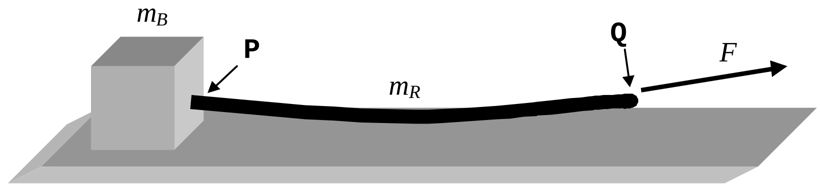
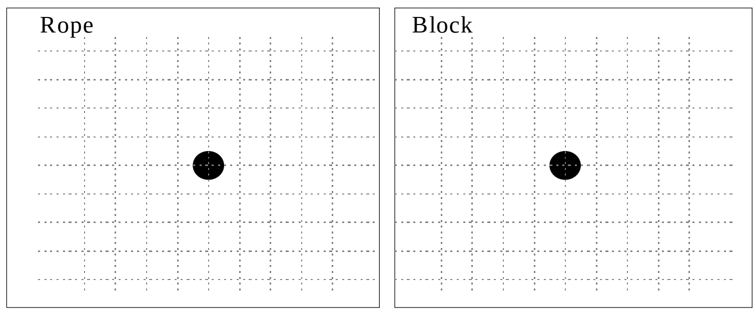
Mechanics Problem Solving I

1. A hand applies a force ***F*** to the end of a rope attached to a block. The rope has a mass m_R, and the block has a mass m_B. Assume that the friction between the block and the surface is negligible.



a) In the space at right sketch a free-body diagram for the rope and the block. Be sure the relative magnitudes of the forces are consistent with the physical situation. For each force in your free body diagrams indicate the object exerting the force and the object upon which the force is exerted.



b) Compare the horizontal components of tension at point **P** and point **Q**. Explain your reasoning.

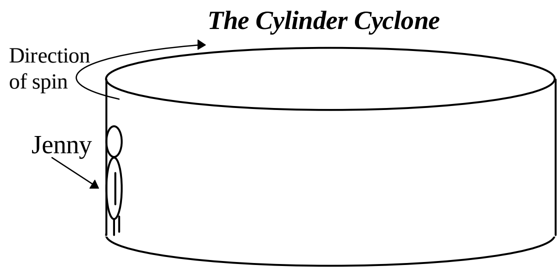
For the remainder of the problem assume the rope to be nearly parallel with the surface.

c) Calculate the tension in the rope at points **P** and **Q** if m_B=5kg, m_R=0.2kg, and the system accelerates at 2m/s^2. Assume that the rope is nearly parallel with the surface. Explain your reasoning and show all work.

d) If the rope is replaced with a massless string, calculate the tension at points **P** and **Q** and compare the two tensions. Explain your reasoning.

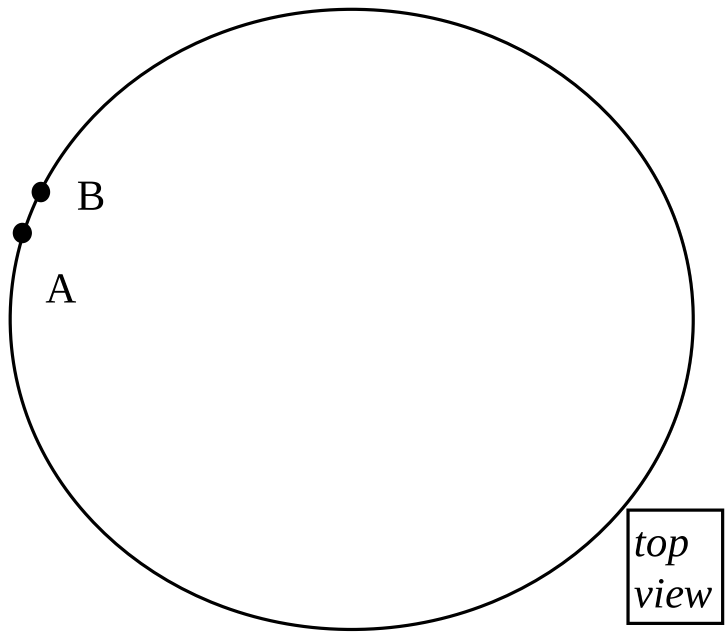
e) Compare the acceleration of the block using the rope with the acceleration using the massless string. Explain your reasoning.

2. At an amusement park, Jenny decides to take the Cylinder Cyclone ride, shown in the diagram at the right. In this ride, a cylinder spins at a constant speed and then suddenly the bottom drops out from underneath everyone's feet.



a) On the top view diagram provided at the right, draw Jenny's velocity at the indicated points.

Use your velocity vectors to find the direction of Jenny's average acceleration between points A and B. Explain.



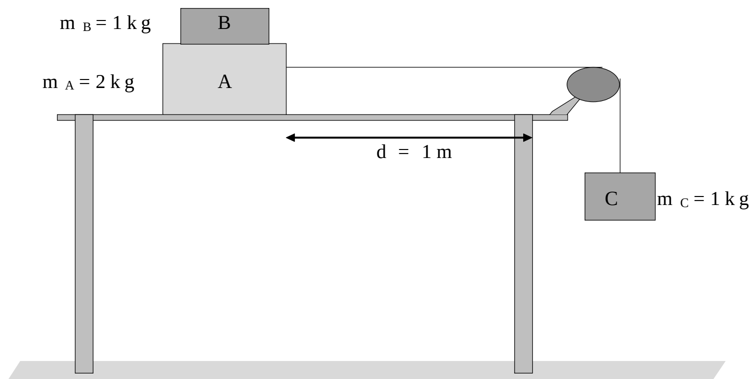
Use your velocity vectors to find how the acceleration would change if Jenny's speed were doubled. Use your velocity vectors to find how the acceleration would change if the radius of the cylinder were doubled but the speed were held constant.

Are your answers consistent with the equation $a = v^2/r$? Resolve any discrepancies.

b) Draw a free body diagram for Jenny when she is at the position indicated in the top diagram. Label all forces clearly. What is the work done by *each force* acting on her? Relate your answer to the change in Jenny's kinetic energy. Explain.

c) The knowledgeable ride attendant says that the coefficient of static friction between cotton and the edge of the cylinder is 0.9. If Jenny has a mass of 50 kg, is moving with a speed of 10 m/s, and knows the cylinder is 10 m in diameter, should she worry about slipping when the bottom drops out? Should her boyfriend, who has a mass of 80 kg? Explain.

1. Consider the situation below where two blocks, A and B are attached by a string attached to another block, C. At t=0s block C is released and blocks A and B move together. The blocks travel a distance d in time t_o. The values of the masses and the distance d are shown in the diagram. (Assume the string and pulley are massless and that there is no friction between A and the table.)



a) In the space below draw a free body diagram for block A, block B, and block C.

b) For each force acting on block B identify its NIII force pair.

Block A	Block B	Block C

c) Rank the magnitudes of the impulses exerted on carts A, B, and C between t=0s and t_o. Explain how you know.

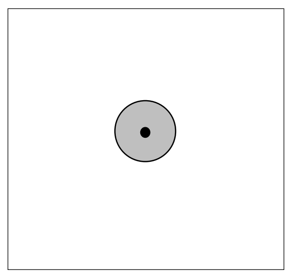
d) Rank the magnitudes of the change in momentum for carts A, B, C. Explain your reasoning.

e) Obtain the velocity of mass A at time t_o. Show all work.

f) Suppose the massless pulley is replaced with a pulley of mass m_p and radius r_p, where m_p=½kg and r_p=0.2m. (Assume the string does not slip on the pulley and that the pulley is a solid cylinder.)

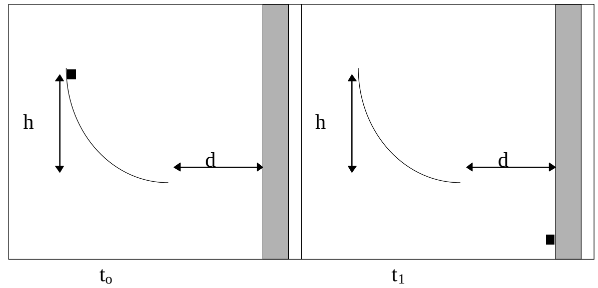
i. Will the velocity of A at t_o be greater than, less than, or equal to the velocity you found in part (f)? Explain how you know.

ii. Draw a free body diagram of the pulley in the space provided and identify the forces that exert a torque on the pulley. Explain your reasoning.

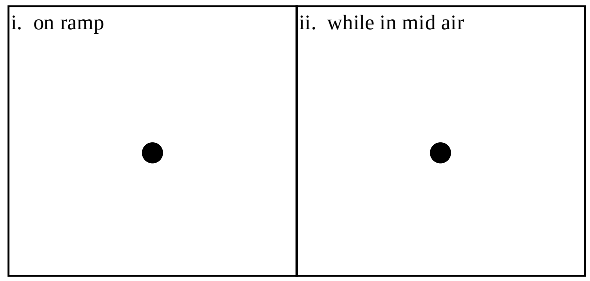


iii. Obtain the velocity of mass A at time t_o. Show all work.

2. A block slides down a frictionless track, flies through the air, and collides with a wall, sticking to it. The diagrams at right show the system at successive times.



a) Draw a free body diagram for the block:
   i. at some instant while it is on the ramp.
   ii. at some instant while in between the ramp and the wall.



b) What forces do work on the block at the following times?
   i. while on the ramp

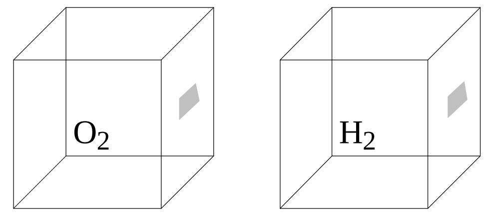
   ii. while in mid-air

c) Compute the vertical distance the block falls between t_o and t_1 in terms of h and d. Show all work.

d) What is the approximate direction of the impulse from the wall on the block during the collision. Explain how you found the direction.

Heat and Temperature Problem Solving

1. Two cubic containers of equal volume are kept at the same temperature. Both containers hold the same number of moles of gas. Container A holds O_2 and container B holds H_2. A shaded area of the same size is shown on each container.



   a) On average, compare the amount of time it takes molecules of O_2 to cross the container to the amount of time it takes molecules of H_2 to cross the container. Explain your reasoning and discuss any assumptions you have made.

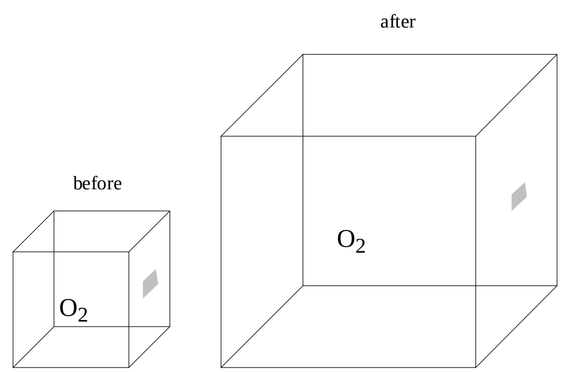
   b) On average, compare the change in momentum of a single molecule of O_2 to the change in momentum of a single molecule of H_2 in a collision with the wall. Explain your reasoning and discuss any assumptions you have made.

   c) Use the Kinetic Model of gases to compare the pressure on the shaded area in container A to the pressure on the shaded area in container B. Explain your reasoning.

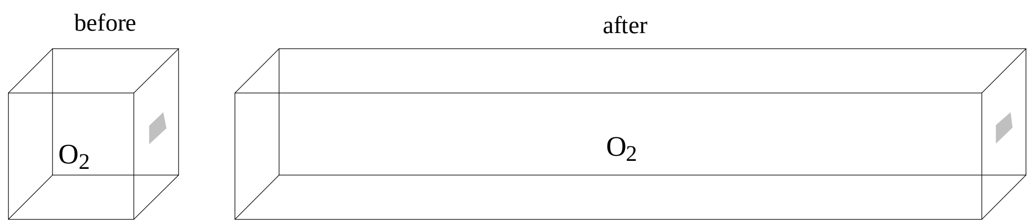
   d) Is the pressure comparison using the Kinetic Model consistent with the Ideal Gas Law? If they are not consistent resolve any discrepancies.

e) If the original pressure on container A is 5 N/m^2 what is the new pressure on the shaded area when the temperature is doubled. Explain your answer in terms of the Kinetic Model **and** the Ideal Gas Law.

f) If the original pressure on container A is 5 N/m^2 what is the new pressure on the shaded area when the length of each side is doubled as shown in the figure. Explain your answer in terms of the Kinetic Model.



g) If the original pressure on container A is 5 N/m^2 what is the new pressure on the shaded area when the length of one side is increased eight times as shown in the figure. Explain your answer in terms of the Kinetic Model.



Not drawn to scale

2. (from Arons, 1997) Several small pieces of copper, having a total (combined) mass of 350 g are placed in liquid nitrogen and, when removed, are at a temperature of -180^{o}C. The pieces of copper are quickly transferred to a 200 g brass calorimeter containing 420 g of water. Both the calorimeter and the water are at 9.0^{o}C and the temperature of the room in which the experiment is conducted is 20^{o}C.

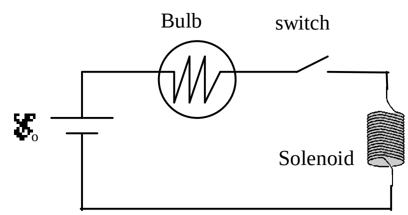
a) Describe qualitatively what happens in the way of heat transfers and temperature changes after the copper has been placed in the calorimeter. Describe the conservation relation that governs the phenomena taking place, and indicate the idealization we make in applying this relation to the interaction between the copper and the calorimeter. What role does the concept of "closed system" play in the idealizations you invoke?

b) Now proceed to predict, numerically, the final equilibrium state that is attained within the calorimeter. Explain your reasoning as you set up expressions and interpret, in words, the physical meaning of each separate term that is present in the equation you end up with. (Hint: It is wise to make a preliminary, rough calculation to estimate the final physical condition the system attains and to identify the relevant unknown, or unknowns. Otherwise you may find yourself putting numbers into expressions that turn out to be irrelevant.)

c) Noting that it is, in fact, never possible to attain a perfectly closed system in these circumstances, analyze how interaction with the surroundings will, in this instance, affect the final result: Will the calculated value (of whatever you calculated) be greater than. equal to, or less than the “correct” value that would have been obtained in the ideal situation? Explain your reasoning.

Inductive Circuits

1. Consider the circuit shown at right. Assume that the resistance of the wires and across the solenoid are zero and that the battery is ideal. It is observed that when the switch is closed, the bulb is initially not lit, and then gradually increases in brightness. Once the brightness of the bulb is the same as its brightness when connected directly to the battery, it remains unchanged.



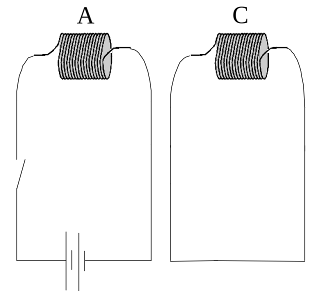
   a) Just after the switch is closed, what is the voltage across the bulb? Explain how you know.

   b) Just after the switch is closed, what is the voltage across the solenoid? How can you account for this in terms of Lenz's law?

   c) After a long time, what is the voltage across the bulb? Explain how you know.

   d) After a long time, what is the voltage across the solenoid? How can you account for this in terms of Lenz's law?

2. Two solenoids A and C are sufficiently close together that the magnetic field formed in A, in the presence of the electric current, also penetrates into C. The figure is shown at right.

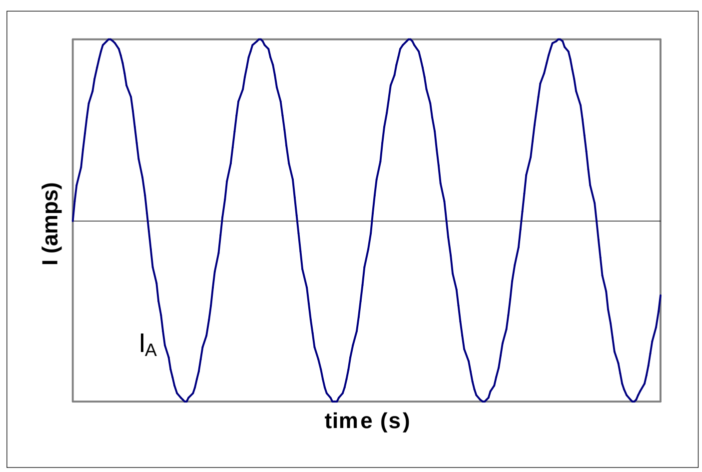


   a) We start with switch S closed so that a steady current is present in solenoid A. Establish the direction of the B-field penetrating into solenoid C and show its direction. Explain how you arrived at your result. If the B-field is zero, say so explicitly and explain your reasoning.

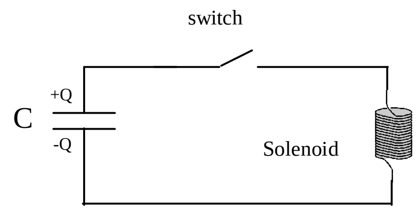
   b) While the switch is closed and the steady current is present in A, what is the direction of the induced current in C? Explain how you arrived at your result. If the current is zero, say so explicitly and explain your reasoning.

   c) The switch is now opened, and the current in A drops to zero. Describe what, if anything, happens in C, showing the direction of any possibly induced current. Explain how you arrived at your conclusion. What is the situation in C after the current in A has dropped to zero? Explain your reasoning.

   d) Suppose the battery in the diagram above is replaced with an AC voltage source such that the current, I_A, through solenoid A is shown at right. A positive current on the graph indicates a clockwise current around the circuit. Sketch the current in solenoid C as a function of time on this graph and explain your reasoning.



3. Consider the circuit shown at right. Assume that the resistance across the solenoid and the wires is zero and there is an initial charge on the capacitor of Q.



a) At the instant after the switch is closed:

i. What is the voltage across the capacitor and the voltage across the solenoid? Explain how you know.

ii. Describe the current in the circuit. (In which direction, if any, is it? Is it increasing or decreasing?) Explain using Lenz's Law.

b) At some later time, t_1, the charge on the capacitor has been reduced to Q/2.

i. What is the voltage across the capacitor and the voltage across the solenoid? Explain how you know.

ii. Describe the current in the circuit. Explain using Lenz's Law. (Hint: Does the EMF across the solenoid correspond to an increasing current or a decreasing current?)

c) At some later time, t_2, the charge on the capacitor is 0.

i. What is the voltage across the capacitor and the voltage across the solenoid? Explain how you know.

ii. Describe the current in the circuit using Lenz's Law. Explain.

d) Describe what happens in the circuit after t_2. Explain your reasoning.