Midterm Exam No. 03 (2022 Spring)

PHYS 205A-001: UNIVERSITY PHYSICS

Department of Physics, Southern Illinois University–Carbondale

Date: 2022 Apr 11

(Name) (Signature)

Instructions

- Seating direction: Please be seated on seats with seat numbers divisible by 2.
- Total time = 50 minutes.
- There are 7 questions in this exam.
- Equation sheet is provided separately.
- To be considered for partial credit present your work in detail and organize it clearly.
- A simple calculator (with trigonometric functions) is allowed.
- Use of mobile phones is strictly prohibited. It should stay out of reach during the exam.

1. (**5 points.**) What are conservative forces? Give two examples of forces that are conservative.

2. (**5 points.**) The potential energy of a particle moving along the x axis is described by $U(x)$. What physical quantity is associated to the negative derivative of the potential energy with respect to x,

$$-\frac{\partial U}{\partial x}. \tag{1}$$

3. (**5 points.**) The object in Figure 1 is constructed by cutting out a disc of diameter R out of a circular disc of diameter $2R$. Assume uniform density of material (shown in blue). When the object is in the position shown in the figure is it stable under small disturbances? Hint: The system tries to minimize the total energy. Analyze how the center of mass moves under small movements.

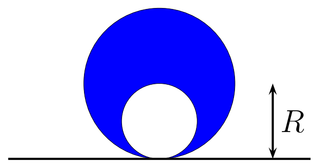

Figure 1: Problem 3.

4. (**10 points.**) A mass $m = 20.0\,\mathrm{kg}$ slides down a frictionless incline, starting from rest at point A at height $h = 1.0\,\mathrm{m}$. After sliding down the incline it moves horizontally on a frictionless surface before coming to rest by compressing a spring of spring constant $k = 2.0 \times 10^4\,\mathrm{N/m}$ by a length x. See Figure 2. Determine the energy stored in the spring when it is maximally compressed.

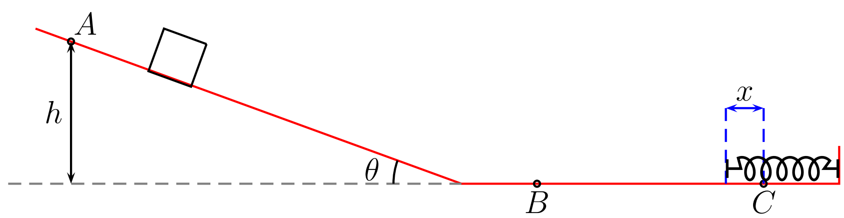

Figure 2: Problem 4.

5. (**10 points.**) The potential energy of a particle moving along the x axis is given by

$$U(x) = ax^2 + bx^4, \qquad a > 0, \quad b > 0. \tag{2}$$

Caution: Both a and b are positive here.

(a) Determine the points on the x axis where the potential energy is zero.

(b) Determine the points on the x axis where the force on the particle is zero.

(c) Evaluate

$$\frac{d^2U}{dx^2} \tag{3}$$

at each of the points where the force is zero. What can you conclude about the stability of the particle at the points where the force is zero? That is, is it a stable point or an unstable point?

6. (**10 points.**) A 100. kg mass moving with a speed 10. m/s (elastically) collides with another 1.0 kg mass that is initially at rest. Determine the magnitude and direction of the final velocities of the masses after collision.

7. (**10 points.**) Consider a thin rod of length L placed on the positive x-axis with one end at the origin. It has a mass density described by

$$\rho(x) = a + b\,x + c\,x^2, \qquad a = 1.0\,\frac{\text{kg}}{\text{m}}, \qquad b = 0, \qquad c = 0, \tag{4}$$

where x is the distance from the end placed at the origin. At what distance (in terms of L) from the end placed at the origin is the center of mass of the rod?