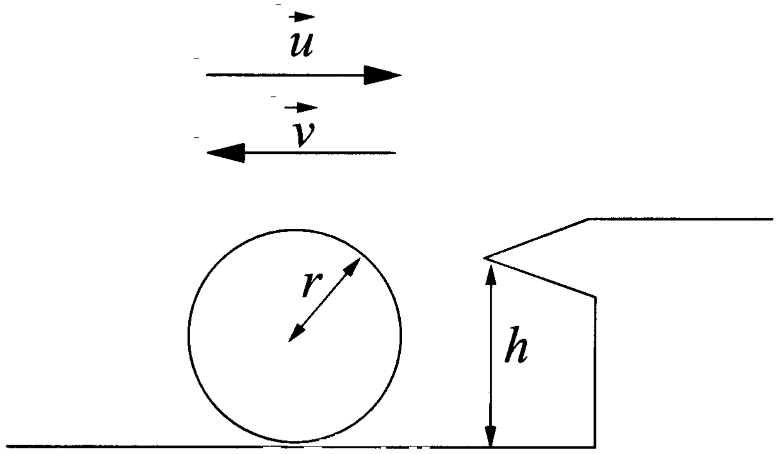
1. A ball of mass m and moment of intertia $I = \frac{2}{5}mr^2$ (where r is the radius of the ball) rolls on a smooth horizontal billiards table and impacts a cushion at normal incidence with translational speed u. The cushion exerts a horizontal force on the ball during impact at a height h above the table's surface. The ball rebounds from the cushion with speed v. At no time before, during, or after the collision with the cushion does the ball slip; it always rolls without slipping. Consider the change in momentum of the ball and derive an expression for the ratio $\frac{h}{r}$.



2. The limit to the sensitivity of a spring balance (a weight on the end of spring) is obtained when the root-mean-square fluctuation of its displacement becomes equal to the elongation produced by the weight. If the spring constant is α, calculate the smallest mass which can be measured at temperature T.

3. Find the spectrum of states for the two dimensional potential $V(x, y)$ which is equal to $a(x^2 + y^2)$ for $x \geq 0, y \geq 0$ and which is infinite elsewhere.

4. The single coil for a large superconducting magnet is driven with an external power supply in parallel with a 0.1 ohm resistor. The internal resistance of the supply is small compared to 0.1 ohm. The magnet is designed so that essentially all of the magnetic energy stored in this magnet is from a region bounded by a cylinder of length 2 meters and diameter 0.5 meters. Within this region the field is approximately constant and equal to $B(0)$.

When the magnet is operating at full field, the voltage across the power supply is essentially zero. To bring the field down quickly, the power supply is disconnected (although the parallel resistor remains in place). The instant after disconnection, the voltage across the resistor is 20 volts. This voltage decreases exponentially in time with a time constant $(1/e)$ of 100 seconds.

(a) Determine the current in amperes in the coil just before the switch is opened.

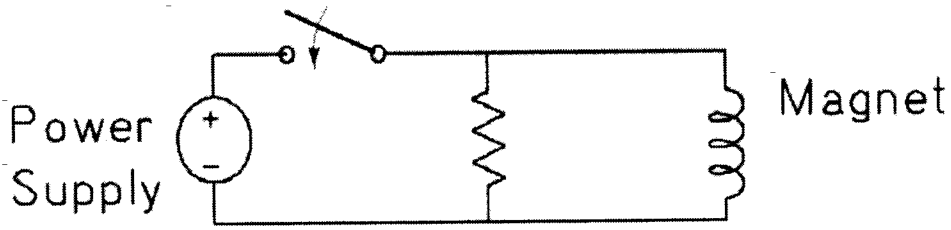
(b) What is the power in watts being dissipated in the resistor the instant after the supply is disconnected.

(c) Write down an expression for the rate of power produced in the resistor as a function of time.

(d) Determine the number of Joules of energy initially stored in the magnetic field.

(e) Determine $B(0)$, the magnitude of the initial field in the region of constant field.

Note: $\mu_0 \quad 4\pi \times 10^{-7} \frac{N}{m^2}$



5. In a potential free region, the electrons in a 10.0 μA beam have deBroglie wavelengths of 0.3 nm. At the position $x = 0$, the beam enters a sharply defined region where the potential drops by 16.0 eV

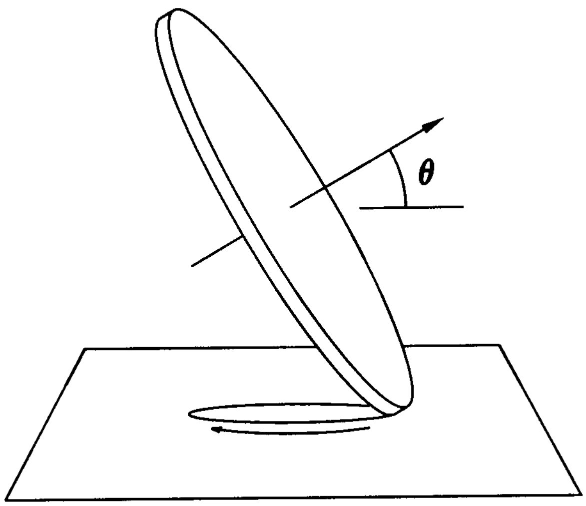
(a) Using $\psi_I(x)$ for $x \leq 0$ and $\psi_{II}(x)$ for $x \geq 0$, write the continuity conditions for the wavefunction at $x = 0$.

(b) What current is reflected at the boundary?

6. Consider the electric potential of a collapsing soap bubble of radius 10 cm and wall thickness 3.3×10^{-8} m. The bubble is initially charged to a potential of 100 Volts. The bubble bursts and collapses to a spherical droplet containing all of the soap solution which formed the bubble. The soap solution conducts electricity.

Determine the potential on the droplet.

7. A coin is spinning on a horizontal surface, and the axis of the coin maxes an angle θ with the surface. The point of contact between the coin and the surface does not slip. Consider the coin to be a thin disk with mass m and radius a. Find the expressionfor the angular rate at which the point of contact moves around the circle of contact points on the horizontal surface. Express your solution in terms of m, a, θ and Earth's gravity g, as necessary.



8.

A paramagnetic solid is composed of N atoms per unit volume, each with permanent magnetic dipole moment μ. In the presence of a magnetic field with flux density B the particles occupy one of two spin-states with the magnetic moments oriented parallel or antiparallel to the B field, with energies $\pm\mu B$.

(a) Use Boltzman statistics to determine the fraction f of dipoles oriented parallel to the field and the fraction $(1-f)$ oriented antiparallel to the field at temperature T.

(b) Determine the net dipole moment per unit volume, or magnetization, M.

(c) The solid is held at a temperature of $1K$ in a magnetic field of 1 Tesla and thermally isolated so there are no thermal spin fluctuations. If the magnetic field is now reduced to 0.3 T, what is the temperature of the system?