Notre Dame Physics Department Qualifying Examination

SAMPLE (not for distribution)

Part I

Each problem will be graded on a scale of 0-4 points. You are asked to do any 8 of the problems.

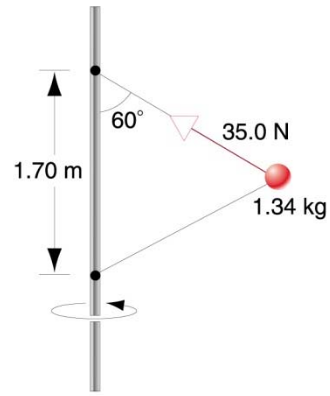
Clearly indicate your choices, by listing here the two problems that you are not going to attempt:
a) ________ b) _______.

Use only pencil for this test. Show all your work on separate pages for each problem. Please use only one side of the paper to work the problems!
Collect your work together in numerical order (number each page) by problem when you finish, including your equation sheet at the end, use the envelope provided to store your work and the exam. Good luck!

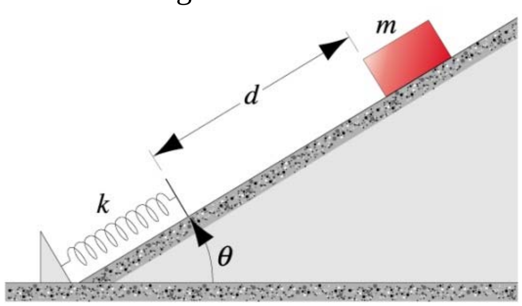
Please confirm your student ID number: **«ND_ID».**

DO NOT WRITE YOUR NAME!

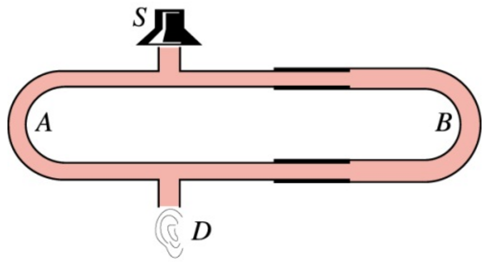
1. A 1.34-kg ball is attached to a rigid vertical rod by means of two massless strings each 1.70 m long. The strings are attached to the rod at points 1.70 m apart. The system is rotating about the axis of the rod, both strings being taut and forming an equilateral triangle with the rod, as show in the figure. The tension in the upper string is 35.0 N.
   (*a*) Find the tension in the lower string.
   (*b*) Calculate the net force on the ball at the instant shown in the figure.
   (*c*) What is the speed of the ball?



2. An ideal massless spring can be compressed 2.33 cm by a force of 268 N. A block whose mass is m = 3.18 kg is released from rest at the top of the incline as shown in the figure, the angle of the incline being 32.0ᴺ. The block comes to rest momentarily after it has compressed this spring by 5.48 cm.
   (*a*) How far has the block moved down the incline at this moment? (*b*) What is the speed of the block just as it touches the spring?



3. In the figure below we show an acoustic interferometer, used to demonstrate the interference of sound waves. *S* is a source of sound (a loudspeaker, for instance), and *D* is a sound detector, such as the ear or a microphone. Path *SBD* can be varied in length, but path *SAD* is fixed. The interferometer contains air, and it is found that the sound intensity has a minimum value of 10 $\mu W/cm^2$ at one position of *B* and continuously climbs to a maximum value of 90 $\mu W/cm^2$ at a second position 1.65 cm from the first. Find (*a*) the frequency of the sound emitted from the source (assume the speed of sound in air is 343 m/s) and (*b*) the relative amplitudes of the waves arriving at the detector for each of the two positions of *B*. (*c*) How can it happen that these waves have different amplitudes, considering that they originate at the same source?



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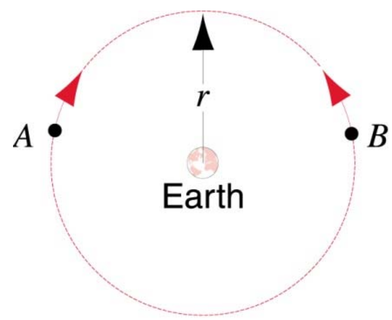
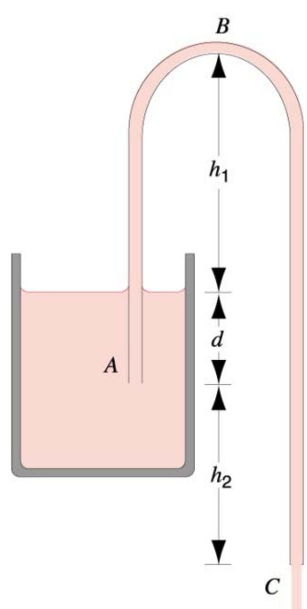
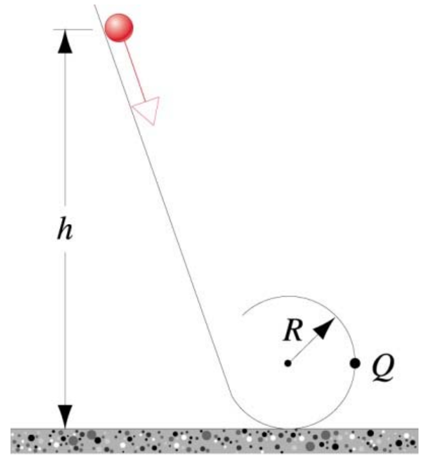
4. Consider two satellites *A* and *B* of equal mass *m*, moving in the same circular orbit of radius *r* around the Earth but in opposite senses of revolution and therefore on a collision course (see figure below). (*a*) In terms of *G*, M_E, *m* and *r*, find the total mechanical energy of the two-satellite-plus-Earth system before collision. (*b*) If the collision is completely inelastic so that wreckage remains as one piece of tangled material, find the total mechanical energy immediately after collision. (*c*) Describe the subsequent motion of the wreckage.



5. A siphon is a device for removing liquid from a container that is not to be tipped. It operates as shown in the figure at the right. The tube must initially be filled, but once this has been done the liquid will flow until its level drops below the tube opening at *A*. The liquid has density *p* and negligible viscosity.
(*a*) With what speed does the liquid emerge from the tube at *C*?
(*b*) What is the pressure in the liquid at the topmost point *B*?
(*c*) What is the greatest possible height *h* that a siphon may lift water?



6. A small marble of mass *m* and radius *r* rolls without slipping along the loop-the-loop track shown in the figure, having been released from rest somewhere on the straight section of track. (*a*) From what minimum height above the bottom of the track must the marble be released in order that it just stays on the track at the top of the loop? (The radius of the loop-the-loop is $R >> r$. (*b*) If the marble is released from height 6*R* above the bottom of the track, what is the horizontal component of the force acting on it at point *Q*?

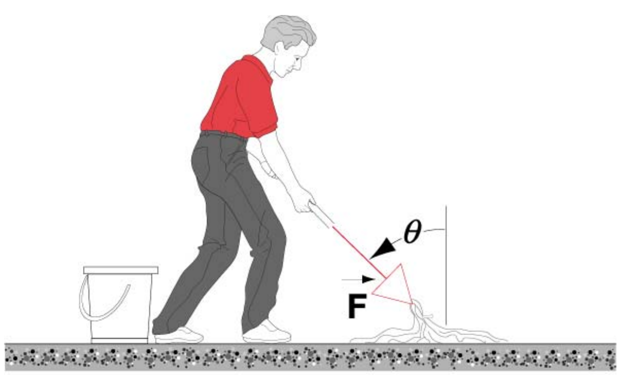


7. The fastest possible rate of rotation of a planet is that for which the gravitational force on material at the equator barely provides the centripetal force needed for the rotation. (Why?) (*a*) Show then that the corresponding shortest period of rotation is given by

$$T = \sqrt{\frac{3\pi}{Gp}},$$

Where *p* is the density of the planet, assumed to be homogeneous, (*b*) Evaluate the rotation period assuming a density of 3.0 g/cm^3, typical of many planets, satellites, and asteroids. No such object is found to be spinning with a period shorter than found by this analysis.

8. The handle of a floor mop of mass *m* makes an angle θ with the vertical direction; as seen in the figure. Let μ_k be the coefficient of kinetic friction between mop and floor and μ_s the coefficient of static friction between mop and floor. Neglect the mass of the handle. (*a*) Find the magnitude of the force *F* directed along the handle required to slide the mop with uniform velocity across the floor. (*b*) Show that if θ is smaller than a certain angle θ_0 the mop cannot be made to slide across the floor no matter how great a force is directed along the handle. What is the angle θ_0?



9. A radioactive nucleus moves with a constant speed of 0.240*c* along the *x* axis of a reference frame *S* fixed with respect to the laboratory. It decays by emitting an electron whose speed, measured in a reference frame *S'* moving with the nucleus, is 0.780*c*. Consider first the cases in which the emitted electron travels (*a*) along the common xx' axis and (*b*) along the *y'* axis and find, for each case, its velocity (magnitude and direction) as measured in frame *S*. (*c*) Suppose, however, that the emitted electron, viewed now from frame *S*, travels along the *y* axis of that frame with a speed of 0.780*c*. What is its velocity (magnitude and direction) as measured in frame *S'*?

10. A cylinder has a well-fitted, 2.0-kg metal piston whose cross-sectional area is 2.0 cm^2 (as seen in the figure below). The cylinder contains water and steam at constant temperature. The piston is observed to fall slowly at a rate of 0.30 cm/s because heat flows out of the cylinder through the cylinder walls. As this happens, some steam condenses in the chamber. The density of the steam inside the chamber of 6.0×10^{-4} g/cm^3 and the atmospheric pressure is 1.0 atm = $1.01 \cdot 10^5$Pa. (*a*) Calculate the rate of condensation of steam. (*b*) At what rate is heat leaving the chamber? (*c*) What is the rate of change of internal energy of the steam and water inside the chamber? (Heat of vaporization for water: 2.256×10^6 J/kg; the molecular weight of water is 18g/mole)