

Physics Qualifying Examination

Friday August 23, 2002
9:00 a.m. – 12:30 p.m.

This examination has general questions from six areas of physics:

- I. Mechanics
- II. Thermodynamics
- III. Electricity and Magnetism
- IV. Optics
- V. Mathematical Physics
- VI. Modern Physics.

Attempt all problems using a separate sheet of paper for each.

Grading of the examination will be based on your approach to solving the problem, and on your application of basic physical principles.

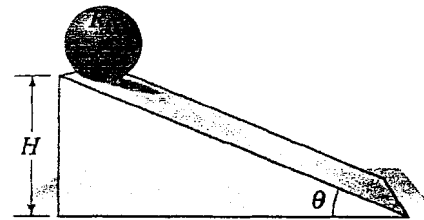
Physical Constants

Speed of light in vacuum	c	$3.00 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
Planck's constant	h	$6.63 \times 10^{-34} \text{ J}\cdot\text{s} = 4.14 \times 10^{-15} \text{ eV}\cdot\text{s}$
Electronic charge	e	$1.60 \times 10^{-19} \text{ C}$
Electron rest mass	m_e	$9.11 \times 10^{-31} \text{ kg}$
Proton rest mass	m_p	$1.67 \times 10^{-27} \text{ kg}$
Boltzmann's constant	k	$1.38 \times 10^{-23} \text{ J}\cdot\text{K}^{-1}$
Gas constant	R	$8.315 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
Permittivity of free space	ϵ_0	$8.85 \times 10^{-12} \text{ C}^2\cdot\text{N}^{-1}\cdot\text{m}^{-2}$
Permeability of free space	μ_0	$4\pi \times 10^{-7} \text{ T}\cdot\text{m}\cdot\text{A}^{-1}$
Gravitational constant	G	$6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2\cdot\text{kg}^{-2}$
Avogadro's number	N_A	$6.02 \times 10^{23} \text{ mol}^{-1}$

I. **Mechanics**

- A. A block of mass m , initially at rest, is dropped from a height h onto a scale on the earth's surface containing an initially uncompressed spring whose force constant is k . Find an expression for the distance the spring will be compressed. (*The mass of the plate of the scale onto which the mass falls may be neglected.*)

- B. What will be the speed of a solid sphere of mass M and radius R_0 when it reaches the bottom of an incline at angle θ if it starts from rest at a vertical height H and rolls without slipping? ($I_{\text{sphere}} = \frac{2}{5} mr^2$). *Ignore frictional losses.*



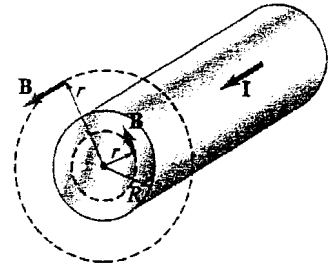
- C. If the solid sphere above is replaced by a hollow sphere of the same mass and radius, will its speed at the bottom of the incline be greater, the same or less than that of the solid sphere? Explain your answer.

II. Thermodynamics

- A. How much work is done when an ideal gas expands isothermally from volume V_i to volume V_f at temperature T ?
- B. A 30 MW geothermal electric power plant uses steam from the earth at 157°C to heat and vaporize isobutane, which is directed to a turbine connected to a generator. Upon exiting the turbine, the isobutane is cooled to 27°C using fans and condensed back to a liquid. The plant operated at 40% of the ideal (Carnot) efficiency. How many joules of energy are extracted from the steam each second?
- C. How many joules of heat are released by the power plant to the atmosphere each second?

III. Electricity and Magnetism

- A. A charge Q is placed on a solid, insulating sphere of radius a . Find expression for the magnitude of the electric field as a function of distance r from the center of the sphere for $r < a$ and $r > a$.
- B. What are the corresponding expressions for the electric field if the above sphere is conducting?
- C. Find an expression for the magnitude of the magnetic field B as a function of distance r from the center of a long, straight cylindrical conducting wire of radius R that carries a current I of uniform density. Consider both $r < R$ and $r > R$.



IV. Optics

- A. Use ray diagrams to illustrate the formation of real and virtual images of an object using a converging lens
- B. A swimming pool with a flat bottom is 2 m deep. What is the apparent depth to an observer standing next to the pool, if the index of refraction of water is $4/3$?
- C. The Hubble Space Telescope has a diameter of 2.4 m. Ignoring optical aberrations, what is the minimum angular separation of two stars that can be resolved by the telescope using visible light of wavelength 500 nm?