THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

082 **ELECTRICAL ENGINEERING SCIENCE**

(For Both School and Private Candidates)

Time : 3 Hours **ANSWERS** **Year : 2014**

Instructions

1. This paper consists of sections A, B and C.
2. Answer all questions in section A and B and **three (3)** questions from section C.
3. Non-programmable calculators may be used.
4. Communication devices and any unauthorised materials are **not** allowed in the examination room.
5. Write your **Examination Number** on every page of your answer booklet(s).

1. For each of items (i) – (x), choose the correct answer from among the given alternatives and write its letter beside the item number in your answer booklet.

(i) In half wave rectifier circuit, diode conducts current when the

A. a.c input voltage is at its average value from zero

B. anode is made positive by positive a.c input voltage

C. plate is made negative by negative a.c input voltage

D. cathode is made positive by square input voltage

E. cathode is made less negative by input voltage.

Correct answer: B. anode is made positive by positive a.c input voltage

Reason: A diode conducts only when anode is positive relative to cathode (forward biased).

(ii) Electrolyte of a battery might be used to determine the status of a battery charge by looking at its

A. level

B. temperature

C. specific gravity

D. colour

E. density.

Correct answer: C. specific gravity

Reason: The state of charge of a battery is determined by specific gravity of electrolyte using hydrometer.

(iii) Which of the following material is not used as fuse material?

A. Silver

B. Magnesium

C. Aluminium

D. Copper

E. Carbon.

Correct answer: E. Carbon

Reason: Fuse materials must have low melting points; carbon is not used due to very high melting point.

(iv) Which of the following remain constant inside a charged conducting sphere?

A. Electric intensity

B. Electric charge

C. Electric field

D. Electric flux

E. Electric potential.

Correct answer: E. Electric potential

Reason: Inside a charged conducting sphere, electric potential is constant everywhere.

(v) Bronze is an alloy of

A. copper and zinc

B. copper and tin

C. copper and lead

D. copper and silver

E. copper and nickel.

Correct answer: B. copper and tin

Reason: Bronze is made of copper and tin, while brass is copper and zinc.

(vi) When the rotor of an induction motor is standstill, the value of slip is

A. two

B. zero

C. four

D. infinite

E. one.

Correct answer: E. one

Reason: Slip $s = (Ns – Nr)/Ns$. At standstill, $Nr = 0$, so $s = 1$.

(vii) Which of the following must match for d.c generators to operate in parallel?

A. Polarities and speed

B. Phase sequences and voltages

C. Polarities and voltages

D. Speed and efficiency

E. Phase sequences and efficiency.

Correct answer: C. Polarities and voltages

Reason: For parallel operation of DC generators, voltage and polarity must match.

(viii) A solar cell is the same as

A. photo-emissive cell

B. photometer cell

C. photoconductive cell

D. photovoltaic cell

E. photo diod cell.

Correct answer: D. photovoltaic cell

Reason: A solar cell is a photovoltaic device which converts sunlight into electricity.

(ix) Lumen/watt is the unit of

A. luminous intensity

B. light flux

C. luminous flux

D. brightness

E. illuminance.

Correct answer: C. luminous flux

Reason: Luminous efficacy is measured in lumens per watt, representing efficiency of converting power to light.

(x) A transformer core is laminated in order to

A. minimize copper loss

B. minimize eddy current loss

C. reduce running cost

D. reduce hysteresis loss

E. eliminate magnetic fields.

Correct answer: B. minimize eddy current loss

Reason: Laminations reduce the path for eddy currents, reducing eddy current loss.

2. Figure 1 shows one node of an electric circuit. Use Kirchhoff's current law to find V_2. Given $i_1 = 4$ A, $i_3 = 1$ A and $i_4 = 2$ A.

Applying KCL: Σ currents entering = Σ currents leaving

$i_1 + i_2 = i_3 + i_4$

$4 + i_2 = 1 + 2$

$i_2 = -1$ A (which means it leaves node opposite assumed).

Now, $V_2 = i_2 \times 2\ \Omega = -1 \times 2 = -2$ V

$V_2 = -2$ V

3. A cell of e.m.f 1.5 V and internal resistance of 2 Ω is connected in series with an ammeter of resistance 0.5 Ω and 5 Ω resistance. What will be the
(i) ammeter reading
(ii) potential difference across the terminals of the cell.

Total resistance = 2 + 0.5 + 5 = 7.5 Ω

Current = E / R = 1.5 / 7.5 = 0.2 A

(i) Ammeter reading = 0.2 A

(ii) Vterminals = E – Ir = 1.5 – (0.2 × 2) = 1.1 V

4. (a) What is d.c generator?

A DC generator is a machine that converts mechanical energy into direct current electricity using electromagnetic induction.

(b) A generator is connected to a load having terminal voltage of 480 V and a current of 8 A flows when the load is connected. If the armature resistance is 1 Ω, determine the generated voltage.

$V_t = 480$ V, $I_L = 8$ A, $R_a = 1\ \Omega$

$E_g = V_t + I_aR_a = 480 + 8 \times 1 = 488$ V

Generated emf = 488 V

5. (a) Differentiate magnetic circuit from electric circuit.

In a magnetic circuit, flux flows, while in an electric circuit, current flows.
The driving force in a magnetic circuit is mmf, in an electric circuit it is emf.
Reluctance opposes flux, resistance opposes current.
Flux is measured in Weber, current is measured in Amperes.

(b) A conductor of length 5 cm is kept in a magnetic field having flux density of 1.8 tesla. If the current flowing is 0.8 A, calculate the maximum force exerted by a conductor.

$F = BIL$

$= 1.8 \times 0.05 \times 0.8$

$= 0.072$ N

Force = 0.072 N

6. Calculate the power dissipated if the bulb of 100 W, 200 V is mistakenly connected to 100 V.

$P = (V^2 / V_{rated}^2) \times P_{rated} = (100^2 / 200^2) \times 100 = (10000 / 40000) \times 100 = 25$ W

Power dissipated = 25 W

7. The design requirements of a 6000/450V, 50 Hz core type transformer are: approximate e.m.f/turn = 15 V and maximum flux density is 1 Wb/m². Calculate suitable number of primary turns and the net cross sectional area of the core.

$E = 4.44\ f\ B\ A\ N$

For primary: V = 6000 V, emf/turn = 15 V,

N = V / emf/turn = 6000 / 15 = 400 turns

Area $A = V / (4.44 f B N) = 6000 / (4.44 \times 50 \times 1 \times 400) = 6000 / 88{,}800 = 0.0676\ m^2$

Number of primary turns = 400, Core area = $0.068\ m^2$

8. (a) What is the importance of using a starter in d.c motors?

A starter is used to limit the high starting current when motor starts, since back emf is zero at standstill.

(b) A d.c motor connected to a 460 V supply has an armature resistance of 0.2 Ω. Find the back e.m.f, if the armature current is 120 A.

$V = 460\ V$, $R_a = 0.2\ \Omega$, $I_a = 120\ A$
$E_b = V - I_aR_a = 460 - (120 \times 0.2) = 460 - 24 = 436\ V$

Back emf = 436 V

9. Two watt-meters are connected to measure power in a three-phase circuit. One of the wattmeter reads 500 W and the other points out in the reverse direction. After reversing the voltage coil terminals, the reading of this watt-meter is found to be 200 W. Determine the power factor of load.

Total power = $W_1 + W_2 = 500 + (-200) = 300\ W$
$\tan\varphi = \sqrt{3}(W_1 - W_2)/(W_1 + W_2) = \sqrt{3}(500 - (-200))/300 = 1.732 \times 700 / 300 = 4.04$
$\varphi = \tan^{-1}(4.04) = 76°$
$pf = \cos\varphi = 0.24$

Power factor = 0.24

10. (a) State the inverse square law of illumination.

The illumination on a surface is inversely proportional to the square of the distance between the surface and the source, provided the source is a point source and light falls normally.

(b) A lamp is mounted 4 m above the floor and it has an intensity of 100 cd. Calculate the maximum illumination given by the lamp.

$E = I / d^2 = 100 / (4^2) = 100 / 16 = 6.25$ lux

Maximum illumination = 6.25 lux

11. Find the expression for the current when a voltage $e = 283 \sin(100\pi t - \pi/4)$ is applied to a coil having resistance of 50 Ω and an inductive reactance of 1 Ω.

Given: $R = 50\ \Omega$, $XL = 1\ \Omega$, $e = 283 \sin(100\pi t - \pi/4)$

Impedance $Z = \sqrt{(R^2 + XL^2)} = \sqrt{(50^2 + 1^2)} = \sqrt{(2500 + 1)} = \sqrt{2501} = 50.01\ \Omega$

Current amplitude $Im = Em / Z = 283 / 50.01 = 5.66$ A

Phase angle $\varphi = \tan^{-1}(XL/R) = \tan^{-1}(1/50) = 0.02 \text{ rad} \approx 1.15°$

Current $i = 5.66 \sin(100\pi t - \pi/4 - 0.02)$ A

12. (a) (i) Give the relationship between line and phase current in delta connected circuit.

$IL = \sqrt{3} \times Iph$

(ii) With the aid of diagram differentiate between series, shunt and compound d.c machines according to the winding connections.

Series machine: Field winding connected in series with armature.

Shunt machine: Field winding connected in parallel with armature.

Compound machine: Has both series and shunt field windings.

(b) A three phase, 415 V star connected motor has an output of 50 kW with an efficiency of 90% and a power factor of 0.85.

(i) Calculate the line current.

(ii) If the motor windings were connected in delta; what would be the correct voltage of a three phase supply suitable for the motor?

Input power = Output / Efficiency = 50000 / 0.9 = 55,556 W

Apparent power S = P / pf = 55556 / 0.85 = 65,360 VA

Line current $IL = S / (\sqrt{3} \times VL) = 65{,}360 / (1.732 \times 415) = 65{,}360 / 718.9 = 91$ A

For delta, correct supply $= \sqrt{3} \times 415 = 718$ V

(i) Line current = 91 A

(ii) Supply voltage = 718 V

(c) A 4-pole, 50 Hz induction motor has a slip of 1% at no load. When operated at full load, slip is 2.5%. Find the change in speed from no load to full load.

$N_s = 120f / P = 120 \times 50 / 4 = 1500$ rpm

At slip 1%, $N_{nl} = (1 - 0.01) \times 1500 = 1485$ rpm

At slip 2.5%, $N_{fl} = (1 - 0.025) \times 1500 = 1462.5$ rpm

Change = 1485 – 1462.5 = 22.5 rpm

Change in speed = 22.5 rpm

13. (a) A water heater having an element of 3 kW is used to heat 140 litres of water from 10°C to 60°C in 3 hours. Determine the efficiency of the heater. Assume the specific heat capacity of water is 4.2 kJ/kg°C and 1 litre of water = 1 kg.

Mass = 140 kg, $\Delta T = 50$°C, c = 4200 J/kg°C

Heat required = $mc\Delta T = 140 \times 4200 \times 50 = 29.4 \times 10^6$ J

Input energy = $P \times t = 3000 \times (3 \times 3600) = 3000 \times 10800 = 32.4 \times 10^6$ J

Efficiency = $(29.4 / 32.4) \times 100\% = 90.7\%$

Efficiency = 90.7%

(b) A 240 V d.c electric furnace is used to raise the temperature of 3.6 kg of brass from 16°C to the annealing temperature of 593°C in 30 minutes at an overall efficiency of 80%. Assuming specific heat capacity of brass is 377 J/kg°C. Calculate:

(i) resistance of the heating element,

(ii) current taken from the supply,

(iii) power absorbed,

(iv) total energy used in kWh.

$\Delta T = 593 - 16 = 577$°C

Heat required = $mc\Delta T = 3.6 \times 377 \times 577 = 783{,}583$ J

Effective energy = Heat / efficiency = 783583 / 0.8 = 979,479 J

Time = 30 × 60 = 1800 s

Power = E/t = 979,479 / 1800 = 544 W

Current = P/V = 544 / 240 = 2.27 A

Resistance = V/I = 240 / 2.27 = 105.7 Ω

Energy in kWh = 979,479 / 3.6 × 10^6 = 0.272 kWh

(i) R = 105.7 Ω

(ii) I = 2.27 A

(iii) P = 544 W

(iv) 0.272 kWh

14. (a) (i) Two capacitors C1 and C2 are connected in parallel across a supply of V (Volts) and a charge of Q (Coulombs) is produced. Show that the equivalent capacitance is given by Ceq = C1 + C2.

Q = Q1 + Q2 = C1V + C2V = (C1 + C2)V

So Ceq = C1 + C2

(ii) You need 10 μF capacitance in a certain application. The only available capacitance in store is of value 0.05 μF only. How can you get the total capacitance that you need?

Required number = 10 / 0.05 = 200 capacitors in parallel.

(b) For the circuit shown in Figure 2; find the

(i) equivalent capacitance

(ii) voltage across a parallel group

(iii) total charge in μC

(iv) total energy stored in mJ.

Capacitors in top branch: three × 4.5 μF in series = 1.5 μF

Parallel with 3 μF = 4.5 μF

Bottom branch: two × 1 μF in series = 0.5 μF

Total Ceq = 4.5 + 0.5 = 5 μF

(i) Ceq = 5 μF

(ii) Voltage = 500 V

(iii) $Q = CV = 5 \times 10^{-6} \times 500 = 2.5 \times 10^{-3}$ C = 2500 μC

(iv) Energy = $\frac{1}{2} CV^2 = 0.5 \times 5 \times 10^{-6} \times 500^2 = 0.625$ J = 625 mJ

15. (a) With the help of diagrams, explain the difference between half wave and full wave rectification.

Half wave uses one diode, conducts only during one half cycle.

Full wave uses two diodes and a center tap or four diodes in bridge, conducts during both half cycles.

(b) If you trouble shoot the rectified power supply system and find out that there is either no or low d.c output; what situations might cause this problem to occur? Give three causes in each case.

No output: diode open circuit, transformer open winding, broken connections.

Low output: faulty diode leakage, high series resistance, transformer problem.

(c) Consider the half wave rectifier circuit shown in Figure 3.

Maximum load voltage = Vm = $\sqrt{2} \times 220/10 = 31.1$ V

RMS load voltage = Vm / 2 = 31.1 / 2 = 15.55 V

Load resistance = 100 Ω

Peak load current = Vm / RL = 31.1 / 100 = 0.311 A

RMS load current = 0.311 / 2 = 0.155 A

Ripple factor = 1.21

(i) Vmax = 31.1 V, Vrms = 15.55 V

(ii) Imax = 0.311 A, Irms = 0.155 A

(iii) Ripple factor = 1.21

16. (a) Two resistors of values 1 kΩ and 4 kΩ are connected in series across a constant voltage supply of 100 V. A voltmeter having an internal resistance of 12 kΩ is connected across the 4 kΩ resistor. Calculate:

(i) true voltage across 4 kΩ resistor before the voltmeter was connected.

Total resistance = 1k + 4k = 5 kΩ

Current = V / R = 100 / 5000 = 0.02 A

Voltage across 4k = I × 4000 = 0.02 × 4000 = 80 V

True voltage = 80 V

(ii) actual voltage across 4 kΩ resistor recorded by the voltmeter.

When voltmeter connected, effective resistance across 4k and 12k in parallel = (4000 × 12000)/(4000 + 12000) = 48,000,000/16000 = 3000 Ω

So total resistance = 1000 + 3000 = 4000 Ω

Current = 100 / 4000 = 0.025 A

Voltage across parallel branch = 0.025 × 3000 = 75 V

Actual reading = 75 V

(iii) change in supply current when the voltmeter is connected.

Without voltmeter: Current = 0.02 A

With voltmeter: Current = 0.025 A

Change = 0.025 – 0.02 = 0.005 A

Change = 0.005 A

(iv) percentage error in voltage across 4 kΩ resistor.

Error = (True – Actual)/True × 100% = (80 – 75)/80 × 100% = 5/80 × 100% = 6.25%

Percentage error = 6.25%

(b) From the given circuit diagram shown in Figure 4; find the

(i) reading of the ammeter.

(ii) value of R.

Total current = 11.5 A

Current through 5 Ω = 3 A

Current through 6 Ω = V/6

Voltage across 5 Ω = 3 × 5 = 15 V

So supply voltage V = 15 V

Then current through 6 Ω = 15 / 6 = 2.5 A

So ammeter reading = 2.5 A

Now total current = 11.5 A = IR + 3 + 2.5

IR = 11.5 – 5.5 = 6 A

So R = V / IR = 15 / 6 = 2.5 Ω

(i) Ammeter reading = 2.5 A

(ii) R = 2.5 Ω