$\int (x^2 + a^2)^{-3/2}\, dx = x\,[a^2 (x^2 + a^2)^{1/2}]^{-1}$

1. A particle with positive charge q and mass m = 1.53×10^{-15} kg is traveling through a region containing a uniform magnetic field $\vec{B} = -(0.0220\ \text{T})\hat{k}$. At a particular instant of time the velocity of the particle is $\vec{v} = (1.22 \times 10^6\ \text{m/s})(4\,\hat{i} - 3\,\hat{j} - 12\,\hat{k})$, and the force $\vec{F}$ on the particle has a magnitude of 1.75 N. a) Determine the charge q. b) Determine the acceleration $\vec{a}$ of the particle. c) Explain why the path of the particle is a helix, and determine the radius of curvature R of the circular component of the helical path. d) Determine the cyclotron frequency of the particle. e) Although helical motion is not periodic in the full sense of the word, the x- and y-coordinates do vary in a periodic way. If the coordinates of the particle at t = 0 are (x, y, z) = (R, 0, 0), determine its coordinates at a time t = 2*T*, where *T* is the period of the motion parallel to the xy-plane. (15 %)

2. Mass M is distributed uniformly over a disk of radius a. Find the gravitational force (magnitude and direction) between this disk-shaped mass and a particle of mass m located a distance x above the center of the disk. Does your result reduce to the correct expression as x becomes very large? (15 %)

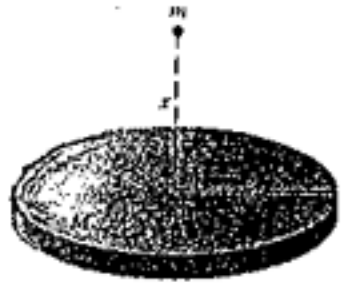

Fig. 1

3. What is the thermal efficiency of an engine that operates by taking n moles of nitrogen gas through the following cycle? The nitrogen can be treated as an ideal gas. $\gamma = 1.40$

a) Start with n moles at p_0, V_0, T_0.

b) Change to $2p_0$, V_0 at constant volume.

c) Change to $2p_0$, $2V_0$ at constant pressure.

d) Change to p_0, $2V_0$ at constant volume.

e) Change to p_0, V_0 at constant pressure.

(16 %)

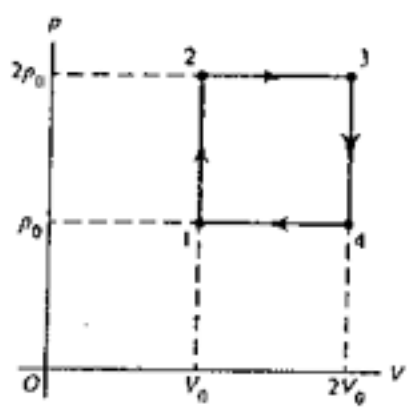

Fig. 2

(背面仍有題目,請繼續作答)

4. The wire in Fig. 3 is infinitely long and carries current *I*. Calculate the magnitude and direction of the magnetic field that this current produces at point P. (15 %)

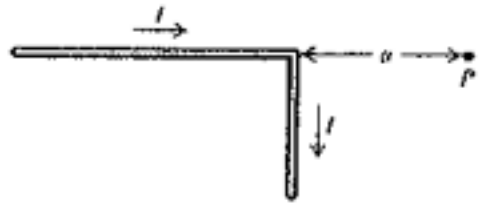

Fig. 3

5. A very long solenoid with *n* turns per unit length and radius *a* carries a current *i* that is increasing at a constant rate d*i*/dt. a) Calculate the magnetic field and induced electric field at a point inside the solenoid at a distance *r* from the solenoid axis. b) Compute the magnitude and direction of the Poynting vector at this point, and show that $\vec{S}$ is directed inward toward the axis of the solenoid. c) Find the magnetic energy stored in a length *l* of the solenoid and the rate at which that energy is increasing due to the increase in the current. d) Consider a cylindrical surface of radius *a* and length *l* that coincides with the coils of the solenoid. Integrate the Poynting vector over this surface to find the total rate at which electromagnetic energy is flowing into the solenoid through the solenoid walls. (20 %)

6. Explain the following terms in words.

a) frame of reference and inertial frame of reference. (4 %)

b) eddy current. (4 %)

c) coherent light. (4 %)

d) a p-n junction in thermal equilibrium and under forward-bias condition. (7 %)