

Physics 110

Exam #2

May 22, 2026

Name _____

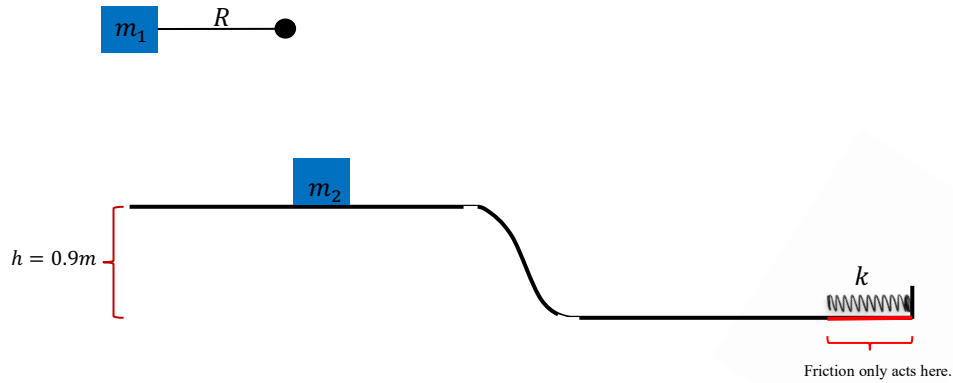
Please read and follow these instructions carefully:

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization clear.
- You must show all work, including correct vector notation.
- You will not receive full credit for correct answers without adequate explanations.
- You will not receive full credit if incorrect work or explanations are mixed in with correct work. Erase or cross out anything you don't want graded.
- Make explanations complete but brief. Do not write a lot of prose.
- Include diagrams.
- Show what goes into a calculation, not just the final number. For example,
 $|\vec{p}| \approx m|\vec{v}| = (5kg) \times (2 \frac{m}{s}) = 10 \frac{kg \cdot m}{s}$
- Give standard SI units with your results.
- Unless specifically asked to derive a result, you may start with the formulas given on the formula sheet including equations corresponding to the fundamental concepts.
- Formulas or constants not explicitly given on the formula sheet need to be derived before they can be used or full credit will not be given even if the formula or answer is correct.
- Go for partial credit. If you cannot do some portion of a problem, invent a symbol and/or value for the quantity you can't calculate (explain that you are doing this), and use it to do the rest of the problem.
- Each free-response part is worth 4 points.

Problem #1	/24
Problem #2	/24
Problem #3	/24
Total	/72

I affirm that I have carried out my academic endeavors with full academic honesty.

1. As mass $m_1 = 2kg$ is connected to a pendulum arm of length $R = 30cm$ and held horizontally at rest as shown below. The pendulum arm is released from rest and makes a head-on collision with a stationary mass $m_2 = 1kg$ when m_1 is at its lowest point.



- a. When m_1 is at its lowest point, and just before it collides with mass m_2 , what is its speed?
- b. When m_1 is at its lowest point, and just before it collides with mass m_2 , what is the magnitude of the tension force in the pendulum arm?

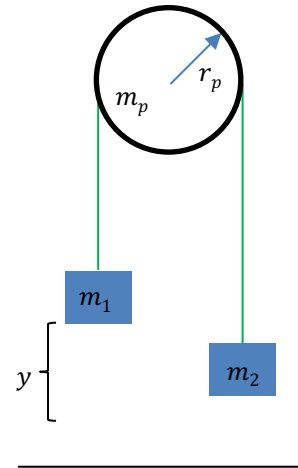
c. After mass m_1 undergoes the collision with mass m_2 , we find that m_2 is launched horizontally forward with a speed, call it v_{2C} , and m_1 continues forward rising up through an angle $\theta = 27^\circ$ measured with respect to the vertical before coming to rest. What was the speed of m_1 , call it v_{1C} , after the collision?

d. What was the speed of mass m_2 after the collision?

e. Was the collision between m_1 and m_2 elastic or inelastic? Explain. Hint: You will need to make a calculation in order to justify elastic or inelastic.

- f. The mass m_2 slides across the horizontal surface, down the curved part of the track, and across a second horizontal surface where it encounters a spring of stiffness $k = 20\frac{N}{m}$. If friction exists under the spring, with coefficient of friction $\mu = 0.4$, how far will the spring be compressed when the block comes to rest? Assume that the spring starts at its equilibrium position.

2. Consider the arrangement of masses shown on the right, called an Atwood's machine, in which two masses m_1 and m_2 are connected by a light rope around a pulley. In the parts below assume that there is no friction in the axle about which the pulley spins and that $m_1 > m_2$.



- a. If the system is released from rest, what is the expression for the speed of mass m_2 after mass m_1 has fallen through a distance y in terms of the quantities given in the problem? Assume the pulley has no mass and you must derive the expression using either forces/torques or energies to earn full credit.

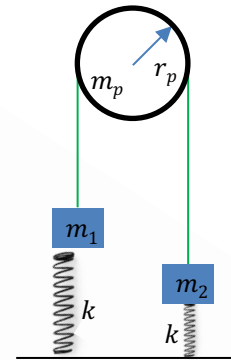
- b. If the system is released from rest, what is the expression for the speed of mass m_2 after mass m_1 has fallen through a distance y if the pulley has mass m_p and radius r_p in terms of the quantities given in the problem? Hint: the moment of inertia of a disk spun about an axis through its center is $I = \frac{1}{2}mr^2$ and you must derive the expression using either forces/torques or energies to earn full credit.

c. Either by using the results from parts a and b, or by deriving the two results asked for, what is the magnitude of the acceleration of the system of masses in the case where the pulley has no mass and the case when the pulley has mass? What can you say about the difference in the two accelerations and how does this affect the final speed of the system of masses? Be sure to fully explain your answer and simply quoting an expression without showing where it came from will earn limited credit.

d. How much work was done by the force of gravity on masses m_1 and on m_2 as each move through distance y , from rest? There should be two expressions here. One for the work done on m_1 and one for the work done on m_2 .

- e. What is the net work done on the system of masses m_1 and m_2 by the force of gravity and how does this work done show up in the system of masses? Hint: Consider separately the case where the pulley does not have mass and the case where the pulley has mass. Be sure to explain your answers for both cases.

- f. Consider the following situation where each of the masses are connected to identical springs of stiffness k . If both of the springs start at their equilibrium positions when the masses are released from rest, what is the maximum extension of the spring connected to mass m_2 ?



3. The rotator cuff is a group of four muscles and their associated tendons that are responsible for holding the humerus (the upper arm bone) in your shoulder socket. These muscles and tendons give stability to the shoulder joint and allow for the arm to be rotated. A cartoon image of two of the 4 main muscles/tendons are shown in Figure A below. The deltoid muscle is the major muscle responsible for you being able to hold your arm outstretched, at any angle above the horizontal. Consider the person shown below holding their arm (of mass $m_a = 3.5\text{kg}$ and total length L) at a 25° angle measured with respect to the horizontal while holding a $m = 4\text{kg}$ mass at rest. In this situation, the deltoid muscle F_M makes an angle 15° measured with respect to the outstretched arm and acts at a point $0.3L$ measured from the shoulder joint, as shown below in Figure B.

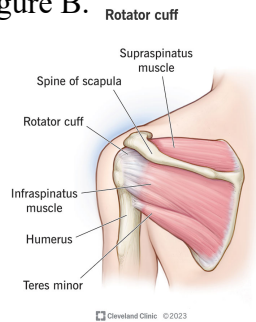


Figure A: Diagram of part of the rotator cuff, showing the deltoid muscle.

<https://my.clevelandclinic.org/health/body/rotator-cuff>

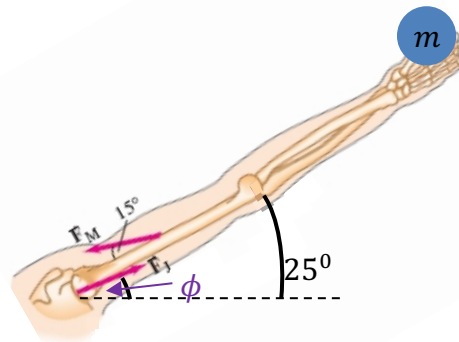


Figure B: Diagram of part of outstretched arm showing the location of the deltoid force application point and the shoulder joint reaction force. Figure adapted from Giancoli, Physics: Principles with Applications 7th ed.

- a. Using Figure B, and applying the condition for translational equilibrium in the x-direction, write the sum of the forces in the horizontal direction. From this, what is the expression for the reaction force, F_{Jx} , on the shoulder joint in the horizontal direction?

b. Using Figure B, and applying the condition for translational equilibrium in the y -direction, write the sum of the forces in the vertical direction. From this, what is the expression for the reaction force, F_{Jy} , on the shoulder joint in the vertical direction?

c. Assuming that the pivot is taken at the shoulder joint and applying the condition for rotational equilibrium, what is the magnitude of the force exerted by the deltoid muscle, F_M ?

d. What is the magnitude of the reaction force of the shoulder joint, F_J ?

e. In what direction, ϕ , (measured with respect to the horizontal) does the reaction force of the shoulder joint point?

f. What, if anything, would change if the deltoid muscle was attached at a point closer to the shoulder joint? That is, would the reaction force on the shoulder joint change? Would this change make supporting the weight in your hand easier or harder? Be sure to explain your thoughts.