

Physics Entrance (Placement) Examination

August 25, 2006, 9 AM - 12:30 PM

- This examination has general questions from six areas of physics:
 - 1. Mechanics**
 - 2. Thermodynamics**
 - 3. Electricity and Magnetism**
 - 4. Optics and Waves**
 - 5. Mathematical Physics**
 - 6. Modern Physics**

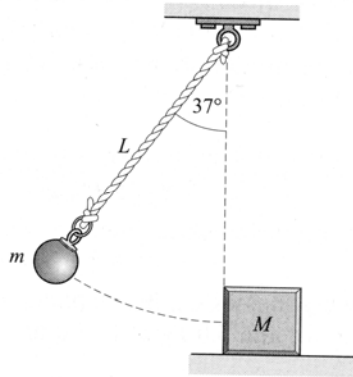
- Attempt nine problems using a separate sheet of paper for each problem (solve at least one from each area).

- Grading of the examination will be based on your approach to solving the problem, and on your application of basic physical principles. All problems are weighed equally.

- The last page includes the list of Fundamental Physical constants.

I. Mechanics

1). A pendulum consisting of a ball of mass m is released from the position shown in figure below and strikes a block of mass M . The block slides a distance D before stopping under the action of a steady friction force $0.2 Mg$. Find D if the ball rebounds to the angle of 20° .



2). At what point between moon and earth do the gravitational fields of these two bodies cancel?

Note that the earth's mass is 5.98×10^{24} kg, and the moon's is 7.35×10^{22} kg. The distance between the centers of the earth and the moon is 3.85×10^7 m.

II. Thermodynamics

1). A spring ($k=500$ N/m) supports a 400-g mass which is immersed in 900 g of water. The specific heat of the mass is 450 J/kg \cdot K. The spring is now stretched 15 cm and, after thermal equilibrium is reached, the mass is released so it vibrates up and down. By how much has the temperature of the water changed when the vibration has stopped?

Note that the specific heat of water is 4180 J/kg \cdot K.

2). Twenty grams of ice at precisely 0° C melts into the water with no change in temperature. By how much does the entropy of the 20-g mass change in this process? Explain the answer.

Note that the heat of fusion of water at 0° C is about 335 kJ/kg or 80 cal/g.

III. Electricity and Magnetism

1) In Rutherford's famous scattering experiments that led to the planetary model of the atom, an alpha particle (charge $+2e$, mass $=6.64 \times 10^{-27}$ kg), initially very far from the gold nucleus (charge $+79e$), is fired with velocity of 2×10^7 m/s directly toward the center of the gold nucleus. How close does the alpha particle get to the center before turning around? Assume the gold nucleus remains stationary.

2) A cyclotron designed to accelerate protons has a magnetic field with a magnitude of 0.45 T over a region of radius 1.2 m. What are:

a) the cyclotron frequency

b) the maximum speed acquired by the protons?

IV. Optics and Waves

- 1) A spherical mirror is to be used to form, on a screen 5 m from the object, an image five times the size of the object.**
 - a) Describe the type of the mirror required;**
 - b) Where should the mirror be positioned relative to the object?**

- 2) In a Young's interference experiment, the two slits are separated by 0.15 mm, and the incident light includes light of wavelengths $\lambda_1=540$ nm and $\lambda_2=450$ nm. The overlapping interference patterns are formed on a screen 1.4 m from the slits. Calculate the minimum distance from the center of the screen to the point where a bright line of the λ_1 light coincides with a bright line of the λ_2 light.**

V. Mathematical Physics

1) Verify that the following matrix is Hermitian. Find its eigenvalues and eigenvectors, write a unitary matrix U which diagonalizes H by a similarity transformation, and show that $U^{-1}HU$ is the diagonal matrix of eigenvalues.

$$H = \begin{pmatrix} 3 & 1-i \\ 1+i & 2 \end{pmatrix}$$

2) If $y = \int_0^{\sqrt{x}} \sin t^2 dt$, find dy/dx .

VI. Modern Physics

1) Calculate the energy of a conduction electron in silver at 800 K if the probability of finding an electron in that state is 0.95. The Fermi energy is 5.48 eV at this temperature.

2) Suppose the ionization energy of an atom is 4.1 eV. In the spectrum of this same atom, we observe emission lines with wavelengths 310 nm, 400 nm, and 1377.8 nm. Use this information to construct the energy-level diagram with the fewest levels. Assume that the highest levels are closer together.

FUNDAMENTAL PHYSICAL CONSTANTS

Speed of light in vacuum	$c=2.99792458 \times 10^8$ m/s
Planck constant	$h=6.626076 \times 10^{-34}$ J s
Boltzmann constant	$k_B=1.38066 \times 10^{-23}$ J/K
Gas constant	$R=8.31451$ J/mol/ K
Avogadro number	$N_A=6.0221367 \times 10^{23}$ particles/mol
Elementary charge	$e=1.60217733 \times 10^{-19}$ C
Coulomb constant	$k_e=8.99 \times 10^9$ N m ² /C ²
Electron rest mass	$m_e=9.1093897 \times 10^{-31}$ kg
Proton rest mass	$m_p=1.6726231 \times 10^{-27}$ kg
Gravitational constant	$G=6.67259 \times 10^{-11}$ m ³ /kg/s ²
Acceleration due to gravity	$g=9.80665$ m/s ²
Rydberg constant	$R_y=13.6056981$ eV
Bohr radius	$a_0=5.29177 \times 10^{-11}$ m
Fine structure constant	$\alpha=1/137.0359895$