Midterm Exam 04 (2020 Fall)

PHYS 203A-002: College Physics

Department of Physics, Southern Illinois University–Carbondale

Date: 2020 Nov 19

Instructions

- There are 10 questions in this exam.
- To be considered for partial credit present your work in detail and organize it clearly.
- This is a timed exam, from 12:35 PM to 01:50 PM. This time includes the time required for downloading the exam and uploading the solutions.
- Submit a single PDF file on D2L. Note that D2L will not allow submissions few minutes after 01:50 PM.
- In case of technical issues contact me by email at the earliest. Accommodations will be made after fairness to other students is taken into consideration.
- This is an open book and open resource examination, and use of Internet is allowed. However, consultation is prohibited.

1 Conceptual questions

1. (**5 points.**) Two identical rods of lengths L are free to rotate about their axes $\mathcal{O}$, see Figure 1. A force of magnitude F is directed at an angle $\theta_1 = 45°$ with respect to rod on the first, and a force of identical magnitude is directed at an angle $\theta_2 = 135°$ with respect to rod on the second. Which of the two rods rotates more freely, that is, which one moves with a larger angular acceleration. Explain.

Figure 1: Problem 1.

2. (**5 points.**) A solid sphere, (with $I = \frac{2}{5}MR^2$ when the axis of rotation passes through the center of sphere,) rolls perfectly (without sliding or slipping) on a horizontal surface. Determine the ratio of the translational kinetic energy of the sphere to that of the rotational kinetic energy of the sphere.

3. (**5 points.**) The Atwood machine in Figure 2 consists of two masses m_1 and m_2 connected by a massless (inextensible) string passing over a pulley of mass M in the shape of a uniform disc of radius R such that it has moment of inertia $I = MR^2/2$. Will the resultant acceleration of mass m_1 increase or decrease, if the pulley was replaced with another one of the same mass and radius but designed in the shape of a ring with massless spokes such that the moment of inertia is $I = MR^2$. Explain.

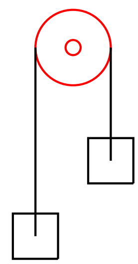

Figure 2: Atwood machine.

4. (**5 points.**) Two hoops, starting from rest, roll down identical inclined planes. Both the hoops have the same mass, but have different radii. Which hoop reaches the bottom of the incline first? Explain.

5. (**5 points.**) While sitting on a chair that is free to spin around a vertical axis you extend your arms outward. If you were initially spinning, what happens to your angular momentum about the vertical axis when you extend your arms. Explain.

6. (**5 points.**) A solid cylinder, (with $I = \frac{1}{2}MR^2$ when the axis of rotation is along the axis of cylinder,) rolls perfectly (without sliding or slipping) on an inclined plane. If the cylinder started from rest at the top, vertical height of 1.20 m, what is the work done by the force of friction when it reaches the bottom of the incline? Explain.

2 Problems

7. (**10 points.**) A motorcycle accelerates uniformly from rest and reaches an angular speed of 75.0 rad/s after traveling 27 m along a straight line. The radius of each tire is 0.300 m. What is the magnitude of the angular acceleration of each tire?

8. (**10 points.**) Two masses $m_1 = 1.0\,\text{kg}$ and $m_2 = 2.0\,\text{kg}$ are placed on a horizontal massless plank at distances $x_1 = 40.0\,\text{cm}$ and $x_2 = 29.0\,\text{cm}$ from the axis $\mathcal{O}$, as illustrated in Figure 3. Where should you place a third mass $m_3 = 3.0\,\text{kg}$ so that the plank is under rotational equilibrium.

9. (**10 points.**) Five balls of masses $m_1 = m$, $m_2 = 2m$, $m_3 = 3m$, $m_4 = 4m$, and $m_0 = 5m$, are connected by massless rods of length a and b, as shown in Figure 4. This configuration

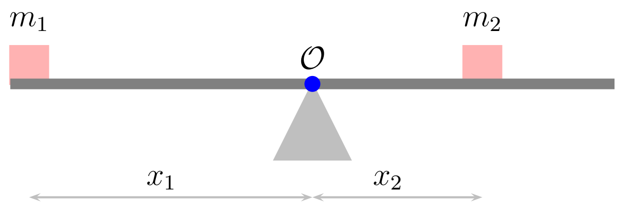

Figure 3: Problem 8.

is rotated about an axis coming out of the plane containing the five masses and passing through the mass m_1. The inertia associated with this rotational motion is quantified by the moment of inertia. Show that the moment of inertia for this configuration can be expressed in the form

$$I = \alpha\, ma^2 + \beta\, mb^2, \tag{1}$$

where α and β are numbers. Determine α and β.

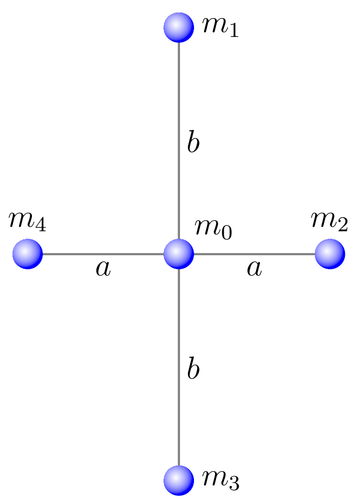

Figure 4: Problem 9.

10. (**10 points.**) An object in the shape of a solid sphere, (with $I = \frac{2}{5}MR^2$ when the axis of rotation passes through the center of sphere,) rolls perfectly (without sliding or slipping) on the surface shown in Figure 5. It starts from rest at point A where the vertical height is $h_A = 40.0\,\text{m}$. Determine the angular velocity of the object at point D, where the vertical height is $h_D = 10.0\,\text{m}$. Given the solid sphere has mass $M = 5.0\,\text{kg}$ and radius $R = 15\,\text{cm}$.

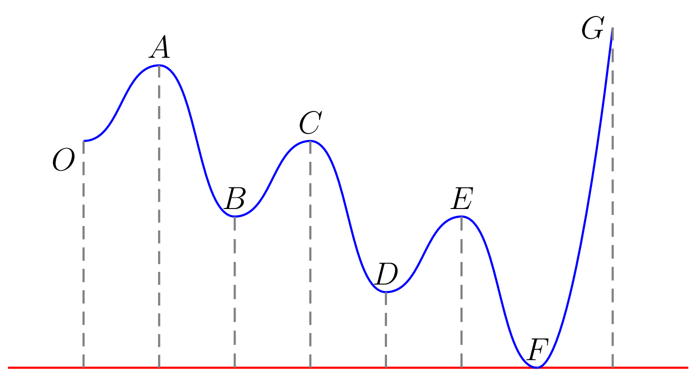

Figure 5: Problem 10.