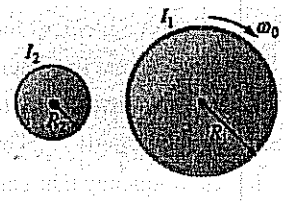
IMPORTANT NOTES:

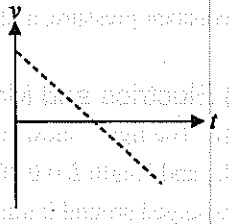
1. Please write down your answer on the answer sheet, NOT on the problem sheet.
2. Please answer the problems in the same order as they appear on the problem sheet, with clearly marked problem numbers on your answer sheet.

(1) Mechanics I

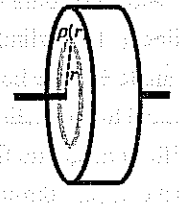
1. Two cylinders (radii R_1 and R_2) and rotational inertias I_1 and I_2 about their central axes are supported by frictionless axles perpendicular to the plane. The large cylinder is initially rotating clockwise with angular velocity ω_0. The small cylinder is moved to the right until it touches the large cylinder and is caused to rotate by the frictional force between the two surfaces. Eventually, slipping ceases, and the two cylinders rotate at each own constant rates in opposite directions. (a)[3] Find the final angular velocity of the small cylinder. (b)[3] Does the total angular momentum of the system conserve? And Why? (c)[3] Does the total kinetic energy conserve? And Why?



2. [6] The figure is the velocity-time graph for an object launched vertically into the air when we do not consider the air resistance. Draw the velocity-time relationship on the same graph when we consider the air-dragging force $D = bv$, where b is a constant.

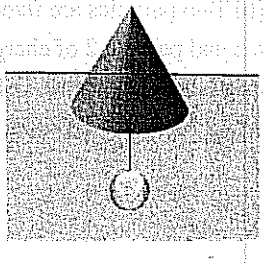


3. [5] A cylinder has a radius R and a thickness h. The density ρ of the material that makes the cylinder is a function of distance r to the central axis. Write down the integral form of the rotational inertia of this cylinder about its central axis: _____.



(2) Mechanics II and Thermodynamics

4. [6] The figure shows an iron ball suspended by thread of negligible mass from an upright cone that floats partially submerged in water. The cone has a height of 10 cm, and 7 cm of its height is above the water surface, a face area of 4π cm^2 on the bottom, and a



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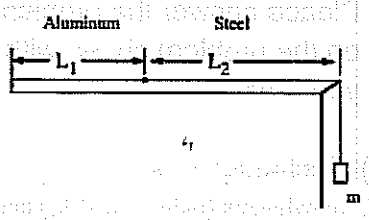
density of 0.3 g/cm^3. The radius of the iron ball is _____ cm. (iron density ≈ 7.8 g/cm^3.)

5. [6] In the attached figure, an aluminum wire, of length $L_1 = 50.0$ cm, cross-sectional area 1.25×10^{-2} cm^2, and density 2.60 g/cm^3, is joined to a steel wire, of density 7.80 g/cm^3, and the same cross-sectional area. The compound wire, loaded with a block of mass m = 10.0 kg, is arranged so that the distance L_2 from the joint to the supporting pulley is 86.6 cm. Transverse waves are set up on the wire by an external source of variable frequency; a node is located at the pulley. How many nodes are observed at the lowest frequency that generates a standing wave having the joint as one of the nodes?



(A) 2 (B) 5 (C) 8 (D) 13 (E) 15

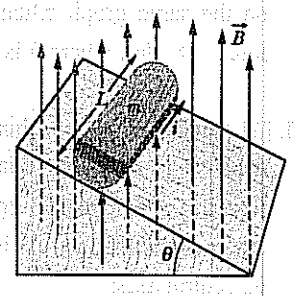
6. [8] Please prove the following relation,

$$PV^{\gamma} = constant$$

under adiabatic process for ideal gas, where $\gamma = C_p / C_v$, C_p is molar specific heat at constant pressure, and C_v is molar specific heat at constant volume.

(3) Electrics and Magnetics

7. [8] The figure shows a wood cylinder of mass $m = 0.50$ kg and length $L = 0.20$ m, with $N = 20.0$ turns of wire wrapped around it longitudinally, so that the plane of the wire coil contains the long central axis of the cylinder. The cylinder is released on a plane inclined at an angle θ to the horizontal, with the plane of the coil parallel to the incline plane. If there is a vertical uniform magnetic field of magnitude 0.25 T, what is the least current i through the coil that keeps the cylinder from rolling down the plane?



8. [6] Two particles are fixed to an x axis: particle 1 of charge $q_1 = 3.5$ C at $x = 20.0$ cm and particle 2 of charge $q_2 = -4.0q_1$ at $x = 70.0$ cm. At what coordinate on the axis is the net electric field produced by the particles equal to zero?

(A) 36.7 cm (B) 30.0 cm (C) 3.3 cm (D) −30.0 cm (E) −50.0 cm

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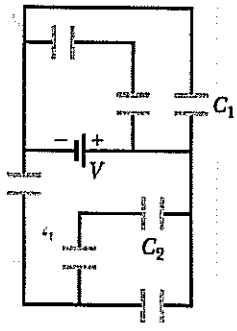
9. [6] In the figure, the battery potential difference V is 10.0 V and each of the seven capacitors has capacitance 10.0 μF. What is the charge on capacitor 2?
(A) 5.0 μC (B) 10.0 μC (C) 20.0 μC (D) 60.0 μC (E) 100.0 μC



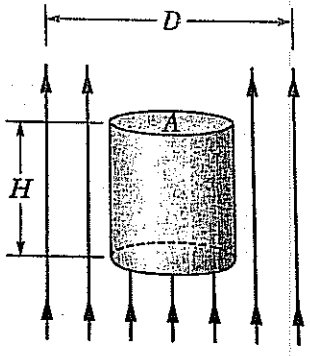
(4) Electromagnetic Waves

10. [5] Find the sum y of the following quantities: $y_1=A\sin(\omega t+\pi/12)$, $y_2=A\sin(\omega t+5\pi/12)$, $y_3=A\sin(\omega t+3\pi/4)$.

11. [8] A pion at rest decays into a muon and a neutrino. Their masses are listed in the table. Please find the momentum of the outgoing muon, in the unit of MeV/c.
(A) 10 (B) 20 (C) 30 (D) 40 (E) 50

Particle	Mass (MeV/c^2)
Pion	139.6
Neutrino	~ 0
Muon	105.7

12. [7] In the figure, a laser beam of power P and diameter D is directed upward at one circular face of a perfectly reflecting cylinder. Assume that the area A is smaller than the cross section of the laser beam. The cylinder is levitated because the upward radiation force matches the downward gravitational force. If the cylinder's density is ρ, what is its height H?



(5) Modern Physics

13. [6] Based on Bohr's model, the radius of a hydrogen atom with principle quantum number $n = 3$ is approximately equal to: (A) 0.5 Å (B) 0.5 nm (C) 1.5 Å (D) 1.5 nm (E) 2.0 Å

14. [4] Which one of the following elementary particles is the most massive? (A) τ lepton (B) top quark (C) W boson (D) Z boson (E) Higgs boson

15. [10] The time-independent ground-state wave function of the hydrogen atom has the following form: $Ae^{-r/a}$, where A stands for the normalization constant and a denotes the Bohr radius. What is the radial probability density function $P(r)$ for the above case? Determine A with the following constraint: $\int P(r)dr = 1$.

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