Illinois Institute of Technology

Physics

M.Sc. Comprehensive and Ph.D. Qualifying Examination

PART II

Physical Constants

Speed of light in vacuum	c	=	2.998×10^{8} m/s
Planck's constant	h	=	6.626×10^{-34} J s
	$\hbar$	=	$h/2\pi$
		=	1.055×10^{-34} J s
		=	6.582×10^{-16} eV s
Permeability constant	μ_0	=	$4\pi \times 10^{-7}$ N/A^2
Permittivity constant	$\frac{1}{4\pi\epsilon_0}$	=	8.988×10^{9} N m^2/C^2
Fine structure constant		=	$\frac{e^2}{4\pi\epsilon_0\hbar c}$
		=	$7.30 \times 10^{-3} = \frac{1}{137}$
Gravitational constant	G	=	6.67×10^{-11} m^3/s^2 kg
Avogadro's number	N_A	=	6.023×10^{23} mole^{-1}
Boltzmann's constant	k	=	1.381×10^{-23} J/K
		=	8.617×10^{-5} eV/K
kT at room temperature	k 300 K	=	0.0258 eV
Universal gas constant	R	=	8.314 J/mole K
Stefan-Boltzmann constant		=	5.67×10^{-8} W/m^2 K^4
Electron charge magnitude	e	=	1.602×10^{-19} C
Electron rest mass	m_e	=	9.109×10^{-31} kg
		=	0.5110 MeV/c^2
Neutron rest mass	m_n	=	1.675×10^{-27} kg
		=	939.6 MeV/c^2
Proton rest mass	m_p	=	1.672×10^{-27} kg
		=	938.3 MeV/c^2
Deuteron rest mass	m_d	=	3.343×10^{-27} kg
		=	1875.6 MeV/c^2
Atomic mass unit ($C^{12} = 12$)	u	=	1.661×10^{-27} kg
		=	931.5 MeV/c^2
Mass of earth	M_E	=	5.98×10^{24} kg
Radius of earth	R_E	=	6.37×10^{6} m
Mass of sun	M_S	=	1.99×10^{30} kg
Radius of sun	R_S	=	6.96×10^{8} m
Gravitational acceleration at earth's surface	g	=	9.81 m/s^2
Atmospheric pressure		=	1.01×10^{5} N/m^2
Radius of earth's orbit		=	1.50×10^{11} m
Radius of moon's orbit		=	3.84×10^{8} m

Conversion Factors

1 eV	=	1.602×10^{-19} J		1 J	=	6.242×10^{18} eV
1 A	=	10^{-10} m		1 Fermi	=	10^{-15} m
1 barn (b)	=	10^{-28} m^2		1 in	=	2.54 cm
0 Celsius	=	273.16 K		1 cal	=	4.19 J

Problem 1: A particle of charge q and mass m is placed at rest at $t = 0$ in perpendicular, constant, electric and magnetic fields $\mathbf{E} = E\hat{z}$ and $\mathbf{B} = B\hat{x}$. Calculate the trajectory of the particle and describe it.

Problem 2: A particle of mass M and magnetic dipole moment $\mathbf{m}$ is placed on the axis of a circular current loop of radius a and current I (which is kept fixed), at a distance z_0 from the center of the loop. $\mathbf{m}$ is aligned in the direction of the loop field. (z_0 is not necessarily much greater or smaller than a.)

(a) What is the force of attraction between the loop and $\mathbf{m}$?

(b) When $\mathbf{m}$ is released, it moves toward the center of the loop. What is its kinetic energy when it arrives there? (Assume that $\mathbf{m}$ is constrained to the z axis.)

(c) If the particle is originally placed at the center of the loop, what is the frequency of small oscillation about this position for motion along the z axis?

Problem 3: A plasma generated inside a long hollow cylinder of radius R has the following charge distribution:

$$(r) = \frac{0}{[1 + (r=a)^2]^2};$$

where r is the distance to the center and $_0$ and a are constants. Determine the electric field everywhere.

Problem 4: Calculate the transmission and reflection coefficients of a particle having total energy E at the potential barrier given by

$$V(x) = \begin{cases} 0 & x < 0 \\ V_0 & 0 \leq x \leq a \\ 0 & x > a; \end{cases}$$

for $E > V_0$ case. Under what condition does the barrier turn out to be 100% transparent?

Problem 5: A plane rigid rotor having a moment of inertia I and an electric dipole moment $\mathbf{d}$ is placed in a homogeneous electric field $\mathbf{E}$