THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

FINAL EXAMINATION: JUNE 2012

PHYS3011 & PHYS3230
Electrodynamics

P 2

Time allowed – 2 hours
Total number of questions – 4
Answer ALL 4 questions
All questions are of equal value

Candidates must supply their own, university-approved calculator.

Answers must be written in ink.
Except where they are expressly required, pencils may only be used for drawing, sketching, or graphical work.
Please do not use red ink.

Candidates may keep this question paper.

Question 1

A radio transmitter transmits an effective power of 100 kW at a frequency of 1 MHz. ('Effective' means this is the power it would need if it radiated uniformly over a sphere.)
(a) Calculate the rms **E** and **B** field strengths at a point 1 km away from the transmitter (you can assume a plane wave front at this distance.)
(b) You have a piece of wire of length 2π m. You can either use it as a straight antenna, responding to the **E** field, or wind it into a circle and respond to the **B** field. Calculate the EMF in the wire in the two cases.

Question 2

$E_x = E_0 \exp i(\omega t - kz)$ is a solution of the wave equation:

$$\frac{\partial^2 \mathbf{E}}{\partial z^2} - \mu_0 \sigma \frac{\partial \mathbf{E}}{\partial t} - \epsilon_0 \mu_0 \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0$$

(a) Of the two time-dependent terms, which dominates in free space, and which dominates in a good conductor?
(b) Show that for a good conductor, the wave number k has real and imaginary components, each of magnitude $\sqrt{\frac{1}{2}\omega\mu_0\sigma}$.
(c) Hence calculate the skin depth and phase velocity of a 1 MHz wave in copper ($\sigma = 5.8 \times 10^7$ Sm^{-1}).

$$Note: \quad \sqrt{(\pm i)} = (1 \pm i)/\sqrt{2}$$

Question 3

A plane electromagnetic wave crosses from a vacuum into an insulating medium of relative permittivity $\epsilon_r = n^2$ and relative permeability $\mu_r = 1$ at normal incidence to the boundary.

Using the appropriate boundary conditions, find the reflection and transmission coefficients, R and T, for the power reflected and transmitted.

Question 4

The **E** field from an oscillating electric dipole, $\mathbf{P} = P_z = P_0 \cos \omega t$, at the origin and aligned along the z axis, is given by:

$$\mathbf{E}(r, \theta, t) = \frac{-\mu_0 P_0 \omega^2 \sin\theta}{4\pi r} \cos[\omega(t - r/c)]\ \hat{\mathbf{z}}$$

(where r is large compared to the size of the dipole, and to the wavelength of the radiation.)

(a) Using the plane-wave approximation, valid for large r, write down the corresponding expression for **B** (both magnitude and direction.) (Note that the direction of propagation, $\hat{\mathbf{k}}$, is along $\hat{\mathbf{r}}$.)

(b) Hence find the Poynting vector for this radiation,

(c) and the average value of **S** over one cycle of the radiation.