1. A uniform solid cylinder with mass of M and radius of $2R$ rests on a flat tabletop. A string wrapped around the cylinder runs over a uniform disk-shaped pulley with mass M and radius R that is mounted on a frictionless axle through its center. A block of mass M is suspended from the free end of the string (**Fig. 1**). The string doesn't slip over the pulley surface, and the cylinder rolls without slipping on the tabletop (Assume the string is massless and inextensible).

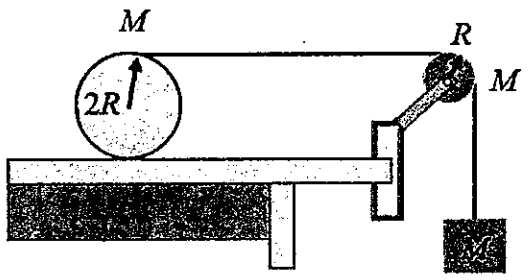


Figure 1

The system is released from rest at $t_0 = 0.0$ s. At time t, find:
(a) the magnitude of the acceleration of the block [6 points],
(b) the magnitude and the direction of the static friction force acted on the cylinder [6 points],
(c) the total kinetic energy of the cylinder [6 points].

2. A heat engine operating using the cycle shown in **Figure 2**. The working substance is n moles of diatomic ideal gas. Find:
(a) The entropy difference between points 2 and 4. [6 points]
(b) Total heat absorption by the gas during the cycle. [6 points]
(c) Total work done by the gas during the cycle. [6 points]
(d) Efficency of the engine. [4 points]

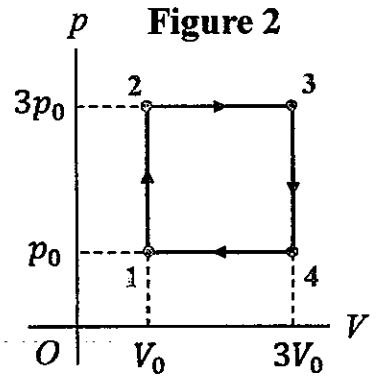


Figure 2

3. A transverse harmonic string wave has an amplitude of 50.0 mm, a wave length of 6.00 m, and a wave velocity of 12.0 m/s in the negative x direction. At $x = 0$ and $t = 80.0$ ms, the transverse displacement is $y =$ 25.0 mm and $\partial y/\partial t < 0$.
(a) Write an expression for the traveling wave function $y(x, t)$. [5 points]
(b) The tension of the string is 36.0 N, what is the average power transferred along the string? [5 points]

4. As shown in **Figure 3**, an infinite nonconducting sheet with a round hole of radius R has a uniform surface charge of density σ. Find the expression of magnitude of the electric field at point P, with a distance z along the central axis of the hole. [10 points]

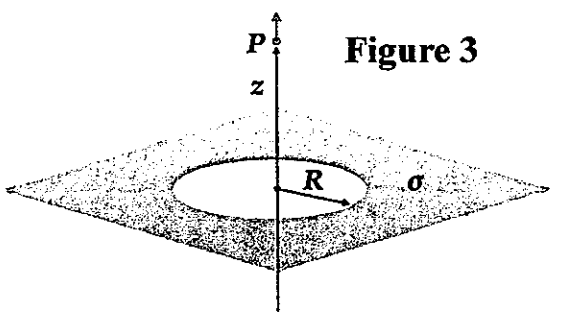


Figure 3

5. As shown in **Figure 4**, in cross section, a cylindrical capacitor of length L formed by two coaxial cylinders of radii a and b. Assuming L is much greater than b so that we can neglect the fringing of the electric field that occurs at the ends of the cylinders. The capacitor is charged in a circuit, and the electric potential difference between the two cylinders is V. The capacitor is then disconnected from the circuit. A liquid dielectric material of dielectric constant κ is injected to the capacitor, and is only half filled. After filling the dielectric material, what is the electric potential difference between the two cylinders? [10 points]

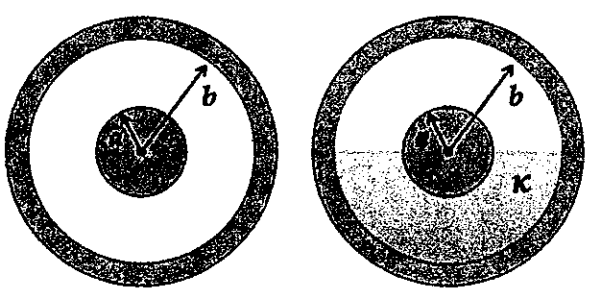


Figure 4

6. A copper rod of mass m rests on two horizontal rails with a distance d apart from each other and carries a current i from one rail to the other as shown in **Figure 5**. The coefficient of static friction between rod and rails is μ. A uniform magnetic field B is applied to the system and puts the rod on the verge of sliding, what is the angle of magnetic field with respect to the direction of tails, if the applied magnetic field is at minimum? [10 points]

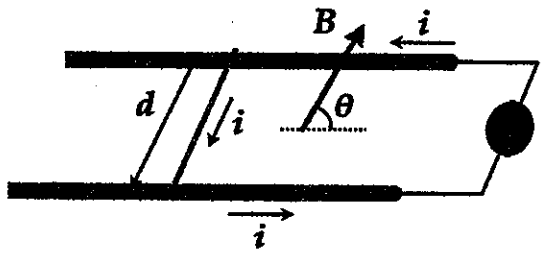
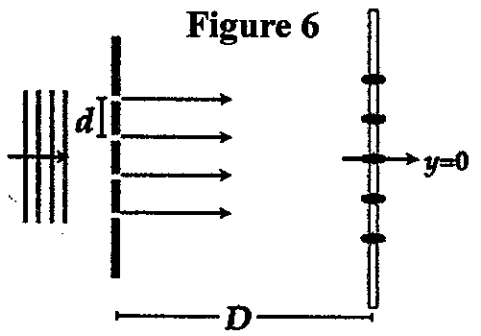


Figure 5

7. Consider a "four-slit" interference experiment as shown in **Figure 6**. The distance between the slits is d, while the distance between the slits and the screen is D ($D \gg d$). A coherent monochromatic light at a wavelength of λ is directed to the slits. Find the distance between the first dark fringe and the central maximum on the screen. [10 points]

Figure 6



8. A relativistic particle of mass M with total energy E decays into a lighter particle of mass m together with some other undetected particles. The particle m also decays afterwards. The proper lifetime of particle M is measured to be T and the proper lifetime of particle m is t. If half of the kinetic energy of particle M has been transmitted to particle m during this process, what are the flight distances of the particle M and of the particle m, from an observer at rest? [10 points]

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