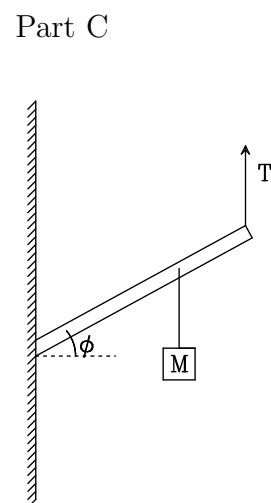
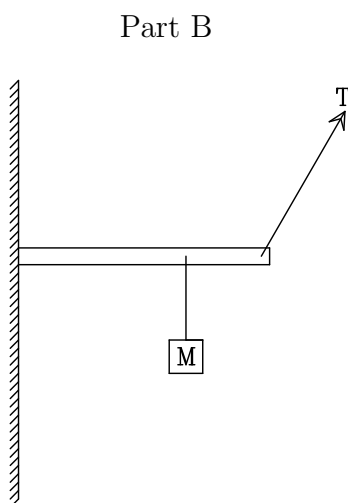
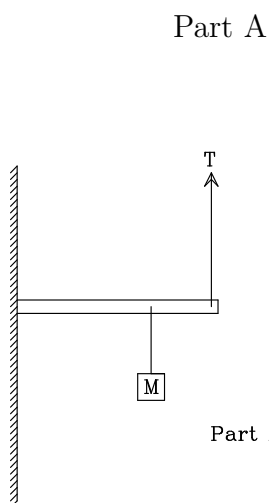


# PHYSICS 211 PRACTICE TEST 3

## QUESTION 1

A board with a mass  $m$  and a length  $L$  is connected to a wall by a hinge on its left side, and is horizontal to the ground. A bucket with a frog in it, with a total mass  $M$ , hangs from the board a distance  $2L/3$  from the left side. To stop the board from falling, a person applies a tension  $T$  to a rope connected to the right side. **These pictures are too small** for you to draw clear diagrams on; you will want to draw your own.



a) Find the tension in the rope if the rope is vertical. Give your answer in terms of  $m$ ,  $M$ ,  $L$ , and  $g$ . (Your answer may not depend on all quantities.) (10 points)

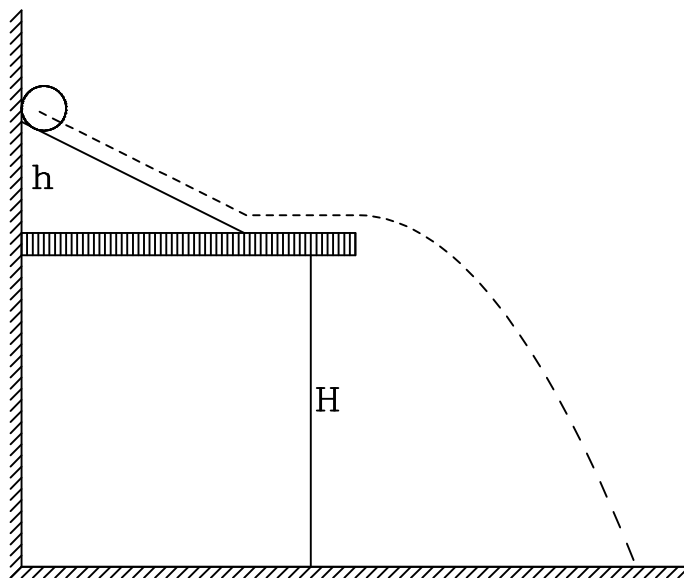
b) Find the tension in the rope if the rope makes an angle  $\theta$  with the vertical. Give your answer in terms of  $m$ ,  $M$ ,  $L$ ,  $g$ , and  $\theta$ . (10 points)

c) Instead, suppose that the board were then elevated, so that it made an angle of  $\phi$  with the horizontal. Calculate the tension  $T$  in the rope now. (10 points)

d) Explain in words how you could have predicted this result without doing any mathematics. (10 points)

## QUESTION 2

In class, you saw a demonstration where a ball bearing (solid sphere, moment of inertia  $I = \frac{2}{5}mr^2$ ) was rolled down a small ramp on top of a table. The ball rolled down the ramp, rolled across the table, and then fell off of the side of the table.



Suppose that the height of the ramp is  $h$ , the height of the table is  $H$ , and the radius of the ball is  $r$ .

a) *How fast is the ball traveling when it reaches the edge of the table? (15 points)*

*(This problem continues on the next page.)*

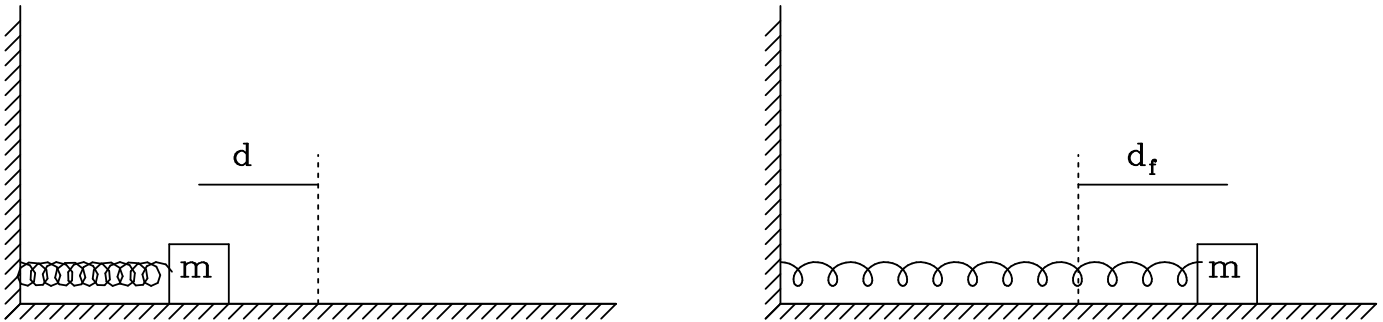
*b) How fast is the ball traveling when it strikes the floor? Think carefully about the kinds of energy that are present here, and how they relate; this problem is not quite as trivial as it seems. (15 points)*

*c) How far past the edge of the table does the ball land? (10 points)*

### QUESTION 3

A spring has spring constant  $k$ . One end is fixed, and the other end is attached to a mass  $m$ , which is free to move horizontally along a table. The mass slides over the table with a coefficient of friction  $\mu_k$ .

The spring is compressed a distance  $d$  from its equilibrium point and released. When the spring is released, it will push the mass to the right, until it reaches some other distance  $d_f$  past the equilibrium point.



a) How fast will the mass be traveling when it crosses the equilibrium point? Give your answer in terms of  $\mu_k$ ,  $d$ ,  $m$ , and  $g$ . (10 points)

b) Write down an expression for the work done by friction as the block slides from its starting point to the final position  $d_f$  to the right of equilibrium. (10 points)

c) Write down an equation in terms of  $\mu_k$ ,  $d$ ,  $m$ , and  $g$  that will let you solve for the distance  $d_f$ . You do not need to solve it. (15 points)

d) What algebraic technique would you have to use to solve this equation for  $d_f$ ? (5 points)

## QUESTION 4

A person tries to support a pipe of length 2 meters from one end horizontally. This pipe has a mass of 10 kg. He puts one of his hands on one end of the pipe, and the other one 50 cm from the end. In this problem, you will find the forces (magnitude and direction) he must exert with each hand to keep the pipe from falling.

*a) Draw a force diagram for the pipe. Label the pivot point that you will choose in computing torques. (10 points)*

*b) Find the forces (magnitude and direction) he must exert with each hand to keep the pipe from falling. (30 points)*

## QUESTION 5

A mad scientist has built a rocket-powered sled and is testing it on the frozen surface of Lake Onondaga. The coefficient of friction between the sled and the lake is  $\mu_k = 0.3$ . She and her rocket sled together have a mass of  $m = 200$  kg, and the sled's rocket provides a constant thrust force of  $F_T = 2$  kN. (Assume that the mass of the expelled propellant is small compared to  $m$ , so that  $m$  does not change.)

She fires the sled's motor and travels forward along the lake's surface. After traveling a distance  $d = 100$  m, she confirms that her rocket will suffice for her mad-scientific purposes <sup>1</sup>, and shuts down the engine; she coasts a further distance  $b$  before coming to a stop.

*a) Find the distance  $b$ . (20 points)*

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<sup>1</sup>World domination, obviously. What else would she be interested in?

b) Suppose now that the rocket exhaust is directed at an angle 45 degrees below the horizontal.<sup>2</sup> Write an expression for the work done by friction in this case. (10 points)

c) Find the distance  $b$  in this case. (10 points)

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<sup>2</sup>Her mad-science graduate student assistant messed up a conversion between radians and degrees and pointed it in the wrong direction.

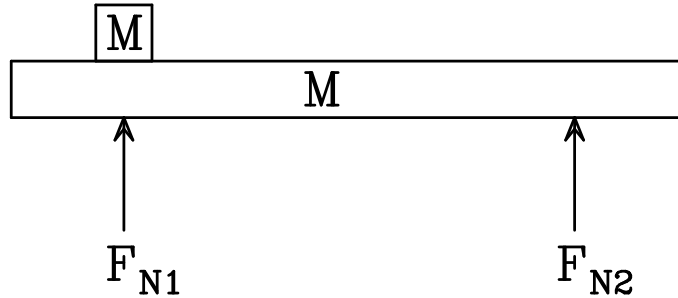


## QUESTION 6

A turntable of mass  $m$  is rotating at an angular velocity  $\omega$  around its center on a frictionless bearing. (The moment of inertia of a disk is  $\frac{1}{2}mr^2$ .) Someone drops a thin ring, also of mass  $m$ , on top of it. What is the new angular velocity  $\omega'$  of the turntable? (*40 points*)

## QUESTION 7

A simplified model of a car or truck can be thought of as shown below. Consider the body of the vehicle to be a uniform plate of mass  $M$ , supported by the normal force of two axles, each located a distance  $L/6$  from each end. The engine, also of mass  $M$ , is located a distance  $L/6$  from the front.



a) Draw a force diagram for the car. (10 points)

b) Calculate the normal forces  $F_{N1}$  and  $F_{N2}$  exerted by each axle. (20 points)

*c) If the coefficient of friction between the vehicle's wheels and the ground is  $\mu_s$ , what is the maximum acceleration of the vehicle if it is front wheel drive? (5 points)*

*d) ... what if it is rear wheel drive?*

## QUESTION 8

A person rolls a solid cylinder ( $I = \frac{1}{2}mr^2$ ) and a ball ( $I = \frac{2}{5}mr^2$ ), each of radius  $r = 10$  cm and mass  $m = 2$  kg, toward a ramp at  $v_0 = 3$  m/s. Both objects roll without slipping. The ramp makes a  $40^\circ$  angle with the horizontal.

*a) How far will each object travel up the ramp? (10 points)*

*b) What if the ball's radius is changed to 5 cm? (10 points)*

*c) What if the cylinder's mass is changed to 4 kg?*

*d) What if the angle of the ramp is changed to  $20^\circ$ ?*

## CONCEPTUAL QUESTIONS

Answer the following with “sometimes”, “always”, or “never”: (5 points each)

1. A larger force applies a greater torque than a smaller force, if they act at the same location.
2. A force that causes an object to accelerate in the negative direction does negative work.
3. A 20 N force applied 20 cm from the pivot will create the same torque as a 40 N force applied 10 cm from the pivot.
4. Whether a force does negative or positive work depends on the coordinate system and choice of origin.
5. An object with a larger mass has a higher moment of inertia than an object with lower mass.
6. A spring that is stretched by 4cm will exert twice as much restoring force than if it were stretched by only 2cm.
7. A spring that is stretched by 4cm will have twice as much potential energy than if it were stretched by only 2cm.
8. Conservation of energy can be used to calculate how much time a particular motion takes.

For each of the following quantities, tell whether it can be positive, negative, or zero. There may be multiple answers: for instance, if I said “the number of pencils in my pocket”, you would say “positive or zero”. (5 points each)

1. Kinetic energy
2. Gravitational potential energy
3. The work done by a normal force
4. The work done by static friction
5. The work done by the tension force in a pendulum
6. The torque exerted by the Earth’s gravity on the Moon, with the pivot point at the Earth
7. The work done by a baseball player on a baseball as he catches it
8. The work done by an archer’s hand on the string as she draws a bow