University of Wisconsin-Madison
Engineering Physics Department
Spring 2014 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, NOT 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. _____

$\mu_0 = 4\pi \times 10^{-7}$ H/m $\quad \varepsilon_0 = 8.854 \times 10^{-12}$ F/m

$G = 6.67 \times 10^{-11}$ $\mathrm{m}^3/\mathrm{kg}\cdot\mathrm{s}^2$ $\quad M_e = 5.97 \times 10^{24}$ kg $\quad R_e = 6{,}371$ km

Center of mass moments of inertia:

$I_{disk} = \frac{1}{2}MR^2 \quad I_{sphere} = \frac{2}{5}MR^2 \quad I_{rod} = \frac{1}{12}ML^2$

$I = Mk^2$ (where k is the radius of gyration)

Student No._____

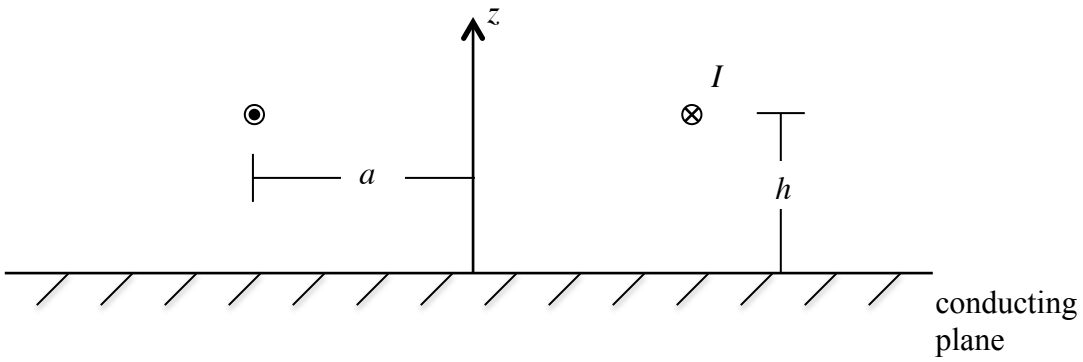
Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

Problem 1. A circular loop of wire of radius *a* carries current *I*. It is positioned in a plane that is parallel to a conducting surface. As shown in the cross section below, the conducting surface is at $z = 0$, the loop is at $z = h$, and the current runs in the right-handed sense around the *z*-axis.

a) (3 points) Is the magnetic force on the loop directed toward or away from the conducting plane? [Provide a brief justification for your answer.]

b) (7 points) What is the magnitude and direction of the magnetic field along the *z*-axis shown in the sketch for $z \geq 0$?



Student No._____

Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

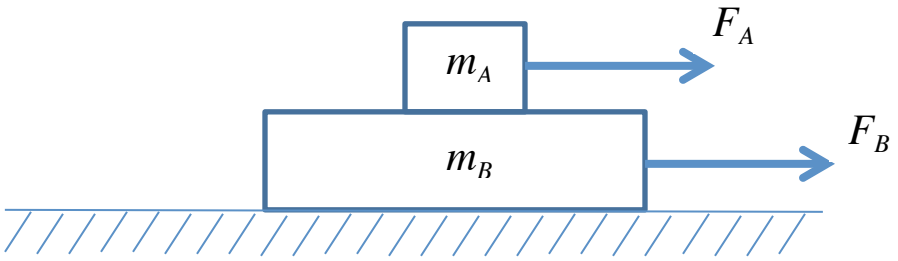
Problem 2. A block of mass m_A=2 kg sits on a second block of mass m_B=5 kg, as shown below. The lower block rests on a frictionless surface. If the coefficients of friction between the two blocks are μ_s=0.4 and μ_k=0.3, find the acceleration of each block for the five cases with applied horizontal forces F_A and F_B given below.

a) Case 1: F_A=0, F_B=6 N (2.5 points)

b) Case 2: F_A=0, F_B=12 N (2.5 points)

c) Case 3: F_A=6 N, F_B=0 (2.5 points)

d) Case 4: F_A=12 N, F_B=0 (2.5 points)

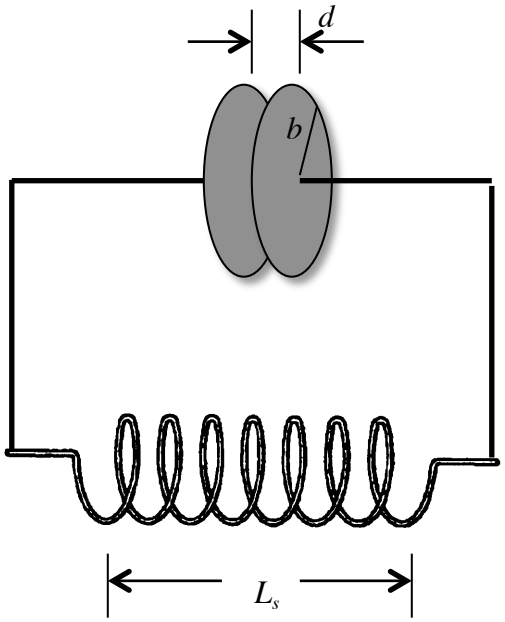


Student No._____

Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

Problem 3. The inductor of a simple, freely oscillating *LC* circuit is a tightly wound cylindrical solenoid with *N* turns of radius *a*, and its length is L_s, where $L_s >> a$. The capacitor is two parallel disks of radius *b* separated by the distance *d*, where $d << b$. As a function of time, the voltage measured across the inductor is $V_0 \sin(\omega t)$.



a) (5 points) What is the oscillation frequency ω in terms of the given parameters?

b) (2 points) What is the magnetic field within the solenoid as a function of time?

c) (3 points) What is the magnetic field within the capacitor as a function of time and radial coordinate *r* from the center of the disks?

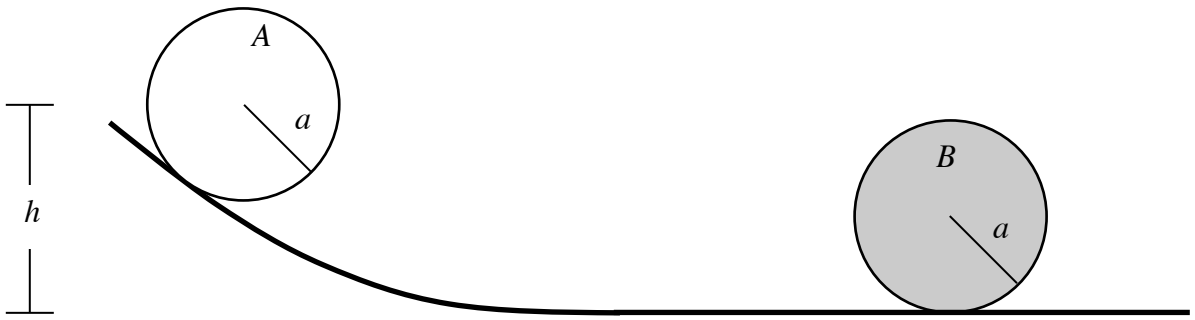
Student No._____

Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

Problem 4. A thin spherical shell (*A*) with radius *a* and mass *M* rolls down an incline that smoothly transitions to a horizontal surface. It then makes a head-on elastic collision with a solid sphere (*B*) of radius *a* and mass 2*M*. Before, during, after the collision, the spheres roll without slipping on the surface. The spherical shell starts at rest with its center of mass located a distance $h > a$ above the horizontal surface.

(10 points) In terms of the constants provided and the gravitational acceleration *g*, what are the velocities of the two spheres after the collision?



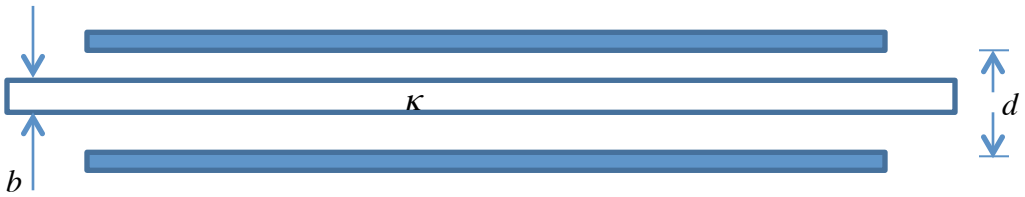
Student No._____

Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

Problem 5. A dielectric slab of thickness b and relative dielectric constant κ is inserted between the plates of a parallel plate capacitor with plate separation distance $d \geq b$ and area A. [Assume that d is much smaller than the dimensions of the plates.]

a) (6 points) Determine the capacitance of this configuration.
b) (1 points) Show that this result is correct for the cases of
   a. an infinitely thin dielectric,
   b. a dielectric with $d=b$, and
   c. a dielectric with $\kappa=1$.
c) (3 points) How would your answer change if the slab was a conductor, rather than a dielectric?



Student No._____

Engineering Physics Department
Spring 2014 Qualifying Exams

Classical Physics

Problem 6. The block shown below is supported at its edges. It has a mass of 8 kg and the coefficients of friction between the supports and the floor are μ_s=0.3 and μ_k=0.2. The height of the block is 2 m and the force F_B shown below is applied a distance of 1.6 m from the floor. The width of the block is 1 meter. You can ignore the height of the supports.

a) (3 points) Determine the minimum force F_B that will cause motion.
b) (1 point) Is this motion sliding or tipping?
c) (3 points) What is the acceleration (either linear or angular) of the block as this motion is initiated?
d) (3 points) What are the vertical components of the reaction forces at the two supports when the motion begins?