IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2014

EEE PART I: MEng, BEng and ACGI

Corrected Copy

ENERGY CONVERSION

Monday, 9 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) : W.T. Pike, E.M. Yeatman
Second Marker(s) : B.C. Pal, B.C. Pal

Special instructions for students

Physical Constants

permittivity of free space:	$\varepsilon_o = 8.85 \times 10^{-12}$ F/m
permeability of free space:	$\mu_o = 4\pi \times 10^{-7}$ H/m
charge of an electron:	$e = 1.6 \times 10^{-19}$ C

The Questions

1.

a) A coaxial cable is used to connect a DC voltage source to a resistive load, with the positive terminal connected to the outer conductor of the cable. Sketch the electric field and magnetic flux in a cross section through the cable looking towards the source. [4]

b) What is the force between two parallel wires, 50 cm long and 10 cm apart, each carrying a current of 100 mA? [4]

c) An iron C-core as shown has a gap length of 0.5 mm, a total path length in the iron of 5 cm, and the coil provides 10 A·turns. If the iron has $\mu_r = 10{,}000$, calculate the magnetic flux density in the gap, stating any assumptions made. [4]

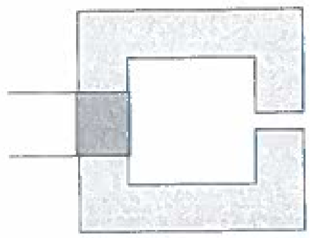

Figure 1 a).

d) A load connected to an 11kV 50Hz AC supply consumes 650kW of real power and draws a current of 60A. Calculate the apparent power, power factor, and magnitude of the load impedance. [4]

e) Fig. 1e) shows the IV curve for a photodiode under illumination. Explain the shape of the curve and on your copy of the curve indicate an estimate for the current draw from the photocell that would maximise the power produced.

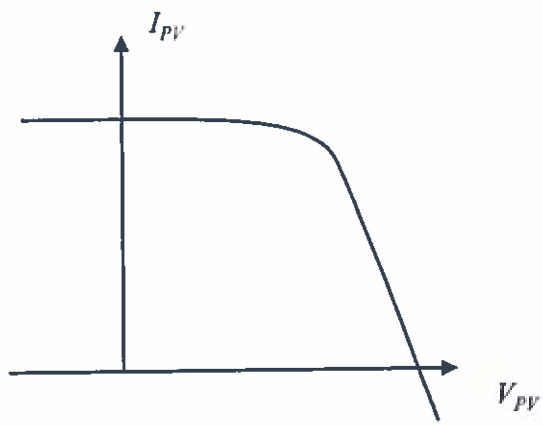

Figure 1 e). [4]

f) An open circuit, 30 turn coil of area 0.05 m^2, initially in the x-y plane, is spun around its x axis at 100 rpm. There is a uniform magnetic field of flux density 0.2 T in the z direction. What will be the peak induced voltage in the coil? [4]

g) A 10 μH inductor is formed by winding a coil around a toroidal core of relative permeability $\mu_r = 800$. At a coil current of 5 A the core is saturated at a flux density of 1.0 T. By considering the energy density in the core, find its volume in cm^3. [4]

h) As part of a certain magnetic circuit, magnetic flux passes down the axis of a cylindrical steel rod of length 10 cm, radius 1 cm and relative permeability $\mu_r = 1200$. What is the reluctance of this part of the flux path? [4]

i) A certain simple DC motor in steady state has a back-EMF $e_A = 80$ V, an armature resistance $R_A = 10\ \Omega$, and an armature current $I_A = 2$ A. Calculate its efficiency η. [4]

j) For a simple DC motor when the input voltage is suddenly increased, give two factors that may limit the rate at which its speed increases. [4]

2.

a) A thin, square, conductive plate of side l has a surface normal in the z direction and its two sides in the x and y direction. If the plate is given a charge $-Q$ sketch the electric field for a cross section through the centre of the plate in the xz plane and derive an expression for the magnitude of the field near the centre of the plate. [4]

b) A second identical plate, but with a charge $+Q$, is displaced a distance d, much smaller than l, directly above the first plate in the positive z direction. Using superposition, or otherwise, sketch the electric field for the two plates for the same cross section as (a) and derive an expression for the magnitude of the field between the plates away from the edges. Hence derive an expression for the capacitance, C, between two parallel plates. [6]

c) Derive expressions for the capacitance in (a) if the second plate is displaced a distance x ($< l/2$) horizontally, or z ($< d$) vertically from its initial position, and hence derive expressions for the change in capacitance with displacement in the vertical and horizontal directions, dC/dx and dC/dz. [8]

d) The change in the capacitance in (c) forms the basis for a displacement transducer. What are two advantages in using such a transducer to measure the horizontal rather than vertical displacement? [6]

e) Suggest a circuit diagram for such a displacement transducer which produces an output that depends on the value of a variable capacitance? [6]

3.

a) Sketch and fully label an equivalent circuit for a simple DC machine operating in steady state. Below the sketch, for each of the labelled quantities give the full name, e.g. V_a = applied armature voltage. [6]

b) A certain DC motor has an armature with $N = 50$ turns, and an applied flux Φ of 100 mWb. The motor torque is measured at both 50 rpm and 100 rpm and found to be 12 Nm and 9 Nm respectively. Calculate the applied armature voltage V_a and the armature resistance R_a. [6]

c) A certain transformer can be modelled by the equivalent circuit shown in Fig. 3.1. Short circuit and open circuit tests are carried out on it, yielding the results shown in Table 3.1. Calculate the values of the equivalent circuit components R_i, X_m, R_{t1} and X_{t1}. [6]

d) The transformer of (c) now has a real load of Z_L = 200 Ω connected to the secondary terminals. Calculate the efficiency η of the transformer in this case. [6]

e) For the transformer of (d), can the power consumed in the load be increased if a capacitor is added in series with the load Z_L? If this is done, will the efficiency η always increase? [6]

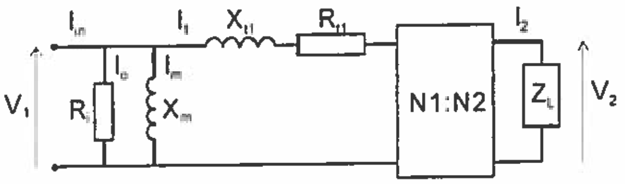

Figure 3.1

Table 3.1

	V_1	V_2	I_{in}	P_{in}
Open Circuit Test	1200 V	240 V	0.44 A	370 W
Short Circuit Test	90 V	0 V	10.4 A	520 W