Course Code: 101180121 **Semester I AY2022/2023**

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 $h = 6.63 \times 10^{-34} J \cdot s$

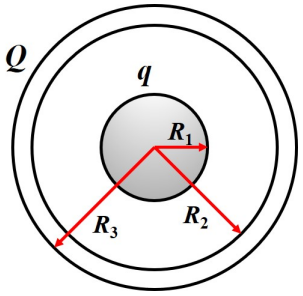
P1. (10=4+3+3 marks)

A conductive sphere, with a radius R_1 and positive charge q, is concentric with a spherical conductive shell (with a thickness) of an inner radius R_2 and an outer radius R_3. The shell has net charge of Q. Find

(a) the distribution of the electric field $\vec{E}$ in space.

(b) the potential difference between the sphere and the shell.

(c) when the *shell* is grounded, what is the potential difference between the sphere and the shell?



P2. (20=3+4+4+4+3+2 marks)

An ideal parallel-plate capacitor with a plate area S and plate separation d, is connected to a power source with a voltage V at all time, as shown in the figure below. The space between the two plates is fully filled with a dielectric material with a *relative* permittivity ε_r. Find

(a) the capacitance of the capacitor.

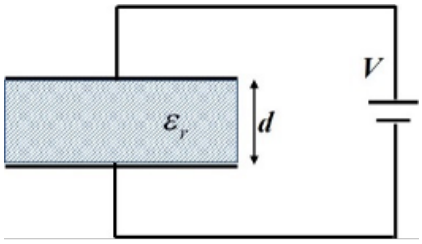
(b) the charge on one plate of the capacitor.

(c) the polarized charge density on the surface of the dielectric.

(d) the energy difference between the capacitor with the dielectric and without the dielectric.

(e) the work done by the power source.

(f) When the dielectric is filled into the capacitor, is the force exerted on the dielectric due to the capacitor attractive or repulsive? Please explain.



P3. (15=5+5+2+3 marks)

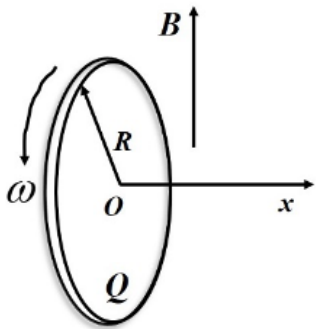
A nonconducting, thin circular disk, of radius R, carries a uniformly distributed electric charge Q. The plate is set spinning with the angular velocity ω about an axis perpendicular to the plate through its center; see the figure below. Determine

(a) its magnetic dipole moment.

(b) the magnetic field at points on the axis a distance x from the center.

(c) in the case $x \gg R$, does the relation $B \propto \frac{1}{x^3}$ apply?

(d) If a uniform magnetic field B is applied, as shown in the figure. Find the torque on the disk (show its direction).



P4. (10=4+2+4 marks)

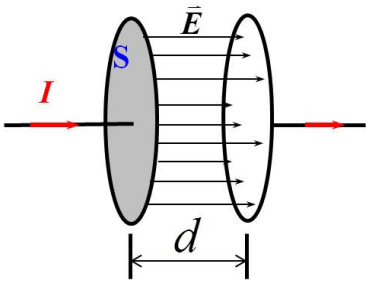
Maxwell's equations are a magnificent summary of electromagnetism.

(a) Write down the four Maxwell's equations in their differential forms.

Hint: $\oint_S \vec{F} \cdot \mathrm{d}\vec{S} = \int_V \nabla \cdot \vec{F} \mathrm{d}V$, $\oint_L \vec{F} \cdot \mathrm{d}\vec{l} = \oint_S (\nabla \times \vec{F}) \cdot \mathrm{d}\vec{S}$

(b) If magnetic monopoles existed, which of Maxwell's equations would be altered, and what would be their new form (in integral form)? Let Q_m be the strength of a magnetic monopole, analogous to the electric charge Q.

(c) By using Maxwell's equations, consider a specific problem as follows. A circular capacitor has a plate area S, and the separation between the two plates is d. The electric field inside the capacitor is given by $E = A \sin \omega t$. Determine the magnetic field between the two plates (Fringing effect is negligible).



P5. (10=4+4+2 marks)

A starship travels past Earth and Mars in a straight line at speed $v = 0.8c$ at a time when Earth and Mars are $2.4 \times 10^{11} m$ apart. The distance is measured in the fixed reference frame in which the Sun, Earth, and Mars are at rest. (Note that any motion of the planets with respect to each other and the Sun during this short time can be safely ignored.)

(a) In the fixed reference frame, how long does it take for the starship to go from Earth to Mars?

(b) In the starship reference frame, how far apart are the Earth and Mars?

(c) In the starship reference frame, how much time elapses between the Earth passing by and Mars passing by?

P6. (10=4+3+3 marks)

In a Compton scattering event, the scattered photon has an energy of $120keV$ and the recoiling electron has an energy of $40keV$. Find

(a) the wavelength of the incident photon.

(b) the angle at which the photon is scattered.

(c) the recoil angle of the electron.

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=5+5 marks)

A circular coil with a radius a, resistance R, and self-inductance L has N turns. The coil is put in a uniform magnetic field $\vec{B}$, and rotates around an axis which is normal to $\vec{B}$. When the coil rotates around the axis with a constant angular velocity ω. Find

(a) the current induced in the coil as a function of the angle θ, where $\theta(t) = \omega t$ is the included angle between the normal direction of the coil surface $\vec{n}$ and the magnetic field $\vec{B}$.

(b) in order to maintain the rotation of the coil with the angular velocity, what is the magnitude of external torque exerted on it?