1. The reaction of Na with CH_3Cl by irradiation is according to the equation

$$Na(g) + CH_3Cl(g) \longrightarrow NaCl(g) + CH_3(g).$$

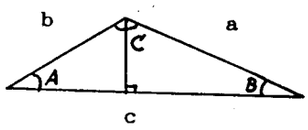
The pressures of Na and CH_3Cl will be adjusted to maintain the size of "flame" (reaction zone) at some convenient magnitude (in radius r). The equation of the mass continuity for sodiu is as

$$\frac{d^2PNa}{dr^2} + \frac{2}{r}\frac{dpNa}{dr} - \frac{kpCH_3Cl}{D_{Na}} = 0.$$

The minimum value of r is the nozzle radius r_o. At this value of radius $pNa = p_o$, and at $r = R$, $pNa = pl$. What is the k value? (10%)

2. Express the Laplace's equation $\partial^2T/\partial x^2 + \partial^2T/\partial y^2 = 0$ in polar coordinates and solve it. (15%)

3. Consider the triangle below.



(a) Show, using elementary trigonometry, that

$$b\cos A + a\cos B = c$$
$$c\cos A + a\cos C = b$$
$$c\cos B + b\cos C = a$$

(b) If the system of part (a) is thought of as a system of three equations in the three unknowns cos A, cosB, and cosC, show that the determinant of the system is nonzero.

(c) Use Cramer's rule to solve for cosC.

(d) Use part (c) to prove the law of cosines:

$c^2 = a^2 + b^2 - 2ab\cos C$. (15%)

4. Find the mass of a metallic sheet in the shape of the hemisphere $x^2 + y^2 + z^2 = 9$, $z \geq 0$, $x^2 + y^2 \leq 9$, if its density is proportional to it distance from the origin. (10%)

5. A block of mass $m = 5\ kg$ slides down a surface inclined 37° to the horizontal, 14% See fig. 1. The coefficient of sliding friction is 0.25. A string attached to the block is wrapped around a flywheel on a fixed axis at O. The flywheel has a mass $M = 20\ kg$, an outer radius $R = 0.2\ m$, and a moment of inertia with respect to the axis of $0.2\ kg \cdot m^2$.

(a.) What is the acceleration of the blocks down the plane?

(b.) What is the tension in the string?

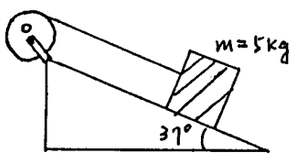


fig. 1.

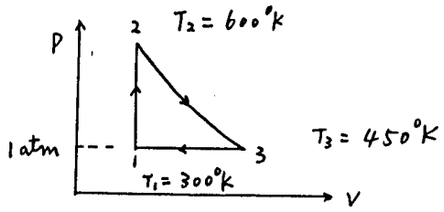


fig. 2.

6. A heat engine takes 0.1 mole of an ideal gas around the cycle shown in 12% fig. 2. The value of γ for this gas is $5/3$.

(a.) Find the pressure and volume at points 1, 2, and 3?

(b.) Find the net works done by the gas in the cycle?

7. See fig. 3. Find $\vec{E}(r, \theta)$ and $V(r, \theta)$ of the electric dipole? 10%

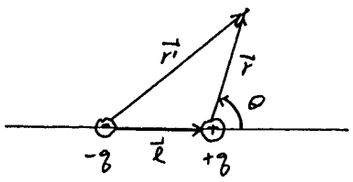


fig. 3

8. A long metal cylinder of radius r_a is supported on an insulating stand on the axis of a long hollow metal cylinder of inner radius r_b. The positive charge per unit length on the inner cylinder is λ, and there is an equal negative charge per unit length on the outer cylinder. 14%

(a.) Calculate the $\vec{E}(r)$ and $V(r)$ for

① $r < r_a$ ② $r_a < r < r_b$ ③ $r > r_b$

(b.) ① Calculate the capacitance of a length ℓ of this capacitor's structure?

② If $r_b - r_a = d$, when $d \ll r_a$. discuss the result about ①?