國　立　清　華　大　學　命　題　紙

94 學年度 物理學系 (0504) 天文研究所 (0505) 0402 碩士班入學考試

科目 普通物理　科目代碼 0501 共 4 頁 第 1 頁 *請在試卷【答案卷】內作答

注意：

1. 請按題目順序作答。
2. 填充題不需要寫計算過程。

甲. 填充題(每空格 3 分，依號碼順序填寫在試卷上)

1. A uniform solid sphere of radius R and mass M rolls smoothly (without sliding) from rest, descending a vertical height h, down to the bottom of a ramp. What are its rotational kinetic energy K_r and translational kinetic energy K_t when it reaches the bottom of the ramp? Express K_r and K_t in terms of M, R, h, and g.
   K_r = (1) ; K_t = (2)

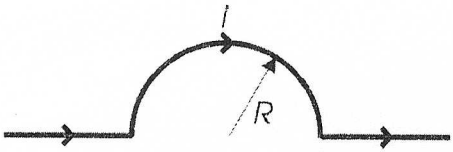
2. A satellite of mass m is in a circular Earth orbit a height h above the surface of Earth. Let M and R be the mass and radius of the Earth. What is the period T of the satellite in terms of M, m, R, h, and G?
   T = (3)

3. Two trains are traveling toward each other at speeds of v_1 and v_2 with respect to the ground. The train with speed v_1 is blowing a whistle at a frequency f. Let v_s be the speed of sound. What is the frequency f' heard on the other train? What frequency (f") is heard on the other train if the wind is blowing at v_w toward the whistle and away from the listener? f' = (4) ; f" = (5)

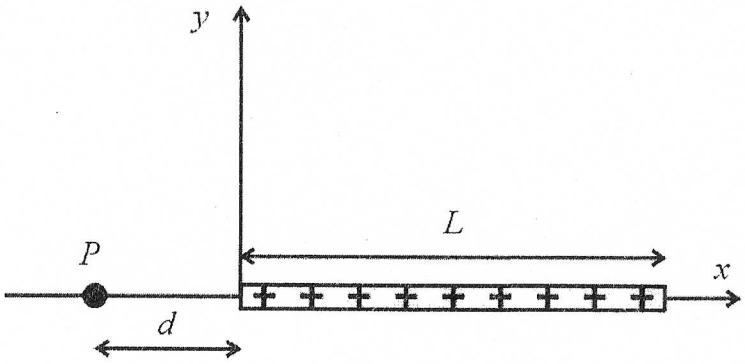
4. A block of metal A with mass m_1 and specific heat c_1 is in thermal contact with a block of metal B with mass m_2 and specific heat c_2 in an insulating box. The initial temperatures of metal A and metal B are T_1 and T_2, respectively. What is the final equilibrium temperature T_f of the two-block system? What is the change in the entropy ΔS of the system? Express T_f and ΔS in terms of m_1, m_2, c_1, c_2, T_1, and T_2. T_f = (6) ; ΔS = (7)

5. Electrons (mass m, charge $-e$) are accelerated from rest through a potential difference V and are then deflected by a magnetic field $\boldsymbol{B}$ that is perpendicular to their velocity. The radius of the resulting electron trajectory is:__(8)__ (in terms of m, e, V, B)

6. Find the magnitude of the magnetic field at point P, at the center of the semicircle shown below in terms of μ_0, I, and R:__(9)__



7. A thin insulating rod of length L and uniform positive charge Q lying on the x axis. (a) With $V = 0$ at infinity, find the electric potential at P on the axis, at distance d from one end of the rod.__(10)__ (b) From that result, find the electric field at P.__(11)__



乙. 計算題 (67%)

1. (10%) A tunnel is drilled all the way through the center of a planet of uniform density with mass M and radius R. The motion of an object of mass m in the tunnel is simple harmonic. Determine (**a**) the maximum speed of the object (**b**) the period of the simple harmonic motion.

2. (10%) The potential energy of the two atoms in a diatomic molecule can be written as

$$U(r) = -\frac{a}{r^6} + \frac{b}{r^{12}},$$

where r is the distance between the two atoms and a and b are positive constants. Determine (**a**) the distance r_{min} where the potential energy is the minimum and (**b**) the binding energy $E_{binding}$.

3. (10%) The Maxwell's speed distribution law for gas molecules can be expressed as $P(v) = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2} v^2 \exp(-Mv^2/2RT)$,

where P(v) is the probability distribution function, M is the molar mass of the gas, R is the gas constant, T is the gas temperature, and v is the molecular speed. Derive (**a**) the average speed v_{avg} and (**b**) the most probable speed v_P.

[Hint: $\int x^{2n+1} e^{-ax^2} dx = \frac{n!}{2a^{n+1}}$ (a>0)]

4. (15%) Consider a constant current (I) in a long straight wire of length ℓ and radius a. This wire has a resistance R. An electric field E in the wire drives the current, and the current produces a magnetic field B that circulates around the wire. (**a**) What is the magnitude and direction (using the cylindrical coordinate system) of the Poynting vector along the wire? (**b**) What is the amount of energy per second that flows into the wire? (**c**) Show that all of the electromagnetic energy converts to the thermal form in the wire (I^2R).

5. (10%) Derive the expression for the intensity pattern for a three-slit grating:

$$I = 1/9 * I_{max}(1+4\cos\phi+4\cos^2\phi),$$

where d is the distance between the centers of the slits, θ is the angle from the central axis to the observation point on the screen, and $\phi = (2\pi d\sin\theta)/\lambda$. Assume that $a << \lambda$, where a is the slit width.

6. (12%) An insulating slab of dielectric constant κ is slowly slid between the plates of a parallel-plate capacitor of area A, length ℓ, and plate separation d. What attractive force acts on the slab if (**a**) the charge ($Q = Q_0$), or (**b**) the voltage ($V = V_0$) of the capacitor is kept constant during the course? (Hint: calculate first the electrostatic energy as a function of x.)