University of Wisconsin-Madison
Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

You must solve 4 out of the 6 problems.
Start each problem on a new page.

SHOW ALL YOUR WORK.
WRITE ONLY ON THE FRONT PAGES OF THE WORKSHEETS, <u>NOT</u> ON THE EXAM PAGES

Grading is based on both the final answer and work done in reaching your answer. All problems receive an equal number of points.

Clearly indicate which problems you want graded. If you do not indicate which problems are to be graded, the first four solutions you provide will be graded.

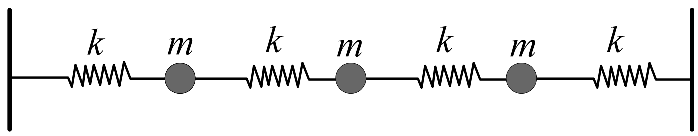
1. ______
2. ______
3. ______
4. ______
5. ______
6. ______

Student No.________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 1. Three masses (m=0.5 kg each) are connected to each other and to two walls by springs with the same spring constant (k) of 100 N/m, as shown in the figure.



One mode of oscillation for the system has an angular frequency of 20 rad/s ($\omega = \sqrt{2k/m}$).

a) What are the equations of motion for the three masses? [Consider 1D motion directed horizontally along the springs only.]

b) Find the angular frequencies of the other two modes of the system.

c) What is the eigenvector for the mode that oscillates at $\omega = \sqrt{2k/m}$?

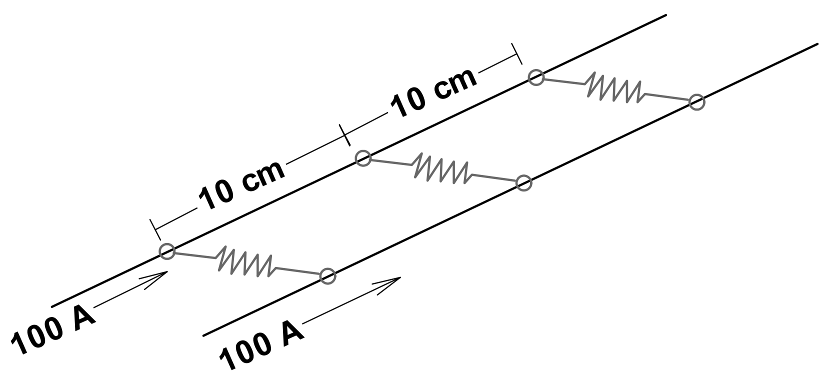
Student No.________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 2.

Two long rigid wires are held apart by insulated springs placed every 10 cm between the wires. For small displacement, the springs respond linearly with a spring constant of 6 N/m, and their length is 2 cm when not subject to an applied force. The wires are connected to a current source, and 100 A of current flows through each wire (in the same direction).



a) (8 points) Assuming that the wires remain parallel and ignoring any initial transient stage and end effects, what is the final equilibrium distance between the two wires?

b) (2 points) If there is more than one solution to your mathematical description, what considerations may justify choosing a single solution?

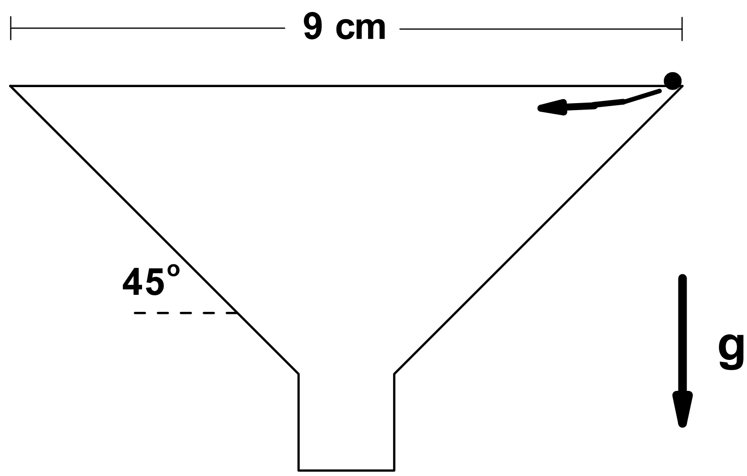
Student No.________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 3.

A mechanic drops a small 1 g spherical bearing, and it lands in a funnel that has a diameter of 9 cm at its top opening and sides that slant at 45° as shown below. The bearing initially rolls just inside and tangent to the rim at 40 cm/s, and friction is negligible in the subsequent motion. You may neglect rotational inertia associated with any rolling (spinning) of the bearing.



a) (7 points) What is the average depth of the bearing's motion around the inside of the funnel?

b) (3 points) In addition to orbits around the funnel, there will be oscillations up and down along the surface of the funnel. Would small deviations from a circular orbit be sinusoidal in time? Provide evidence to justify your answer.

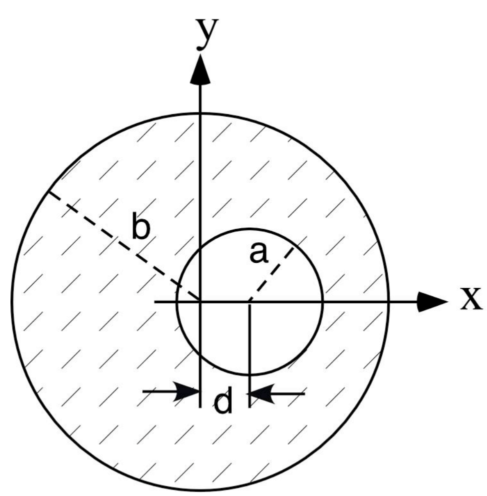
Note: The gravitational acceleration constant is 9.81 m/s^2.

Student No.________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 4. A solid cylindrical conductor (radius = b) has a cylindrical hole (radius = a) whose center is displaced from the center of the cylinder in the x-direction by a distance = d, as indicated in the figure. Assuming a current I that is uniformly distributed in the conductor (crossed-hatched region in the figure), find the magnetic field vector at all locations along the x-axis for $x \geq 0$. The current is directed out of the page in the z-direction.



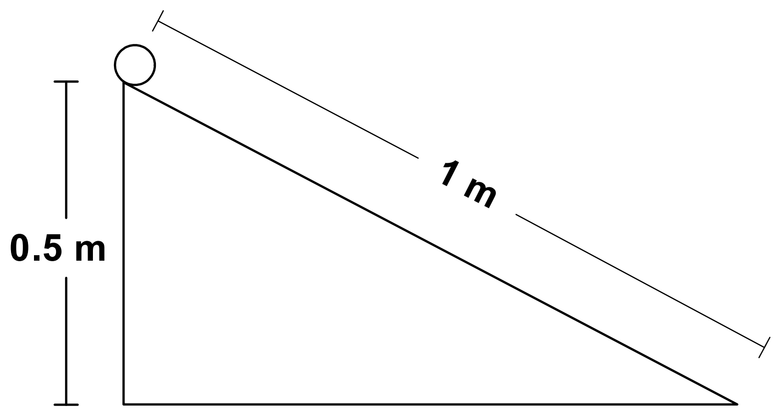
Student No._________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 5.

The ramp shown in the figure below has a frictional surface such that a sphere experiences a coefficient of friction of 0.1. The radius of the sphere is 0.13 m and its mass is 0.2 kg.



a) (3 points) Show that the angular acceleration of the sphere is constant.

b) (7 points) If the sphere is released from rest at the top of the ramp, how much energy is converted into heat by the time the sphere reaches the bottom of the ramp?

Note: $I_{sphere} = \frac{2}{5} mR^2$.

Student No.________________

Engineering Physics Department
Fall 2006 Qualifying Exams

Classical Physics

Problem 6. A line charge λ is fixed onto the rim of a wheel of radius b, which is then suspended horizontally, as indicated in the figure. The wheel is free to rotate and its spokes are made of non-conducting material. In the central region, out to radius a, a uniform magnetic field B_0 is pointing up. The field is reduced to zero at a given rate dB/dt.

a) Calculate the total instantaneous torque on the wheel.
b) What is the total angular momentum imparted to the wheel?