EE1-05

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2016

EEE PART I: MEng, BEng and ACGI

ENERGY CONVERSION

Corrected Copy

Friday, 3 June 10:00 am

Time allowed: 2:00 hours

There are THREE questions on this paper.

Answer All questions.
Q1 carries 40% of the marks. Questions 2 and 3 carry equal marks (30% each).

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible First Marker(s) : O. Sydoruk
Second Marker(s) : B.C. Pal

ENERGY CONVERSION

1. a) A dc current I flows through a thin straight current element of an infinitesimal length dl, as shown in Figure 1.1. Find the magnitude and the direction of the magnetic field strength at point P. Both the current element and point P are in the plane of the paper. The distance between the current element and point P is r. The angle between the current element and the line connecting it with point P is θ. [5]

Figure 1.1

b) The configuration is the same as in part a), but a positive point charge q is now placed at point P. The charge moves with a velocity v in the direction opposite to the current, as shown in Figure 1.2. Find the magnitude and direction of the force on the charge. [5]

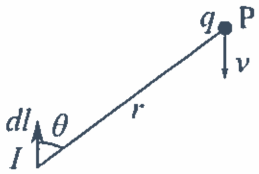

Figure 1.2

c) A dc current I flows along the thin wire shown in Figure 1.3. The wire consists of a half-ring of a radius R whose ends are connected to two straight infinitely long segments. Find the magnetic flux density at the centre of the half-ring denoted by point O in Figure 1.3. [30]

Figure 1.3

2. a) Show that the expression for the electric field created by a point charge q in vacuum satisfies Gauss's law in the integral form. Take the Gauss surface as a sphere whose centre coincides with the position of the point charge. [5]

b) Find the magnitude and the sign of the voltage U_{AB} between point A and point B shown in Figure 2.1. The voltage is due to a positive point charge q. Points A and B lie on the same line at the opposite sides of the charge. The distance between the charge and point A is r_A. The distance between the charge and point B is r_B. [10]

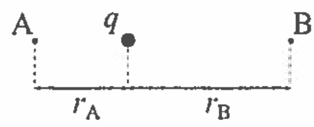

Figure 2.1

c) Consider a parallel-plate capacitor connected to wires as shown in Figure 2.2. An ac current I is flowing through the wires. Show how applying Ampere's law in the form $\oint_l (\mathbf{H} \cdot \mathbf{dl}) = \int_S (\mathbf{J} \cdot \mathbf{dS})$ can lead to a contradictory result for this geometry. Why does the contradiction arise? How is it resolved? [15]

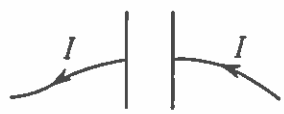

Figure 2.2

3. a) Explain what physical mechanism creates a mutual inductance between two loops carrying time-varying currents. What is the definition of mutual inductance? [10]

b) Two identical loops with a self-inductance L are coupled two each other by a mutual inductance M. Assuming total flux linkage, show that $M = L$. [10]

c) Two identical loops with a self-inductance L are coupled to each other by a mutual inductance M. One of the loops is connected to an ac voltage source that has a complex amplitude U and an angular frequency ω, as shown in Figure 3.1. Find the complex amplitudes of the currents flowing in both loops. [10]

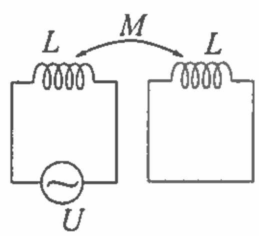

Figure 3.1