Course Code: 101180121 **Semester I AY2020/2021**

BEIJING INSTITUTE OF TECHNOLOGY

College Physics II

Final Exam (A)

Time allowed: 2 hours

ID:_____ Name:_____ Class No.:_____ Total Score:_____

Problem	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Marks								

INSTRUCTIONS: This examination paper contains a total of **EIGHT** problems, with a full score of 100 marks. Solve **ALL** the problems. Write your solutions clearly and neatly on the answer sheets, and nothing on the scratch paper will be counted. This is a closed-book exam, meaning that **NO** personal notes, textbooks, or any other materials shall be used during the exam. However, you may use calculators if needed.

For your reference, the following constants may be helpful.

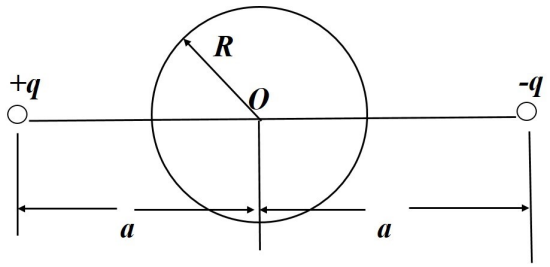
- Charge of an electron $e = -1.6 \times 10^{-19} C$
- Mass of an electron $m_e = 9.11 \times 10^{-31} kg$
- Permittivity constant $\varepsilon_0 = 8.85 \times 10^{-12} C^2/(N \cdot m^2)$
- Permeability constant $\mu_0 = 4\pi \times 10^{-7} N/A^2$
- Speed of light $c = 3 \times 10^8 m/s$
- Planck's constant $h = 6.63 \times 10^{-34} J \cdot s$

P1. (10=5+5 marks)

A conducting sphere with a radius R is electrically neutral. An electric dipole is placed on both sides of the sphere. The center of the dipole is located at the spherical center O, namely, the distance from $+q$, or $-q$ to the point O is a, as shown in figure.

(a) Determine the electric field and potential generated by the *induced charges* at point O.

(b) Remove $-q$, then the conducting sphere is connected to Earth (grounded), find the induced charge q' on the surface of the conducting sphere.



P2. (15=6+2+2+5 marks)

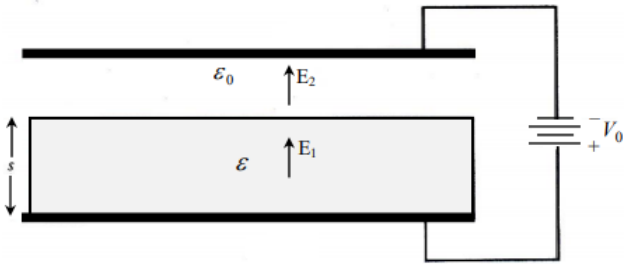
A parallel-plate capacitor with electrodes of area A and separation l has its upper electrode in a free space region in series with a solid dielectric of thickness s and dielectric permittivity ε.

(a) What are the electric fields E_1 and E_2 in the dielectric and free space regions?

(b) What is the free surface charge density on the lower electrode?

(c) What is the capacitance C of the capacitor?

(d) What is the electric force F on the upper electrode?

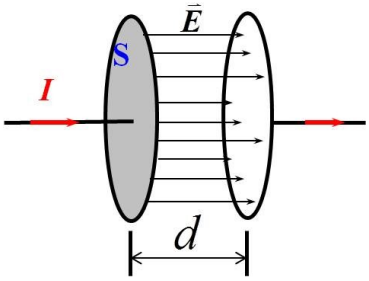


P3. (10=4+6 marks)

Maxwell's equations are a magnificent summary of electromagnetism.

(a) Write down the four Maxwell's equations in their differential forms. (Hint: $\oint_S \vec{F} \cdot d\vec{S} = \int_V \nabla \cdot \vec{F} dV$, $\oint_L \vec{F} \cdot d\vec{l} = \int_S (\nabla \times \vec{F}) \cdot d\vec{S}$)

(b) By using Maxwell's equations, consider a specific problem as follows: a circular capacitor with a plate area S, and the separation between two plats is d. The electric field inside the capacitor is $E = A\sin(\omega t)$, determine the electromagnetic energy stored in this capacitor. (Fringing effect is negligible.)



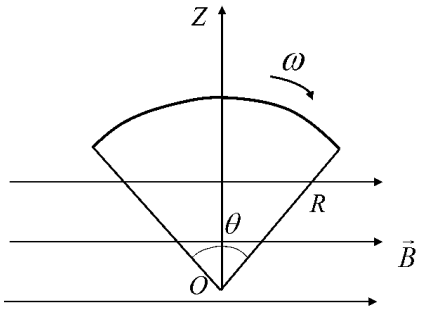
P4. (15=8+4+3 marks)

A thin sector (fan-shaped) with a central angle θ, and a radius R. Surface charge density on the sector is a function of radial function, namely $\sigma = \frac{e^{br}}{r^2}$, b is a positive number. The sector is placed in a uniform magnetic field $\vec{B}$ whose direction is shown as figure. The sector rotates around its central axis with an angular velocity ω. Find

(a) the magnetic moment of the circular disc.

(b) the torque on the disc due to the external magnetic field.

(c) the potential energy of the disc in the field.



P5. (15=4+4+7 marks)

A spaceship moves with a uniform velocity u, *that is close to the speed of light* c, with respect to the ground. The length of the spaceship is L' in the reference of the spaceship itself. One light pulse is emitted from the tail and reaches the head of the spaceship. Find

(a) The length of the spaceship in the reference of the ground.

(b) How long does it take for this spaceship to pass through the observer on the ground?

(c) What is the distance for the light pulse traveled from the tail to the head of this spaceship according to the observer in the reference of the ground?

P6. (10=5+3+2 marks)

In a Compton collision with an electron, a photon of violet light with wavelength $\lambda = 400nm$ is backward scattered through an angle of 180°.

(a) How much energy is transferred to the electron in the collision?

(b) Compare the result with the energy the electron would acquire in a photoelectric process with the same photon.

(c) Could violet light eject electrons from a metal (work function about a few eV) by Compton collision? Please explain.

P7. (15=3+6+6 marks)

The potential energy for a simple one-dimensional harmonic oscillator is given by $U(x) = \frac{1}{2}m\omega^2 x^2$, where m and ω are constants.

(a) Write down the time-independent Schröndinger equation.

(b) One solution to the Schröndinger equation is given by $\psi(x) = A\mathrm{e}^{-\frac{m\omega}{2\hbar}x^2}$, determine the constant A. (Hint: $\int_{-\infty}^{\infty} \mathrm{e}^{-ax^2}\mathrm{d}x = \sqrt{\frac{\pi}{a}}$)

(c) What is the corresponding energy?

P8. (10 marks)

Scoop out a small cylindrical region with radius $R/2$ inside the big cylindrical region with radius R as shown in the figure. The magnetic field $\vec{B}(t)$ directed outward varies with time such that $K = \frac{dB}{dt}$ is positive. A particle P with mass m and charge $q > 0$ entering the small circular region from point O has an initial speed v_0 and direction θ as shown. In order for the particle P to pass by one of the points in the upper circular area of OMN tangentially, then leaves from point N, what values of v_0 and θ must be taken?