CUA

THE CATHOLIC UNIVERSITY OF AMERICA

Department of Physics
200 Hannan Hall
Washington, D.C. 20064
202-319-5315
Fax 202-319-4448

Preliminary Examination

Spring 2007

Thursday, March 15, and Friday, March 16, 2007

Room 133 - Hannan Hall

- **YOU MUST DO TWO QUESTIONS IN EACH OF THE AREAS:**

Thursday, March 15, 2007

Mechanics

Electricity & Magnetism

Friday, March 16, 2007

Thermodynamics

Modern Physics/Quantum Mechanics

- **DO EACH PROBLEM IN A SEPARATE BLUE BOOK**

- **PUT YOUR NAME ON EACH BLUE BOOK**

- **LABEL EACH BOOK WITH CORRECT PROBLEM NUMBERS**
  FOR EXAMPLE: Mechanics #1

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RULES FOR THE PHYSICS COMPREHENSIVE EXAMINATION

SPRING 2007

In order to assure an equitable and fair Comprehensive Examination for all students the following rules will apply to the examination administered by the Department of Physics.

1. The examination will be closed book. Students will not be permitted to bring to the examination room materials such as notes, reference books, calculators, or other aids of any form. The Physics Department will supply copies of the *CRC Mathematical Handbook,* Schaum's *Mathematical Handbook, Table of Functions* by Jahnke and Emde, and the NBS *Handbook of Mathematical Functions*, for the use of those taking the exam should they feel the need for these references during the examination.

   The Physics Department will supply calculators for use during the examination.

   Students who want to use their own mathematical tables and/or handbooks must get permission from the Chairman prior to the beginning of the comprehensive examination. These tables and/or handbooks will remain under the control of the department until after the examination is completed, but will be available to their owners during the exam.

2. If needed, students will be allowed a short break, not to exceed ten minutes, during the examination period. While absent from the examination room students may not consult material or other sources of information concerning any matter pertaining to the examination. Students who leave the examination room will turn in all of their examination materials to the proctor before leaving the room. Examination papers will be returned to the students when they reenter the examination room. Students who fail to return within ten minutes will be considered to have completed that portion of the examination.

   <u>Only one student will be permitted to leave the examination room at a time.</u>

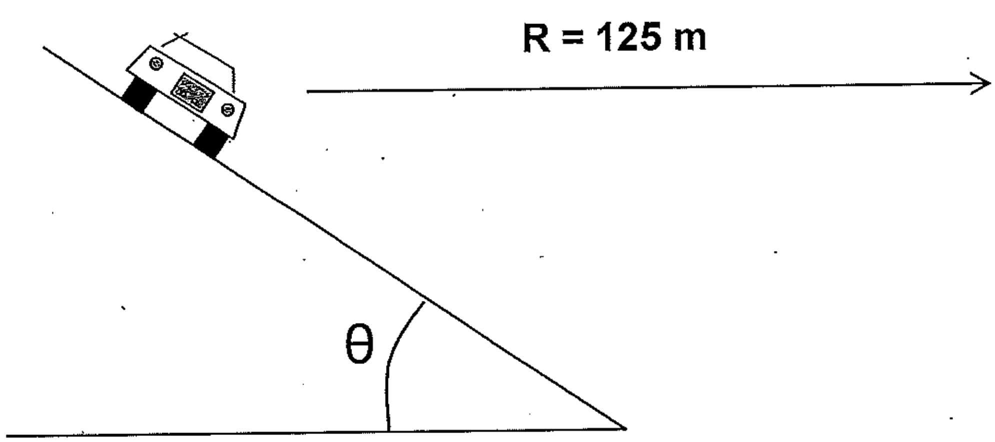
Preliminary/MS Comprehensive Examination
Spring 2007

Mechanics 500-1

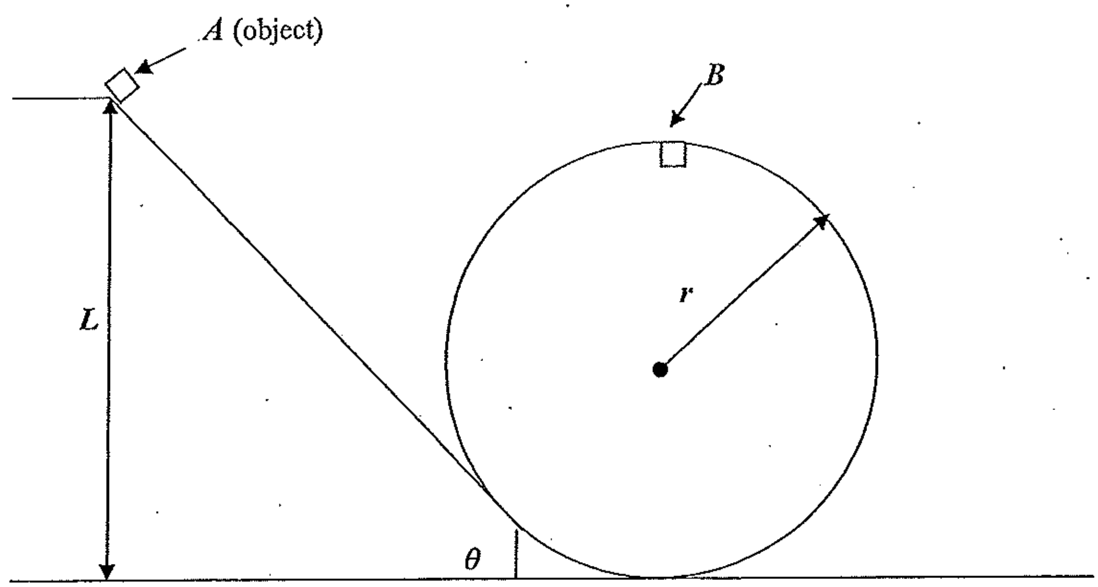
A circular curve for a road with a 125 m radius is banked at an angle such that an automobile traveling at a speed of 24 m/s can go around the curve without slipping, such that no friction is required from the tires.

What is the angle, θ, of the bank for the curve?

If an automobile rounds this curve at 30 m/s, what is the minimum coefficient of static friction (μ_s) needed between the tires and the road to prevent skidding?



Consider an object that will slide in the track shown. Starting from rest, calculate the minimum height, L, which will permit the object not to fall off the track at B.



a) Assume the object is a cube with sides d and no friction. Calculate L_A.

b) Consider the object is a cylinder of radius d/2. Calculate L_B and the frictional co-efficient μ.

c) Explain the differences between L_A and L_B.

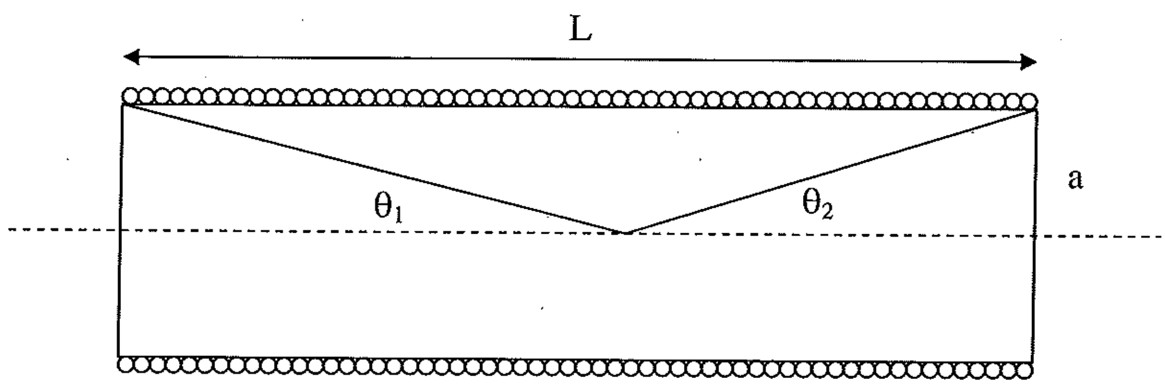
A right-circular hollow solenoid of finite length, L, and radius, a, has N turns per unit length and carries a current I.

(a) Show that the magnetic induction on the cylindrical axis in the limit NL→∞ is given by

$$B_z = \frac{\mu_0 NI}{2}(\cos\theta_1 + \cos\theta_2),$$

where the angles θ_1 and θ_2 are defined in the figure.

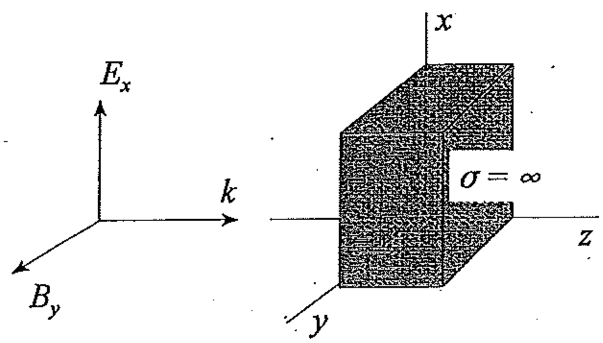
(b) How would the answer change in (a) if we assume that the solenoid is filled with linear material of susceptibility χ_m?



Consider a plane electromagnetic wave normally incident on a perfect conductor that fills the region $z > 0$. Assume that the electric field has amplitude E_0 and angular frequency ω.

(a) Show that standing waves are set up as a result of the reflection.

(b) Determine the resulting $\vec{B}$ field (for $z < 0$) in terms of the electric field amplitude E_0.



Hint: A useful trig identity is $\cos(\theta - \phi) - \cos(\theta + \phi) = 2\sin\theta\,\sin\phi$

Preliminary/MS Comprehensive Examination
Spring 2007

Thermodynamics 500-1

For an adiabatic process and an ideal gas show that for the pressure, P, volume, V, and temperature, T, that:

$TV^{(\gamma-1)}$ =constant

and PV^{γ}= constant, where $\gamma = C_P/C_V$, the ratio of specific heats.

Three identical bodies of constant heat capacity *C*, are initially at temperatures of 300, 300 and 100 K. If no work or heat is available from other sources, then by operating heat engines between the bodies, (a) what is the maximum amount of work which may be obtained, and (b) what is the highest temperature to which any one of the bodies may be raised?

Preliminary/MS Comprehensive Examination
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Modern Physics 500-1

What are the four postulates for the Bohr model for the atom?

By applying these postulates for the Bohr atom, show that the energies of the allowed levels are given by

$$E = -\frac{mZ^2e^4}{(4\pi\varepsilon_0)^2 2\hbar^2}\frac{1}{n^2},$$

where n = 1, 2, 3,...

Preliminary/MS Comprehensive Exam
Spring 2007
Modern Physics 500-2

In quantum mechanics, one can actually demonstrate that Newton's 2nd Law (in terms of momentum and potential) still applies, if one uses expectation values.

a) Show that $d\langle p\rangle / dt = -\langle dV(x)/dx\rangle$. Note, you will need to start with $\langle p\rangle$, and take time derivatives under the integral. Then, you can make a substitution, using the Schrodinger Equation (in one-dimension), assuming a potential *V(x)*.

b) Explain how this result can be used to describe the example of an infinite well (i.e., what happens inside the well? What happens at the walls?)