本試題禁用計算機作答

1. Assume the root-mean-square average speed of a hydrogen molecule (H_2) at temperature T_H is v_H. What is the root-mean-square average speed of an oxygen molecule (O_2) at temperature T_O? (10%)
2. An airplane is flying from city A to city B. Assume the distance is L, the speed of airplane is v_a, and the speed of wind is v_w. Due to the wind, the direction of the airplane must be turned at an angle θ as shown in Fig. 1.
   (a) What is the angle θ? (5%)
   (b) What is the time needed for the airplane to fly from city A to city B? (5%)

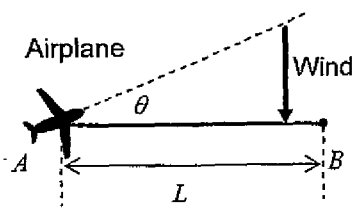

Fig.1 Problem 2.

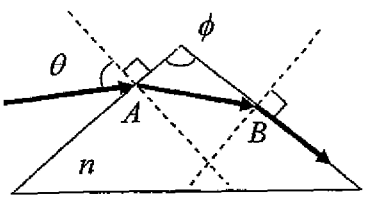

Fig.2 Problem 3.

3. A light ray enters a prism of refractive index n and vertex angle ϕ at point A with an incident angle θ (Fig. 2). The light ray is then refracted at point B. Assume θ is carefully adjusted such that the light ray emerges along the surface of the prism.
   (a) What is the prism index n? (15%)
   (b) When ϕ=90°, what is the maximum value of n? (5%)
4. The Gauss law is $\varepsilon_0 \int_S \mathbf{E}\cdot d\mathbf{S} = q$, where ε_0 is the permittivity of free-space, S is a closed surface of integration, $\mathbf{E}$ is the electric field, and q is the enclosed net charge.
   (a) Show that the potential function $\phi = k/r$ satisfies the Gauss law, where k is a constant. And find the charge q (in terms of k and other constants). (10%)
   (b) Assume the potential function becomes $\phi = A\,[\exp(-r/L)]\,/r$, where A and L are constants. Find the charge q as a function of r. What is q at infinity? (10%)
5. The electric field components of a plane electromagnetic wave traveling in the positive z direction can be written as $E_x = E_{mx}\cos[\omega(t-z/c)]$, $E_y = E_{my}\cos[\omega(t-z/c)]$, and E_z=0, where E_{mx} and E_{my} are constants.
   (a) What are the magnetic field components B_x, B_y, and B_z? (10%)
   (b) What are the instantaneous energy flow rate and the intensity of the wave? (10%)
6. Consider a particle of mass m falling down from a building. Due to air resistance, the equation of motion of is written as $md^2z/dt^2 = mg - \alpha v$, where z is the position, v is the velocity, g is the acceleration of gravity, and α is a positive constant. Assume v is zero initially and the time needed to reach the ground is τ.
   (a) Find v a function of t. (10%)
   (b) What is the height of the building? (5%)
   (c) From the result of part (b), show that the height of the building is approximately equal to $g\tau^2/2$ when α is small. (5%)