Drexel UNIVERSITY

DEPARTMENT OF PHYSICS

PhD Qualifying Exam **Classical Physics**

Friday, September 22, 2000 9 am - 12 noon

PRINT YOUR NAME________________________

EXAM CODE__________________

PUT YOUR EXAM CODE, **NOT YOUR NAME,** ON EACH PIECE OF PAPER YOU HAND IN. (This allows us to grade each student only on the work presented.)

Do each problem or question on a separate sheet of paper. (This allows us to grade them simultaneously.)

Answer 5 of 7 short answer questions in part I and 3 of 5 longer problems in part II, with at least one problem from Group A and one from Group B. ***Circle the numbers*** below to indicate which questions you have answered—write nothing on the lines (your grades go there).

Short questions		*Long Problems*	
1.	_____	A1.	_____
2.	_____	A2.	_____
3.	_____	A3.	_____
4.	_____	B1.	_____
5.	_____	B2.	_____
6.	_____		
7.	_____		

CLASSICAL PHYSICS

PART I: Short answers (25%)

ANSWER 5 OF 7 QUESTIONS

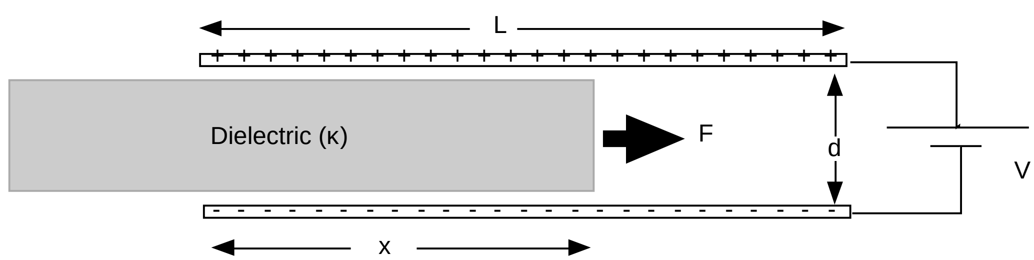
1. A projectile is fired from a gun at an angle θ from horizontal. What is the maximum firing angle θ_{ϖ} for which the gun-projectile distance never decreases?

2. An astronaut is on board a space-station that is shaped like a cylinder, and rotates about its cylindrical symmetry axis to provide "pseudo-gravity". The astronaut on earth can jump to a height h that is one-fourth the radius R of the cylinder. How high can she jump on the space-station?

3. Baggage handlers are placing suitcases onto a rubber conveyor belt that is tilted at an angle θ above the horizontal. The motion of the belt is upward. Under what conditions would a suitcase slide *down* the belt, instead of being pulled upward?

4. A mass is attached to the end of a string. The string passes through a hole in a frictionless table. The mass initially moves in a circle of radius R with kinetic energy E; the string is held taut. If the string is now slowly pulled until the radius of the circle is R/2, how much work has been done pulling the string?

5. A parallel plate capacitor is connected to a battery whose terminal voltage is V. A



dielectric (constant κ) is pulled into the space between the plates by a force F as shown. Find the force F in terms of κ, ε_o, V, d, and the width of the dielectric, w. Assume that L – x >> d and neglect all fringing effects.

6. A bar magnet is oriented vertically and dropped toward a flat, horizontal copper plate. Why is there a repulsive force between the bar and the plate? Is the force elastic (that is, if the magnet is strong enough, will it bounce back)?

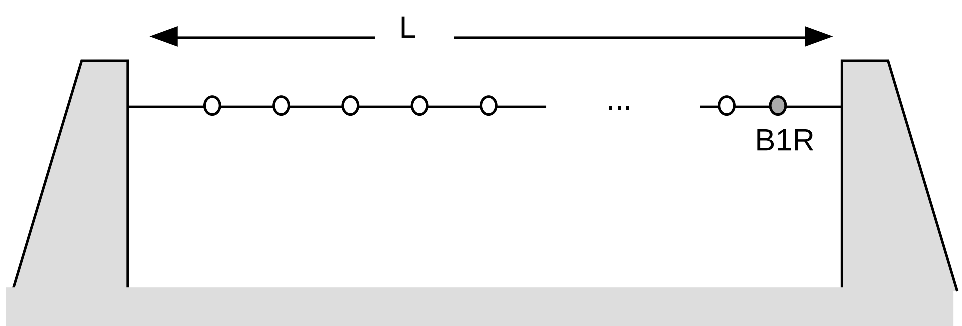
7. An electromagnetic wave crosses a boundary: what are the conditions on the vectors **E, D, B** and **H**?

PART II: Long problems (75%)

ANSWER 3 OF 5 QUESTIONS, WITH AT LEAST ONE FROM GROUP A AND ONE FROM GROUP B.

A1. Drawing a bead on kinetic theory

N identical balls of mass *m* and radius *r* are strung like beads along a smooth horizontal rod of length *L*, mounted between two immovable supports. The balls can slide along the rod, and initially are at rest. Collisions between balls as well as collisions between balls and supports are perfectly elastic while friction between balls and the rod is absent.



(A) Suppose the balls are equally spaced along the rod. What is the average force felt at each support if the ball nearest the right support (B1R) is struck horizontally so as to acquire a speed of *V* towards the *right*?

Enumerate your answers when L = 2m, N = 10, m = 0.1 kg, r=0.02 m, and V = 4 m / s.

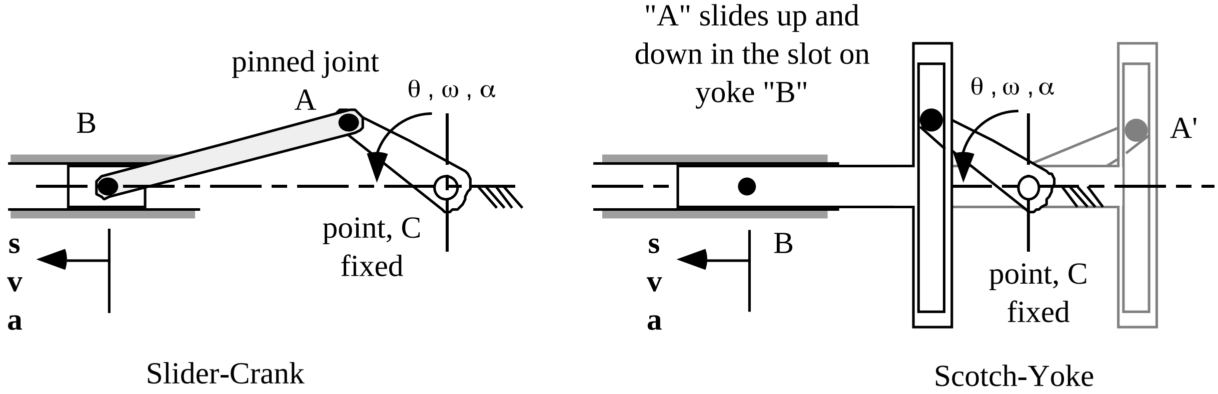
(B) What would happen to your answers if B1R was struck towards the left?

(C) Suppose now B1R is at the same position but the others are randomly spaced to the left. Describe *qualitatively* how your answers would be affected.

(D) If friction is present and introduces a constant declearation of 1 m / s^2 on any moving ball, and initial conditions are those of (A), what is the total number of collisions at each wall?

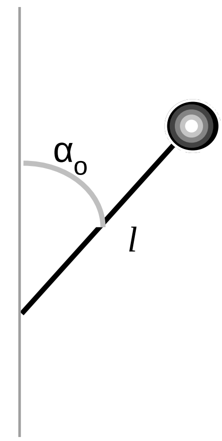
A2. Crank calls

The two mechanisms shown are very common mechanisms that convert rotational movement into linear translational movement. The first is called a "Slider-Crank" mechanism (such as is found in pumps, internal combustion engines, etc.) and the second is a "Scotch-Yoke" mechanism. In both mechanisms the point "C" is fixed to the reference frame , point "B" translates in a horizontal direction only, link "AB" of the slider crank is "2R" long, and link "AC" , called the CRANK, rotates with angular values of θ , ω ,and α . See figure below.



For each of these mechanisms, Assuming $\theta = 0$ and $s = 0$ when AC is pointing vertically upward, determine the expressions for the position, s, velocity, v, and acceleration, a, of point "B" in terms of the crank's length "R", and the angular values of θ, ω and α .

A3. **Enjoy the fall**



A mass is attached at one end of a massless, rigid rod of length l, and the rod is suspended at its other end by a frictionless pivot, as illustrated. The rod is released from rest at an angle $\alpha_o < \pi/2$ with the vertical. At what angle α does the force in the rod change from compression (i.e. force toward the pivot) to tension (force away from the pivot)?

Also describe this physical situation in words.

B1. **A charge will apply**

A neutral spherical conductor is introduced to a uniform electric field pointing to the positive z axis. Let the radius of the conductor be R.

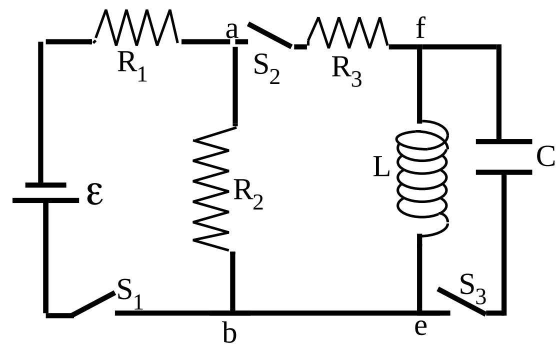
(A) Sketch the charge distribution within and on the conductor.

(B) Calculate the charge density within the conductor and the surface charge density.

(C) Calculate the dipole moment of the charge distribution.

B2. **How can you resist?**

In the circuit shown to the right the resistors are R_1=3 KΩ, R_2=12 KΩ and R_3(unknown), the capacitor is C= 40 µF and the inductor is L of unknown value. Emf of the source is ε = 45 V. There are three switches S_1 , S_2 and S_3. Assume switch S_3 is *open* throughout whereas switch S_2 is kept *closed* all the time. At t = 0, with no current through the inductor, switch S_1 is *closed*.



a. What are the **currents** (in mA) I_1, I_2 and I_3 through the resistors R_1, R_2 and R_3 respectively immediately after S_1 is closed?

b. What is the **voltage** V_{ab} (in V) immediately after S_1 is closed?

c. If the **voltage** V_{ab} = 30 V a long time after S_1 is closed, what is the **voltage** V_1 across the resistor R_1? What is the **current** I_1 (in mA) through the resistor R_1?

d. A long time after S_1 is closed , if the current I_3 through R_3 is 2.5 mA, find the resistor R_3 (in KΩ)? What is the current (in mA) I_2 through the resistor R_2 ?

e.If the energy stored in the inductor a long time after S_1 is closed is 156.3 nJ, what is the value of inductor "L"?

f. What is the rate (A/s) at which the current I_3 through the inductor changes when t =(t_L)*ln(2) s after S_1 is closed?

g. What is the emf (in V) induced in the inductor when t = (t_L)*ln(2) s after S_1 is closed?

h. Find the rate (in nJ/s) at which magnetic field energy is stored in the inductor when t = (t_L)*ln(2) s after S_1 is closed.

j. Find the rate (in mW) at which energy is input to the circuit by the source when t = (L/R)*ln(2) s after S_1 is closed.

k. What is the time constant (in µs) of the circuit?l.

l. A long time after S_1 is closed, the current through the inductor has reached a steady value given in part (d). Now the switches S_1 and S_2 are open and S_3 is closed simultaneously. Describe (qualitatively) the phenomenon that occurs in the closed part of the circuit ? How does this compare to an almost similar situation in mechanics?