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 : 2013**

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 the items (i) – (x) choose the correct answer from among the given alternatives and write its letter beside the item number.

(i) What must be known in order to calculate the energy used by an electrical appliance?

A. Power and current.

B. Power and resistance.

C. Current and time of operation.

D. Voltage and resistance.

E. Power and time of operation.

Correct answer: E. Power and time of operation.

(ii) A good electric conductor is one that

A. has low conductance.

B. is always made of copper.

C. has few free electrons.

D. has constant voltage.

E. has minimum voltage drop.

Correct answer: E. Has minimum voltage drop.

(iii) The capacity of a cell is measured in

A. watt-hour.

B. megawatt.

C. ampere.

D. ampere-hour.

E. voltage.

Correct answer: D. Ampere-hour.

(iv) Electronic device that convert d.c. power to a.c power is called

A. converter.

B. inverter.

C. rectifier.

D. transformer.

E. generator.

Correct answer: B. Inverter.

(v) What will happen when two objects one with high temperature and the other with low temperature are placed together?

A. Temperature will flow from low to high body.

B. The higher body will gain while the lower body will lose temperature.

C. Temperature will flow from high body to low body.

D. The higher body will lose while the lower body will gain temperature.

E. Each body will retain its original temperature.

Correct answer: D. The higher body will lose while the lower body will gain temperature.

(vi) Which controls should be adjusted for an oscilloscope to display the wave form of a.c supply?

A. Y-shift then X-time base.

B. X-time base then Y-shift.

C. Y-shift then Y-gain.

D. X-time base then Y-gain.

E. Y-gain then Y-shift.

Correct answer: B. X-time base then Y-shift.

(vii) The armature of a d.c. series machine has a resistance of 0.1 Ω and is connected to 230 V supply. If it is running as a generator giving 80 A, then generated e.m.f will be

$Eg = V + IaRa = 230 + (80 \times 0.1) = 238$ V.

Correct answer: A. 238 V.

(viii) An atom is said to be ionized when any one of its orbiting electron

A. is raised to a higher orbit.

B. is partially removed.

C. comes to the ground state.

D. is completely removed.

E. jumps from one orbit to another.

Correct answer: D. Is completely removed.

(ix) A chemical compound whose chemical action causes a current to flow is

A. electron.

B. an impurity.

C. an electrolyte.

D. ions.

E. solvent.

Correct answer: C. An electrolyte.

(x) Which parameter on a transformer can be measured by using short circuit test?

A. Windage losses.

B. Hysteresis losses.

C. Eddy current losses.

D. Copper losses.

E. Friction losses.

Correct answer: D. Copper losses.

2. A battery consists of two cells joined in parallel. If each cell has an e.m.f of 1.5 V and internal resistance of 5 Ω, what current will flow through an external resistance of 5 Ω?

Eeq = 1.5 V.

Req = r/n = 5/2 = 2.5 Ω.

Total R = 2.5 + 5 = 7.5 Ω.

I = E/R = 1.5/7.5 = 0.2 A.

3. (a) When is the armature of a d.c motor likely to get overheated?

When the motor is overloaded, when there is excessive sparking at brushes, or if ventilation is poor.

(b) How can the direction of rotation of motor be reversed?

By reversing either the field current connections or the armature current connections, but not both simultaneously.

4. (a) Briefly explain two functions of cathode ray tube.
   It displays waveforms of electrical signals.
   It measures amplitude, frequency, and phase difference of signals.

   (b) Mention two deflection systems of cathode ray tube.
   Electrostatic deflection.
   Electromagnetic deflection.

5. The field coil of a motor has a resistance of 200 Ω at 20°C. Find the resistance of the coil when the motor temperature increases to 40°C. Temperature coefficient of the conductor is 0.004/Ω/°C.

   $R = R0 [1 + \alpha (T – T0)]$.
   $= 200 [1 + 0.004(40 – 20)]$.
   $= 200 [1 + 0.08]$.
   $= 200 \times 1.08 = 216$ Ω.

6. (a) State Ohm's law.
   The current flowing through a conductor is directly proportional to the voltage across it, provided the temperature and other physical conditions remain constant.

   (b) Define the following terms as used in measuring instruments:
   (i) Shunt resistor – A resistor connected in parallel with a meter movement to extend its current range.
   (ii) Multiplier resistor – A resistor connected in series with a meter movement to extend its voltage range.

7. (a) Define the term rectification.
   Rectification is the process of converting alternating current (a.c.) into direct current (d.c.).

   (b) Give two main advantages of half wave rectifier.
   Simple design.
   Low cost.

8. (a) State a Coulomb's law.

   The force between two charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

   (b) At what velocity must a conductor 75 mm long cut a magnetic field of flux density 0.6 tesla, if an e.m.f of 9 V is to be induced in it. Assume the conductor, the field and the direction of motion are mutually perpendicular.

   $E = B\,l\,v.$

   $v = E/(B\,l).$

   $= 9 / (0.6 \times 0.075) = 9 / 0.045 = 200$ m/s.

9. A four pole wave connected armature has 51 slots with 12 conductors per slot and is rotated at 900 r.p.m. If the useful flux per pole is 25 mWb, calculate the value of the generated e.m.f.

   $Z = 51 \times 12 = 612.$

   $P = 4.$

   $A = 2$ (wave).

   $N = 900$ rpm.

   $\Phi = 0.025$ Wb.

   $Eg = (\Phi\,Z\,P\,N)/(60\,A).$

   $= (0.025 \times 612 \times 4 \times 900)/(60 \times 2).$

   $= 55{,}080/120 = 459$ V.

10. (a) State two particles consisted in the nucleus of an atom.

    Protons.

    Neutrons.

    (b) Explain how positive ions can be created between atoms.

    Positive ions are created when an atom loses one or more electrons, leaving behind more protons than electrons.

11. An electric cattle consumes 3 kW at 240 V supply. Calculate the current and the resistance of the heating element.

P = 3000 W, V = 240 V.
I = P/V = 3000/240 = 12.5 A.
R = V/I = 240/12.5 = 19.2 Ω.

12. (a) Define the following terms and state how they are related.
(i) Specific heat capacity is the amount of heat required to raise the temperature of 1 kg of a substance by 1 K.
(ii) Quantity of heat is the total amount of thermal energy absorbed or released by a body, calculated as Q = mcΔT.
(iii) Temperature is the measure of the average kinetic energy of the particles of a substance.
They are related in the equation Q = mcΔT, which shows that the quantity of heat depends on the specific heat capacity, mass, and temperature change.

(b) 2000 g of lead at 100°C are dropped into a copper vessel containing 300 g of water at 0°C and rapidly stirred. If the final temperature attained by the vessel and its contents is 16°C, calculate the heat capacity of copper vessel. Take specific heat capacity of lead = 0.13 J/gK and water = 4.2 J/gK.
Heat lost by lead = heat gained by water + vessel.
Qlead = m c ΔT = 2000 × 0.13 × (100 – 16) = 2000 × 0.13 × 84 = 21,840 J.
Qwater = 300 × 4.2 × 16 = 20,160 J.
Let C be the heat capacity of vessel, so Qvessel = C × 16.
21,840 = 20,160 + 16C → 16C = 1680 → C = 105 J/K.

(c) Draw a diagram which demonstrates the magnetic, heating and chemical effects of electric current. Describe how the effects are achieved.
Magnetic effect: When current flows through a conductor, it produces a magnetic field which can deflect a compass needle.
Heating effect: When current passes through a resistor or filament, it produces heat as given by H = I^2Rt.
Chemical effect: When current passes through an electrolyte, it causes decomposition (electrolysis), e.g. deposition of copper in electroplating.

13. (a) Define the following terms as used in electric networks.
(i) Circuit is a closed conducting path through which electric current flows.

(ii) Node is a junction in an electric circuit where two or more components are connected.

(iii) Branch is a path connecting two nodes and containing circuit elements.

(b) Find the magnitude and direction of currents in each of the batteries shown in Figure 1.

Using Kirchhoff's laws, simultaneous loop equations are set up. The calculations give currents distributed among the three batteries such that the 30 V and 20 V batteries supply current while the 10 V battery is being charged.

(c) Differentiate between linear and nonlinear resistors.

Linear resistors obey Ohm's law, where current is directly proportional to voltage, and resistance remains constant (e.g. metallic resistors).

Nonlinear resistors do not obey Ohm's law, their resistance varies with voltage or current (e.g. diodes, filament lamps).

(ii) A potential difference of 250 V is applied to a copper field at a temperature of 15°C, and the current is 5 A. What will be the mean temperature of the coil when the current has fallen to 4 A, the applied voltage being the same as before? Assume $\alpha = 1/234.5$ per °C.

Initial resistance $R1 = V/I = 250/5 = 50\ \Omega$.

Final resistance $R2 = V/I = 250/4 = 62.5\ \Omega$.

$R2 = R1\ [1 + \alpha\ (T - 15)]$.

$62.5 = 50\ [1 + (1/234.5)(T - 15)]$.

$62.5/50 = 1 + (T - 15)/234.5$.

$1.25 - 1 = (T - 15)/234.5$.

$0.25 \times 234.5 = T - 15$.

$58.6 = T - 15 \rightarrow T = 73.6°C$.

14. (a) Define the following terms.

(i) Luminous flux is the measure of the total amount of visible light emitted by a source, measured in lumens.

(ii) Luminous intensity is the luminous flux emitted per unit solid angle, measured in candela.

(b) State two laws of illumination.

Illumination is inversely proportional to the square of the distance from the source (Inverse Square Law).

Illumination on a surface is directly proportional to the cosine of the angle of incidence (Lambert's Cosine Law).

(ii) An office 18 m by 43 m requires an illumination at desk level of 330 lux. The mounting height of the lamps above desk level will be 2 m. The following alternatives are suggested:
80 W fluorescent lamps giving 4800 lumens.
150 W tungsten filament lamps giving 1950 lumens.
Calculate the number of lamps needed for each alternative, assuming a coefficient of utilization of 0.6 and a maintenance factor of 0.85.
Area = 18 × 43 = 774 m².
Required flux = (E × A)/(CU × MF) = (330 × 774)/(0.6 × 0.85) = 255,420/0.51 = 500,824 lumens.
Number of 80 W fluorescent lamps = 500,824 / 4800 ≈ 105 lamps.
Number of 150 W filament lamps = 500,824 / 1950 ≈ 257 lamps.

(c) The average luminous output of an 80 W fluorescent lamp 1.5 m long and 3.5 cm diameter is 3300 lumens. Calculate its average brightness. If the auxiliary gear consumes a load equivalent to 25% of the lamp, calculate the total energy consumed for running a twin unit for 2500 hours.
Surface area = πDL = 3.142 × 0.035 × 1.5 = 0.165 m².
Brightness = luminous flux / area = 3300 / 0.165 ≈ 20,000 lm/m².
Power of lamp + gear = 80 + 0.25(80) = 100 W.
Twin unit power = 200 W.
Energy = 200 × 2500/1000 = 500 kWh.

15. (a) Mention two types of transformer tests that are commonly used and briefly explain the function of each.
Open circuit test – used to determine iron losses and no-load parameters.
Short circuit test – used to determine copper losses and equivalent impedance.

(b) The core of a 100 kVA, 1100/550 V, 50 Hz single phase core type transformer has a cross section of 20 cm × 20 cm. Find the
(i) Number of turns of high voltage and low voltage turns per phase.
Area = 20 × 20 = 400 cm² = 0.04 m².
E = 4.44 f N Φmax.
Φmax = Bmax × A = 1.3 × 0.04 = 0.052 Wb.
Turns/volt = 1/(4.44 × 50 × 0.052 × 0.9) = 1/10.37 = 0.0965 turns/volt.

HV turns = 1100 × 0.0965 ≈ 106 turns.

LV turns = 550 × 0.0965 ≈ 53 turns.

(ii) e.m.f per turn if the maximum core density is not to exceed 1.3 T.

Eturn = 4.44 × f × Φ = 4.44 × 50 × 0.052 × 0.9 = 10.37 V per turn.

(c) A 150 kVA single phase transformer has a core loss of 1.5 kW and a full load Cu loss of 2 kW.

(i) Calculate the efficiency of the transformer at full load 0.8 power factor lagging.

Output = 150 × 0.8 = 120 kW.

Losses = 1.5 + 2 = 3.5 kW.

Efficiency = Output / (Output + Losses) × 100.

= 120 / (123.5) × 100 ≈ 97.2%.

(ii) Calculate the efficiency of the transformer at one half load at unit power factor.

Output = 150/2 = 75 kW.

Cu loss at half load = (½)² × 2 = 0.5 kW.

Total losses = 1.5 + 0.5 = 2 kW.

Efficiency = 75 / (77) × 100 ≈ 97.4%.

(iii) Determine the secondary current at which the efficiency is maximum, if the secondary voltage is maintained at its rated value of 240 V.

Condition for maximum efficiency: Iron loss = Cu loss.

Cu loss = I^2R = 1.5 kW.

Rated full load Cu loss = 2 kW at Ifl.

Therefore at Iopt: $(Iopt/Ifl)^2 \times 2 = 1.5$.

$(Iopt/Ifl)^2 = 0.75 \rightarrow Iopt/Ifl = \sqrt{0.75} = 0.866$.

Iopt = 0.866 × Ifl.

Ifl = 150,000 / 240 = 625 A.

Iopt = 0.866 × 625 = 541 A.

16. (a) Enumerate three methods in which low power factor can be improved or minimized.

By using capacitors.

By using synchronous condensers.

By using phase advancers.

(b) A 200 V, 50 Hz single phase induction motor consumes 1 kW at 0.7 power factor. Calculate the size of the capacitance to be placed in parallel with the motor to change the power factor to unity.

P = 1000 W, V = 200 V, pf = 0.7.

$I = P / (V \times pf) = 1000 / (200 \times 0.7) = 7.14$ A.

Reactive power $Q = V \times I \times \sin\theta$.

$\theta = \cos^{-1}(0.7) = 45.57°$.

$Q = 200 \times 7.14 \times \sin(45.57) \approx 200 \times 7.14 \times 0.714 = 1020$ VAR.

$C = Q / (V^2 \times 2\pi f) = 1020 / (200^2 \times 314) \approx 8.1 \times 10^{-5}$ F = 81 μF.

(c) A coil having a resistance of 15 Ω and an inductance of 0.5 H is connected in series with a capacitance of 50 μF. Find the

(i) Impedance of the electric circuit.

$XL = 2\pi fL = 2\pi \times 50 \times 0.5 = 157$ Ω.

$XC = 1 / (2\pi fC) = 1/(2\pi \times 50 \times 50 \times 10^{-6}) = 63.7$ Ω.

$Z = \sqrt{(R^2 + (XL - XC)^2)} = \sqrt{(15^2 + (157 - 63.7)^2)}$.

$= \sqrt{(225 + 93.3^2)} = \sqrt{(225 + 8700)} = \sqrt{8925} = 94.5$ Ω.

(ii) Current flowing, when 250 V at 50 Hz is supplied across the circuit.

$I = V/Z = 250/94.5 = 2.65$ A.

(iii) Power factor of the circuit.

$\cos\varphi = R/Z = 15/94.5 = 0.159$ lagging.