10 ?

$I_{solid} = \frac{2}{5} mr^2$

$I_{hollow} = \frac{2}{3} mr^2$

$\boxed{A)}$ $\frac{\left(\frac{2}{3}\right)^2}{\left(\frac{2}{5}\right)^2} = \frac{25 \nearrow \checkmark}{9 \rightarrow ?}$