1. a) A cylinder with moment of inertia $I_1$ rotates about a vertical, frictionless axle with angular velocity $\omega_i$.

A second cylinder, this one having moment of inertia $I_2$ and initially not rotating, drops onto the first cylinder. Because of friction between the surfaces, the two eventually reach the same angular velocity $\omega_f$.

   i) (6 points) Calculate $\omega_f$.

   j) (8 points) The kinetic energy of the system decreases in this interaction. Calculate the ratio of the final to the initial rotational energy.

   k) (3 points) What happened to the “missing” energy?

b) A playground merry-go-round of radius $R = 2.00$ m has a moment of inertia $I = 250$ kg·m² and is rotating at 10.0 rev/min about a frictionless vertical axle. It started from rest and took 2 minutes to reach the above speed.

   i) (5 points) What was the average angular acceleration in radians per second?

   j) (4 points) What was the average torque applied to the merry-go-round?

   k) (4 points) How much work was done in bringing the merry-go-round up to speed?
2. A basketball player who is 2.00 m tall is standing on the floor 10.0 m from the basket. The basket height is 3.05 m.

a) (15 points) If he shoots the ball at a 40.0° angle with the horizontal, at what initial speed must he throw so that it goes through the hoop without striking the backboard?

b) (5 points) If the shot clock shows 6.00 s when the ball leaves his hands, what does it read when the ball passes through the hoop?

c) (5 points) At the peak height of the trajectory, how high is the basketball above the floor?
3.  
   i) (7 points) A falling meteoroid of mass m is at a distance above the Earth’s surface of 3.00 times the Earth’s radius, what is its acceleration due to the Earth’s gravitation? Your answer should be given in terms of G, ME, and RE.

   j) (7 points) What is the increase in kinetic energy of the meteoroid from the value at 3.00 times the Earth’s radius to the value when it hits the ground? Your answer should be given in terms of G, m, ME, and RE.

   k) (8 points) The free-fall acceleration on the surface of the Moon is about one-sixth that on the surface of the Earth. If the radius of the Moon is about 0.250 RE, find the ratio of their average densities, \( \rho_{\text{Moon}}/ \rho_{\text{Earth}} \).

   l) A tennis player receives a shot with the ball (0.060 kg) traveling horizontally at 50.0 m/s and returns the shot with the ball traveling horizontally at 40.0 m/s in the opposite direction.

      | (a) (4 points) | (b) (4 points) |
      |----------------|---------------|
      | What is the impulse delivered to the ball by the racquet? | What work does the racquet do on the ball? |
4. Two objects with weights \( m_1g = 422 \text{ N} \) and \( m_2g = 185 \text{ N} \) are connected by a massless string running over a frictionless pulley as shown. Mass \( m_1 \) slides on a horizontal plane with a coefficient of kinetic friction \( \mu_k = 0.2 \).

d) \((5 \text{ points})\) Sketch neat free body diagrams for both objects clearly labeling the forces. Denote the tension force by \( T \), the normal force by \( n \), the frictional force by \( f_k \) and the acceleration due to gravity by \( g \).

e) \((8 \text{ points})\) Write down the three equations obtained by applying Newton’s laws to this problem. Your equations should involve only \( T, g, n, m_1, m_2, \mu_k \) and \( a \), the acceleration of the system.

f) \((8 \text{ points})\) Solve the above equations to obtain an equation for \( a \) in terms of \( g, m_1, m_2, \) and \( \mu_k \).

\((4 \text{ points})\) Use your equation to obtain a numerical value for \( a \).
A roller coaster consists of a car sliding on a track, which is frictionless from a-b-c, but has a rough surface between c and d. The maximum height is 10 m and the car has a mass of 400 kg when fully loaded.

a) \(6\) points A motor is used to pull the car at a constant speed from a to b which takes a time of 20s. What is the average power output of the motor?

b) \(8\) points Assume that force due to the motor is always parallel to the track and that the total length of track from a to b is 14 m. Find the magnitude of the average force produced by the motor.

c) \(8\) points The car is now released from rest at b and slides down the frictionless section to point c. What is its speed at c?

d) \(8\) points If the speed of the car at d is 12 m/s, what is the coefficient of sliding friction between the car and the section of track from c to d?
6. An amusement park ride consists of a large vertical cylinder that spins about its axis fast enough that any person inside is held up against the wall when the floor drops away.

The coefficient of static friction between person and wall is \( \mu_s \), and the radius of the cylinder is \( R \).

a) (4 points) Draw a free body diagram for the person, clearly indicating each force and its direction.

b) (9 points) Write down the two equations obtained by applying Newton’s laws to the problem.

c) (7 points) Solve the equations to show that the maximum period of revolution necessary to keep the person from falling is \( T = \left( \frac{4\pi^2 R \mu_s}{g} \right)^{1/2} \).

d) (5 points) Obtain a numerical value for \( T \) if \( R = 4.00 \text{ m} \) and \( \mu_s = 0.400 \).