Some constants: $e = 1.6\times10^{-19}$ C, $\varepsilon_0 = 8.85\times10^{-12}$ C^2/Nm^2, $m_p = 1.67\times10^{-27}$ kg

1. A uniform solid disk of radius R of 10 cm and mass M of 1.0 kg (rotational inertia through center of mass: $MR^2/2$) is free to rotate on a frictionless pivot through a point on its rim (*Figure 1*). If the disk is released from rest in position shown by the circle with free-fall acceleration g of 9.8 m/s^2, (a) what is the speed of its center of mass when the disk reaches the position indicated by the dashed circle? (3%) (b) What is the speed of the lowest point A on the disk in the dashed position? (2%) (c) What is its speed at point B? (5%)

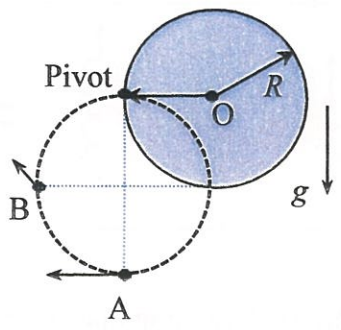

Figure 1

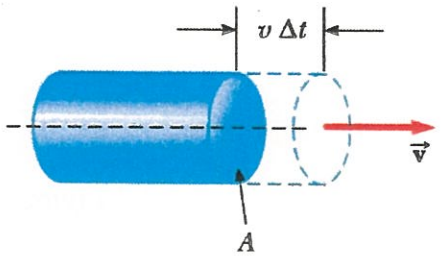

Figure 2

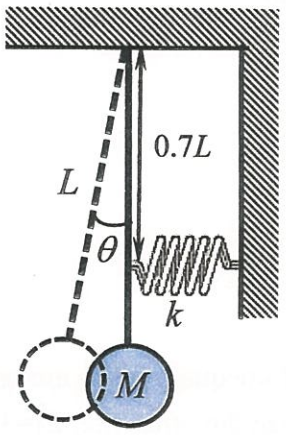

Figure 3

2. Suppose a car of mass M is modeled as a cylinder with cross-sectional area A moving with a speed v, as in *Figure 2*. In a time Δt, a column of air of mass Δm must be moved a distance $v\Delta t$ and given a kinetic energy $(1/2)(\Delta m)v^2$. (a) Using this model, show that the drag force due to air resistance is $(1/2)\rho Av^2$, where ρ is the density of air. (3%) (b) For a car with maximum driving power of P, find its terminal speed (denoted by ρ, A, and P) as the maximum power is driven. (3%) (c) If the driving power is turned off as the car reaches the terminal speed and neglect other resistive forces, find its speed at any time t after it reaching the terminal speed.(4%) (denoted by ρ, A, P, M, and t)

3. A pendulum of length L and mass M has a spring of force constant k connected to it at a distance $0.7L$ below its point of suspension (*Figure 3*). For small values of the amplitude ($\theta << 1$), find (a) the angular frequency (8%) and (b) the period of vibration of the system. (2%) (denoted by L, M, k, and gravitational acceleration g)

4. A uniform rope of mass m and length L hangs from a ceiling. (a) Show that the speed of a transverse wave on the rope is a function of y, the distance from the lower end, and is given by $v = \sqrt{gy}$. (5%) (b) Show that the time a transverse wave takes to travel the length of the rope is given by $t = 2\sqrt{L/g}$. (5%)

5. An ideal gas with $C_p/C_V \equiv \gamma = 5/3$ is the working substance in an engine that operates on the cycle shown in *Figure 4*. Here C_p is the molar specific heat at constant pressure and C_V is the molar specific heat at constant volume. Volume $V_3 = 4.0V_1$. Processes 2→3 and 4→1 are reversible and adiabatic. (a) What is the temperature ratio of T_2/T_1? (2%) (b) Show that pV^γ = a constant during such adiabatic processes via *the first law of thermodynamics* and *the ideal gas law*, where p is the pressure and V is the volume. (4%) (c) What is the engine efficiency? (4%)

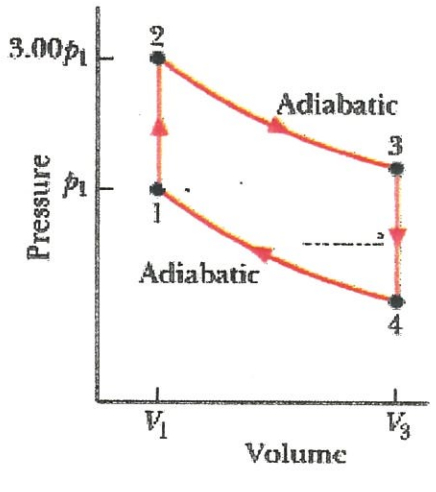

Figure 4

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6. If the measured electric field on earth surface is in the average of 100 N/C pointing downward, what is the total charge on the earth surface? You need to specify the sign of the charge and write down the needed equation for your answer.

7. A cyclotron with Dee radius 2.5 m is operated at an oscillator frequency of 100 MHz to accelerate protons. What magnitude B of magnetic field is required to achieve resonance? What is the maximum kinetic energy (in MeV) of an emerging proton?

8. Left figure (*Figure 5*) shows an R-L-C circuit connected in parallel with an AC voltage source $V_S = V_0 \cos(\omega t)$. Find out I_R, I_L, I_C and I_S.

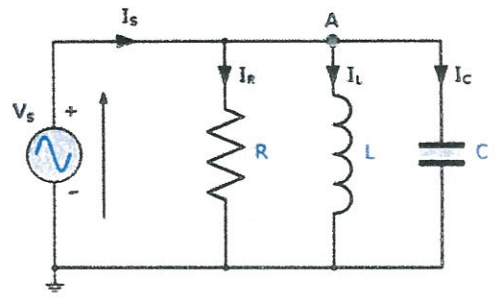

Figure 5

9. Slits of unequal widths are used in a double-slit experiment with laser beam (wave length λ). Assuming one slit can pass 9 times light than the other (i.e. $E_1=3E_2$). Determine the intensity function $I(\theta)$. Note that the separation between the two slits is d and we have the maximum intensity I_0 at $\theta = 0$.

10. Write down the Maxwell's equations and the related physical meaning for each equation.

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