Drexel UNIVERSITY

DEPARTMENT OF PHYSICS

PhD Qualifying Exam — **Classical Physics**

Friday, September 24, 2004 — 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).

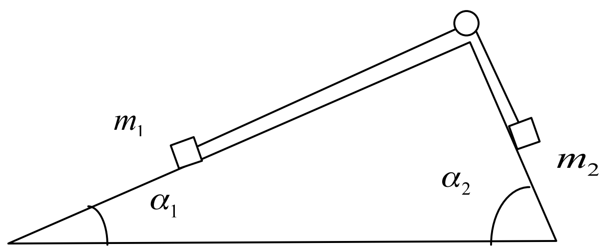
Short questions		*Long Problems*	
circle	grade	*circle*	grade
1.	_____	A1.	_____
2.	_____	A2.	_____
3.	_____	A3.	_____
4.	_____	B1.	_____
5.	_____	B2.	_____
6.	_____		
7.	_____		

CLASSICAL PHYSICS

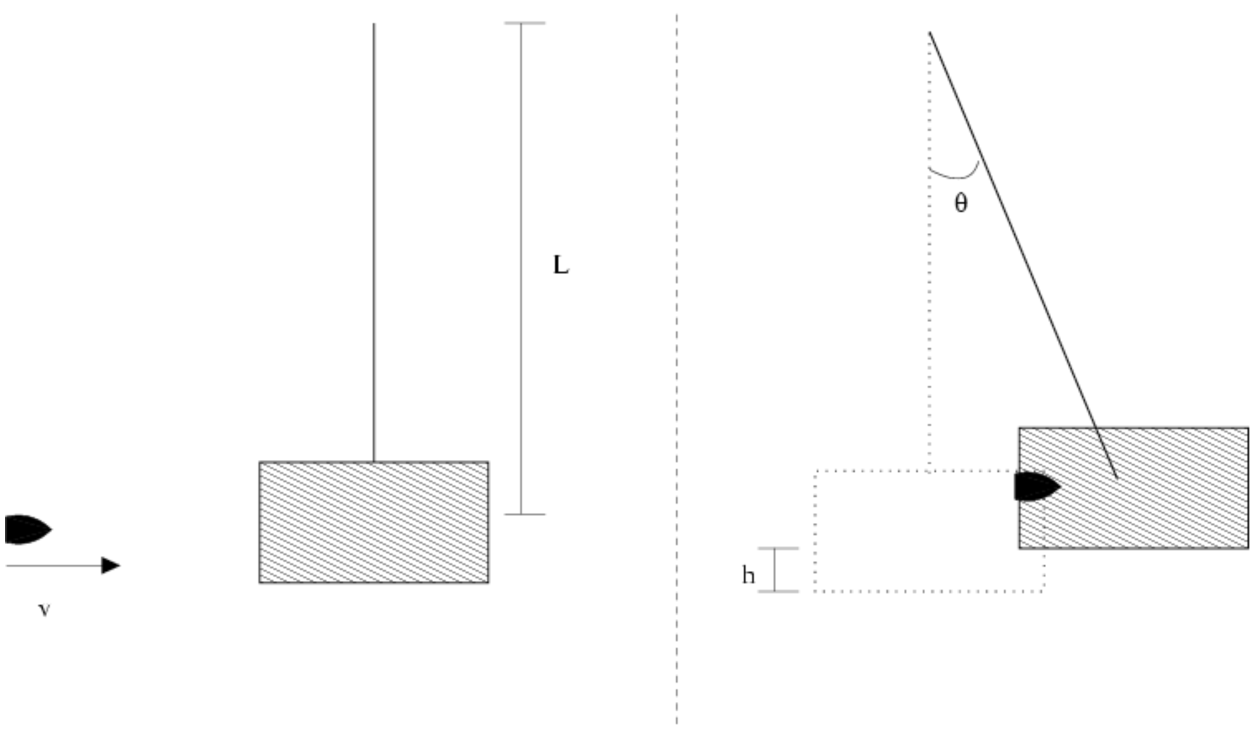
PART I: Short questions (25%)

ANSWER 5 OF 7 QUESTIONS

1. Find the relation between α_1 and α_2 for the static condition shown below (no friction):



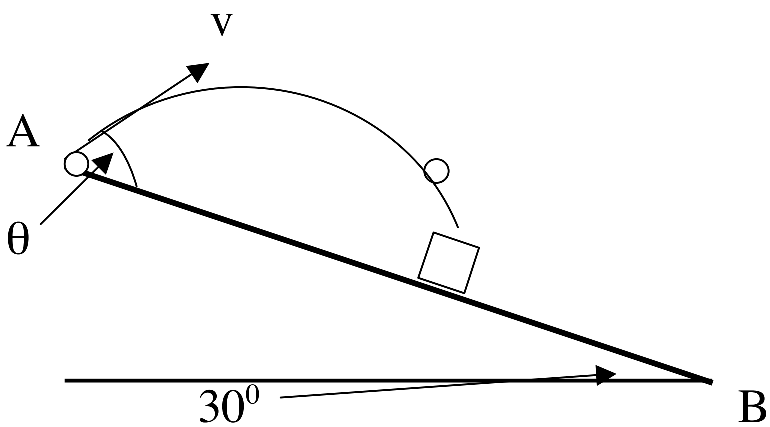
2. A 50 g bullet travels at 500 m/s toward a hanging wooden block of mass 4.95 kg, and becomes embedded (as shown). The block hangs from a 2m length (L) of rope.



What is the maximum angle, θ, reached by the pendulum? What fraction of the initial kinetic energy is lost due to the collision?

3. In a demonstration experiment (see Figure below), a ball is shot from A with an initial speed

v at an angle θ with an inclined plane AB. At the same instant, a cup is released from A and slides frictionlessly down the plane which is at an angle of 30^0 with the horizontal. If θ is chosen properly, the ball will always land in the cup regardless of the value of v. What is that proper value of θ?



4. When an unpolarized electromagnetic wave is incident on a medium at an incident angle θ_i=55°, the reflected rays are completely polarized. What is the refractive index of the medium?

5. Two conducting spheres of radius, R have centers separated by a distance, d, and are used as a capacitor. What is the capacitance?

6. A 10 μF capacitor is charged to 1000V. The capacitor is then discharged by connecting it to a 10kΩ resistor. How long does it take for the capacitor to dissipate 2J of energy in the resistor?

7. A star of mass M radiates energy isotropically into space at a rate of L watts. A particle of mass m at distance r from the star presents an effective cross-section σ to the star's radiation.
(a) Write down the condition for the star's radiation pressure to exceed the gravitational force on the particle.
(b) Hence estimate the maximum possible luminosity of a star of mass equal to that of the Sun. (Assume that the particles are protons, with mass $m_p = 1.7 \times 10^{-27}$ kg and cross section $\sigma_T = 6.7 \times 10^{-29}$ m^2, and the mass of the Sun is 2.0 x 10^{30} kg.)

PART II: Long problems (75%)

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

A1.

Two masses m and $M = 2m$ are connected by a light inextensible string which passes without slipping over a uniform circular pulley of mass $2m$ and radius r. The pulley is free to rotate about a frictionless horizontal axis of rotation. Using the angular position of a point on the rim of the pulley as a generalized co-ordinate, write down the Lagrangian equation, and determine the acceleration of mass M.

A2.

Consider the motion of a bead of mass m which slides on a smooth fixed wire bent in the form of a helix having radius R and a constant inclination angle α relative to the horizontal. The helix is at the surface of the earth.

(a) Use cylindrical coordinates and write down the constraint equation for z and θ with the parameter P (the pitch, defined as the vertical distance corresponding to 2π rotation in θ).

(b) Assuming that the central axis of the helix is vertical, find the time required for the bead to slide through a vertical distance d, in terms of d, R and P, after it is released from rest.

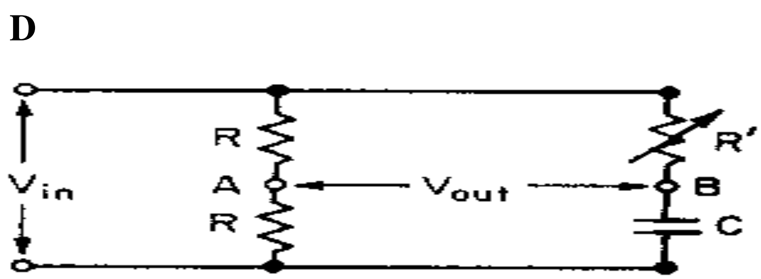
A3.

In an experiment, a shuttlecock is dropped from rest and falls to the ground from a building. It encounters air resistance during its flight. If its position-time data are as shown,

Total distance fallen	Total time taken
0.61 m	0.347 s
1.00	0.470
1.22	0.519
1.52	0.582
1.83	0.650

(a) Try to fit the data points with a resistive force that is linear in velocity, i.e. of the form kv. Note what you believe to be the value of the resistive constant (k) that yields a "reasonably good" fit.
(b) For that good fit, by comparing the difference between the potential energy lost and the kinetic energy gained to the total work done by friction to any point (all to be evaluated explicitly) during the shuttlecock's travel, show that the Work-Energy Theorem is confirmed.

B1.



The above circuit contains several resistors of fixed resistance, R, a capacitor of known capacitance, C, and a tunable resistor, R'. At some initial time, t=0, an induced alternating Voltage is applied to the system:

$$V_{in} = V_0 \exp(i\omega t)\ .$$

(a) What is the current passing through point, A, as a function of time? (Use only the real component)
(b) What is the potential at A with respect to D as a function of time? (What is the real component?)
(c) What is charge on the capacitor as a function of time? (What is the real component?)
(d) What is current through B as a function of time? (What is the real component?)
(e) For an arbitrary value of R', what is the potential difference between A & B (No need to compute the real part explicitly)?
(f) What is the purpose for this circuit?

B2.

Charge density

$$\sigma(\theta) = k\cos\theta\ ,$$

(where k is a constant) is glued over the surface of a spherical shell of radius a. Find the resulting electric potential inside and outside the sphere.

(Remember that the boundary conditions on the electric field at the surface assures continuity of the potential Φ at $r = a$ and that $(\frac{\partial \Phi_{out}}{\partial r} - \frac{\partial \Phi_{in}}{\partial r})_{r=a} = -\frac{\sigma(\theta)}{\varepsilon_0}$, where ε_0 is the electrical permittivity of vacuum).