Karlsruhe Institute of Technology - International Department GmbH

Pre-Semester 2010 - Physics Course - Extra Tutorial

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1. Generator

In a homogeneous magnetic field B a rectangular metal frame is rotated around one of its (central) axes with constant angular velocity ω. Each of the edges which are *parallel* to the rotation axis is a wire with length ℓ, circular cross section with (small) diameter d, and resistivity $\rho_\parallel$. Each of the edges which are *perpendicular* to the rotation axis is a wire with length s, (small) cross section A_{cs}, and resistivity $\rho_\perp$.

Initially, the frame is oriented perpendicular to the magnetic field.

(a) Calculate the total resistance R of the metal frame.

(b) What voltage $U_{\mathrm{ind}}(t)$ is induced in the metal frame? (Neglect self-induction effects.)

(c) Find the current $I(t)$ which runs through the frame in terms of B, ω, ℓ, s, and R.

(d) What electric power $P_{\mathrm{el}}(t)$ is dissipated in the frame?

(e) What force $F_L(t)$ is exerted by the magnetic field on each of the edges parallel to the rotation axis?

(f) What is the moment of torque $M(t)$ which is necessary to keep the frame rotating with constant angular velocity ω?

(g) What is the mechanical power $P_{\mathrm{mech}}(t)$ provided by this moment of torque?

2. Physical Pendulum

Consider a physical pendulum which consists of a rod with mass m_r and length ℓ (and negligible lateral extent) and of a point mass with mass m_p which is attached in the middle of the rod. The pendulum may rotate around an axis which goes through one of the rod's ends. Gravity g is acting.

(a) Calculate the moment of inertia Θ of the pendulum.

(b) In case the pendulum makes an angle ϕ with its equilibrium (vertical) position, what is the moment of torque acting on it?

(c) Write down the equation of motion for $\phi(t)$ and approximate it for small angles.

(d) Assuming the physical pendulum to be initially at rest and to make a (small) angle ϕ_0 with the vertical, give the solution $\phi(t)$.

(e) Sketch $\phi(t)$ and mark the initial angle ϕ_0 and the period T in the diagram.

(f) Sketch what would change (qualitatively) if we took, say, (weak) Stokes friction into account?

Note: The moment of inertia of a rod (mass m_r, length ℓ) with respect to a perpendicular axis through its center of mass is $\Theta_{\mathrm{cm}} = \frac{1}{12} m_r \ell^2$.

3. Falling Stone

A stone is shot in horizontal (x-)direction with velocity $v_{x0} = 10\,\mathrm{m/s}$, starting at $x(t = 0) = 0$ and in a height $y(t = 0) = h = 5\,\mathrm{m}$. Gravity is acting in negative y-direction, $g = 10\,\mathrm{m/s^2}$.

(a) Give the coordinates $x(t)$, $y(t)$ as function of time.

(b) At what time T does the stone hit the ground? What is its range s?

(c) What is the stone's velocity v_f shortly before the impact? What angle α does it make with the ground?