INSTRUCTIONS: Write your NAME and your LECTURE (01: 8:30/Eskildsen, 02: 10:40/Goussiou, 03: 3:00/Bunker) on the front of the blue exam booklet. The exam is closed book, and you may have only pens/pencils and a calculator (no stored equations or programs and no graphing). Show all of your work in the blue book. For problems II-V, an answer alone is worth very little credit, even if it is correct – so show how you get it. **Please enter the multiple-choice answers in the stamped form on the first inside page of the exam.**

Suggestions: Draw a diagram when possible, circle or box your final answers, and cross out parts which you do not want us to consider.

I. **Multiple Choice Questions**

1. A moving particle is stopped by a single head-on collision with a second, stationary particle, if the moving particle undergoes

   A) an elastic collision with a second particle of much smaller mass.
   B) an elastic collision with a second particle of much greater mass.
   C) an elastic collision with a second particle of equal mass.
   D) an inelastic collision with a second particle of any mass.
   E) any type of collision in which the coefficient of restitution is zero.

2. The torque exerted on a perfectly spherical orbiting communications satellite by the gravitational pull of the earth is

   A) directed toward the earth.
   B) directed parallel to the earth's axis and toward the north pole.
   C) directed parallel to the earth's axis and toward the south pole.
   D) directed toward the satellite.
   E) zero.

3. A student sits on a turntable which is free to rotate around the vertical axis without friction. She is handed a spinning bicycle wheel (rotating clockwise as seen from the student) as shown in the figure. As the student tips the axis of the rotating wheel upwards or downwards she will (as seen from above):

   A) Do nothing – she stays in her original position.
   B) Rotate clockwise in both cases.
   C) Rotate counterclockwise in both cases.
   D) Rotate clockwise when the wheel is tipped up and counterclockwise when it's tipped down.
   E) Rotate counterclockwise when the wheel is tipped up and clockwise when it's tipped down.

4. Which of the following are required for the total momentum (both angular and linear) of a system to be conserved?

   1. The sum of the external torques acting on the system must be zero.
   2. The sum of the external forces acting on the system must be zero.
   3. The total kinetic energy must remain constant.
   4. There can be no external torques or forces acting on the system.
   5. There can be no internal torques or forces acting on the system.

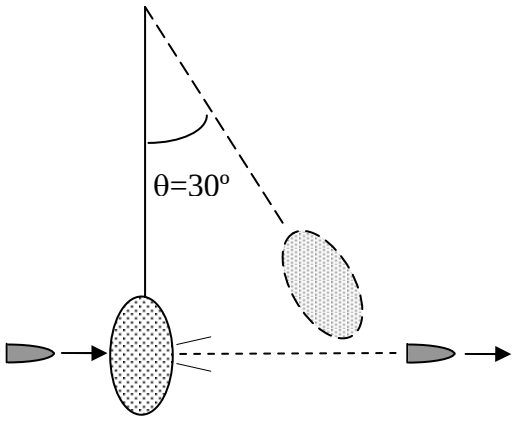
   A) 1 and 2
   B) 1, 2, and 3
   C) 1, 2, and 4
   D) 1, 2, 3, and 4
   E) 1, 2, 3, 4, and 5

5. Two solid balls (one large, the other small) and a solid cylinder roll down a hill. Which has the greatest speed at the bottom and which the least?

   A) The large ball has the greatest; the small ball has the least.
   B) The small ball has the greatest; the large ball has the least.
   C) The cylinder has the greatest; the small ball has the least.
   D) The cylinder has the greatest; both balls have the same lesser speed.
   E) Both balls have the same greater speed; the cylinder has the least.

Problems

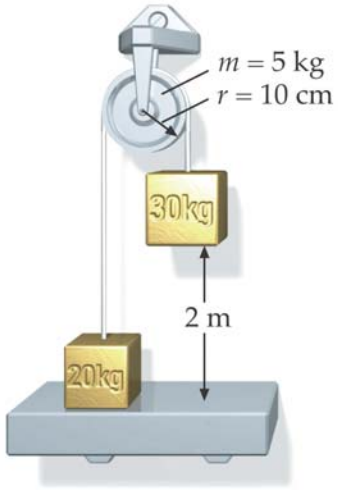
II. A small bag of sand is suspended by a thread of length L = 1.5 m. A bullet of mass m = 5.0 g moving with speed v_0 = 600 m/s in the horizontal direction hits the bag and leaves with a speed v = 250 m/s. The bag swings up to a maximum angle of $\theta = 30°$ from the vertical.



a) What is the velocity of the sandbag immediately after the bullet leaves the bag?

b) What is the mass of the sandbag?

III. The system shown in the figure is released from rest with the 30 kg block 2 m above the ledge. The pulley is a uniform disc with a mass of 5 kg and a radius of 10 cm. Assume that the string does not slip on the pulley.



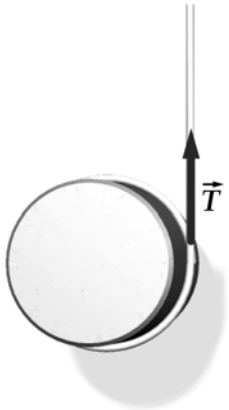
a) What is the speed of the 30 kg block when it reaches the ledge?

b) What is the angular speed of the pulley at that time?

c) What are the tensions of the string (left and right side)?

d) How long does it take for the 30 kg block to reach the ledge?

IV. A uniform cylinder of mass M = 300 g and radius R = 10 cm has a string wrapped around it. The string is held fixed and the cylinder falls vertically.



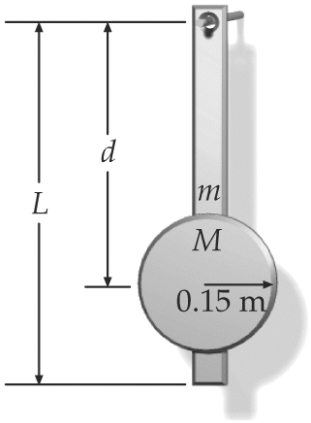
a) Draw a free-body diagram indicating all forces acting on the cylinder.

b) Write down Newton's 2nd Law for translation and rotation of the cylinder around its center of mass.

c) Find the angular and linear acceleration of the cylinder.

d) Find the tension in the string.

V. A grandfather clock has a pendulum which consists of a disk with radius r = 15 cm attached to a uniform rod of length L = 0.75 m. The center of mass of the disk is at a distance d = 0.65 m from the axis of rotation. The mass of the arm is m = 0.20 kg, while the mass of the disk is M = 1.5 kg. The axis of rotation is at the end of the rod.



a) What is moment of inertia of the rod/disk system?

b) Where is the center of mass of the rod/disk system relative to the pivot point?

c) If the pendulum is raised to an angle of 25º from the vertical and released from rest, what will be the angular speed of the pendulum when it is vertical (θ = 0º)?