1. (a) The position $y$ of a particle moving along the $y$ axis depends on the time $t$ according to the equation $y = at - br^2$. Find the dimensions of the quantities $a$ and $b$. (b) Plot a graph which represents the motion of an object moving with a constant speed. The $x$-axis is the time and the $y$-axis is the displacement.

2. (a) A system of $n$ moles of ideal gas undergoes an isothermal process at temperature $T$. The initial and final volume of the system is $V_i$ and $V_f$, respectively. Find the work done by this process. In your answer, you may need to use the ideal gas constant $R$. (b) Consider a system of $n$ moles of ideal gas follows a free expansion process which takes the system from an initial state to a final state where the volume of the system is doubled, i.e., $V_f = 2V_i$. Find the entropy change of this system. $R$ is the ideal gas constant.

3. A solid disk of radius $r$ and mass $m$ rolls down a slope from rest, as shown in the figure.

Let the angle of the slope be $\theta$. Find (a) (3 points) the linear acceleration of the rolling disk; (b) (3 points) the frictional force between the disk and the slope; (c) (4 points) the speed of the disk at the bottom of the slope if the disk travels a distance $L$ to reach the bottom of the slope.

4. A tank is filled with water to a height $H$. A hole is punched in one of the walls at a depth $h$ below the water surface, as shown in the figure right:

(a) (3 points) Evaluate $x$, the distance from the base of the tank to the point at which the resulting stream strikes the floor. (b) (3 points) Could a hole be punched at another depth which would give the same range? (c) (4 points) At what depth should the hole be punched to maximize the range?

5. A spherical hollow is made in a lead sphere of radius $R$, such that its surface touches the outside surface of the lead sphere and passes through its center. The mass of the sphere before hollowing was $M$. With what force, according to the law of universal gravitation, will the hollowed lead sphere attract a small sphere of mass $m$, which lies a distance $d$ from the center of the lead sphere on the straight line connecting the centers of the spheres and of the hollow?
6. (10 %)
   Please calculate the current $i$ through the battery (a) just after $S$ is closed (b) a long time later. [where $\mathcal{E}$ = emf of the battery, $L$ = inductor, $R$ = resistor, and $S$ = switch]

![Diagram](image)

7. (10%)
   For a charging circular plates with area $A$ (neglecting the edge effect), the external current $i$ that is charging the plates changes the electric field $E$ between the plates. If, between the plates, $i_d$ is the displacement current associated with that changing field $E$ then show that $i_d = i$.

![Diagram](image)

8. (10%)
   If a light enters a 90° triangular prism at point $P$ with incident angle $\theta$ and then some of it refracts at point $Q$ with an angle of reflection of 90°. (a) What is the index of reflection of the prism in terms of $\theta$? (b) What, numerically, is the maximum value that the index of refraction can have?

![Diagram](image)

9. (10%)
   The plastic rod of length $L$ has the non-uniform linear charge density $\lambda = cx$, where $c$ is a positive constant. (a) With $V = 0$ at infinity, find the electric potential at point $P$ on the $y$ axis. (b) Find the electric field component $E_y$ at $P$.

![Diagram](image)

10. (10%)
    An electron with mass $m$ is confined to an (one-dimensional) infinitely deep potential energy well of width $L$. (a) What is the normalized wave functions $\psi_n(x)$? (b) What is the quantized energies $E_n$?