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 : 2011**

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.

(i) The resistance of a wire is ‘r’ ohms. The wire is then stretched to double its length. What will be the resistance of a wire in ohms?

A. r/2

B. 4r

C. 2r

D. r/4

E. r

Correct answer: C. 2r.

(ii) "The mass of an ion liberated at an electrode is directly proportional to the quantity of electricity which passes through the electrolyte." This statement is associated with

A. Weber’s theorem

B. Lagrange law

C. Coulomb’s law

D. Gauss’s theorem

E. Faraday’s law of electrolysis

Correct answer: E. Faraday’s law of electrolysis.

(iii) The unit of magnetic flux is

A. Weber

B. Ampere-turn

C. Tesla

D. Coulomb

E. Weber per meter square

Correct answer: A. Weber.

(iv) Kirchhoff’s law is applicable to

A. A.C circuits only

B. Passive networks only

C. A.C as well as D.C circuits

D. D.C circuits only

E. Active network only

Correct answer: C. A.C as well as D.C circuits.

(v) Which loss in a d.c generator significantly varies with the load current?

A. Magnetic loss

B. Field copper loss

C. Armature copper loss

D. Windage loss

E. Mechanical loss

Correct answer: C. Armature copper loss.

(vi) The instruments which are free from hysteresis and eddy current losses are called

A. Moving iron

B. Electrostatic

C. Hot wire

D. Induction type

E. Electro-dynamometer

Correct answer: B. Electrostatic.

(vii) Which of the following lamps has minimum initial cost of installation but maximum running cost?

A. Incandescent lamp

B. Fluorescent lamp

C. Mercury vapour lamp

D. Neon lamp

E. Sodium vapour lamp

Correct answer: A. Incandescent lamp.

(viii) At which speed in cm/s does the light of wave travel?

A. 3×10^{10}

B. 3×10^{12}

C. 3×10^{5}

D. 3×10^{8}

E. 3×10^{6}

Correct answer: D. 3×10^{10} cm/s.

(ix) The primary function of a filter in rectifier is to

A. Select frequency range correspond to output voltage

B. Minimize a.c input voltage variations

C. Remove ripples from the rectified output voltage

D. Stabilize d.c level of the rectified output voltage

E. Suppress odd harmonics in the rectifier output voltage

Correct answer: C. Remove ripples from the rectified output voltage.

(x) The capacity of a cell is always measured in

A. Watt – hours

B. Watts

C. Ampere – hours

D. Amperes

E. Watt – Amperes

Correct answer: C. Ampere – hours.

2. Three capacitors have capacitances of 10 μF, 15 μF, and 20 μF respectively. Calculate the total capacitance when they are connected in series.

   $1/Ceq = 1/10 + 1/15 + 1/20 = (6 + 4 + 3)/60 = 13/60.$

   $Ceq = 60/13 = 4.62$ μF.

3. A 10 hp motor is used to pump water for a certain purpose for 10 hours. Calculate the

   (a) Energy consumed by the motor.

   1 hp = 746 W → 10 hp = 7460 W.

   $Energy = P \times t = 7460 \times 10 \times 3600 = 268.6 \times 10^6$ J = 268.6 MJ.

   (b) Cost of the energy consumed if one unit of electric energy costs 50 cts.

   1 unit = 1 kWh.

   7460 W = 7.46 kW.

   Energy = 7.46 × 10 = 74.6 kWh.

   Cost = 74.6 × 0.50 = 37.3 shillings.

4. (a) Define the term mean value with reference to an alternating e.m.f.

   The mean value of alternating e.m.f is the average value of all the instantaneous values taken over one half cycle.

   (b) The equation for an alternating current is given by $i = 28.28 \sin (314t + 30°)$ A. Find its r.m.s value

and frequency.

Im = 28.28 A.

Irms = Im/√2 = 28.28/1.414 = 20 A.

ω = 314 rad/s, f = ω/2π = 314/6.283 = 50 Hz.

5. (a) Draw a diagram which shows how a diode can be connected to achieve half wave rectification.

   A single diode connected in series with the load and secondary of the transformer.

   (b) Sketch the input and output signals that an oscilloscope in (a) above would display.

   Input waveform = full sine wave.

   Output waveform = only positive half cycles.

6. The measured voltage across resistance R is V and the current through it is I. If these quantities contain systematic error in the measured values of V and I are 0.75% and 1% respectively, and if the value of R is independently known within ±0.5%, which formula between $P = I^2R$ and $P = V^2/R$ would you recommend for computing the power consumed by R?

   Error in P = 2 × error of I + error of R = 2 × 1 + 0.5 = 2.5%.

   If $P = V^2/R$, error = 2 × error of V + error of R = 2 × 0.75 + 0.5 = 2.0%.

   Therefore, $P = V^2/R$ is better.

7. (a) Write the expression for the resonance frequency for the L-C series circuit.

   $f = 1/(2\pi\sqrt{LC})$.

   (b) A sinusoidal voltage of peak value 10 V is applied across an inductor of 2 H inductance. This causes a current of 5 A peak value to flow through the inductor. Sketch the voltage and current waveforms on the same axes.

   Voltage leads current by 90° in a pure inductor.

8. (a) What is the difference between a cell and a battery?

   A cell is a single electrochemical device, while a battery is a combination of two or more cells connected together to provide higher voltage or current.

   (b) A battery consists of two cells joined in parallel through an external resistance of 5 Ω. If the equivalent internal resistance for the two cells is 2.5 Ω and each cell has e.m.f of 1.5 V, equivalent internal resistance of two cells is 2.5/2 = 1.25 Ω.

   Total resistance = 5 + 1.25 = 6.25 Ω.

   Current = E/R = 1.5/6.25 = 0.24 A.

9. The voltage measured by an oscilloscope is shown by the sine wave below. Use the graph to determine the following:

(a) Maximum amplitude voltage.

From the graph, the peak value is ±10 V. Therefore, the maximum amplitude is 10 V.

(b) Period.

From the graph, one cycle is completed in 8 ms. Therefore, the period $T = 8 \times 10^{-3}$ s.

(c) Frequency.

$f = 1/T = 1/0.008 = 125$ Hz.

(d) Angular speed.

$\omega = 2\pi f = 2\pi \times 125 = 785$ rad/s.

10. State the material used to make the filaments in an incandescent lamp and then give two reasons why the material is most preferred.

The filament material used is tungsten.

It is preferred because it has a very high melting point of about 3400°C, which prevents it from melting easily.

It also has high tensile strength and low rate of evaporation at high temperature, which makes it durable.

11. A single phase transformer is 2:5 turns ratio. The net cross-sectional area of the core is 60 cm². If the primary winding is connected to a 50 Hz supply at 520 V, calculate the:

(a) Voltage induced in the secondary winding.

Turns ratio = N2/N1 = 5/2.

Therefore, V2 = V1 × (N2/N1) = 520 × (5/2) = 1300 V.

(b) Peak value of flux density in the core.

Equation: V1 = 4.44 f N1 φm.

But since ratio is 2:5, assume N1 = 2, N2 = 5 turns.

520 = 4.44 × 50 × 2 × φm.

520 = 444 φm.

φm = 1.17 Wb.

Flux density Bm = φm/A = 1.17 / (60 × 10^{-4}) = 1.95 T.

12. (a) Mention two indicators and then explain briefly four causes of an overloaded generator.

Indicators: overheating of windings and fall in terminal voltage.

Causes include excessive demand beyond rated capacity, short circuit fault, poor cooling system, and sudden load fluctuations.

(b) Describe four conditions under which a self-excited d.c generator can fail to build up voltage.

If there is no residual magnetism in the poles.

If field resistance is greater than the critical resistance.

If the speed of rotation is below the critical speed.

If field connections are reversed.

(c) A d.c generator delivers a load current of 50 A at a terminal voltage of 220 V. The total resistance of its armature circuit is 0.015 Ω and there is a 2 V drop at the brushes. Calculate the:

(i) Generator e.m.f.

E = V + IaRa + brush drop.

= 220 + (50 × 0.015) + 2 = 220 + 0.75 + 2 = 222.75 V.

(ii) Speed at which it must be driven.

Using E = (φZN/60) × (P/A). Assume given flux and conductors, speed can be computed proportionally.

(iii) Total power generated.

P = E × Ia = 222.75 × 50 = 11.14 kW.

13. (a) Give three advantages and three disadvantages of dynamometer type wattmeter.

Advantages: accurate for both AC and DC, high sensitivity, measures true power.

Disadvantages: expensive, bulky, errors due to stray magnetic fields.

(b) The output of a gas engine was found to be 4.7 kW. A dynamometer used to check the output contained 20 kg of water of specific heat capacity 4.18 kJ/kgK. How much did the temperature of the water rise during a 20 minute running period? Neglect losses.

Energy = Power × time = 4.7 × 1200 = 5640 kJ.

$Q = mc\Delta T \rightarrow \Delta T = Q/(mc)$.

$= 5640/(20 \times 4.18) = 5640/83.6 = 67.4$ K.

(c) With the aid of a diagram, explain how two watt-meters can be used to measure total power in a star connected three phase load.

In two wattmeter method, each wattmeter is connected between one line and the other line, measuring power in two phases. The algebraic sum of both readings gives total power.

(ii) The circuit in Figure 1 is used to measure the power consumed by the load. The current and the voltage coil of the wattmeter have 0.02 Ω and 1000 Ω resistances respectively. What will be the measured power compared to the load power?

By considering power loss in coils, measured power will be slightly greater than actual load power due to extra power consumed by the current coil and potential coil resistances.

14. (a) (i) What do you understand by the term resistivity of a conductor?

Resistivity is the property of a material which defines how strongly it opposes the flow of electric current.

(ii) Explain four factors in which the resistance of a conductor depends on.

It depends on the length of the conductor, cross sectional area, type of material, and temperature.

(b) An aluminum wire 7.5 m long is connected in parallel with a copper wire 6 m long. When a current of 5 A is passed through the combination, it is found that the current in the aluminum wire is 3 A. If the diameter of the aluminum wire is 1 mm, determine the diameter of the copper wire.

Resistance of aluminum $Ra \propto \rho aL/A$.

Current division ratio $Ia/Ic = Rc/Ra$.

By using resistivity values of Al and Cu and solving equations, diameter of copper can be found.

(c) A piece of silver wire has a resistance of 1 Ω. What will be the resistance of a manganin wire half the length and half the diameter, if the specific resistance of manganin is 30 times that of silver?

Resistance $R \propto \rho L/A$.

New resistance $= (30 \times 0.5L/0.25A)/ (\rho L/A)$.

$= 30 \times 0.5 / 0.25 = 60$.

Thus, resistance of manganin wire = 60 Ω.

15. (a) Two differences between series and parallel circuits are: In a series circuit, the same current flows through all the components while in a parallel circuit, the same voltage is applied across all the components. In a series circuit, if one component fails the entire circuit is broken, while in a parallel circuit, if one component fails the others continue to work.

(b) Consider the circuit shown in Figure 2. Calculate the:

(i) Total current.

First, reduce the left-hand side: 5Ω, 10Ω and 15Ω are in parallel.

$1/R1 = 1/5 + 1/10 + 1/15 = (6/30) + (3/30) + (2/30) = 11/30$.

So, $R1 = 30/11 = 2.73\Omega$.

On the right-hand side, 18Ω and 24Ω are in series: $18 + 24 = 42\Omega$.

Now 12Ω, 6Ω, and 42Ω are in parallel.

$1/R2 = 1/12 + 1/6 + 1/42 = 0.0833 + 0.1667 + 0.0238 = 0.2738$.

$R2 = 3.65\Omega$.

Now R1 and R2 are in series with the 7Ω at the bottom.

$R_{total} = 2.73 + 3.65 + 7 = 13.38\Omega$.

Total current $= V/R = 100/13.38 = 7.47$ A.

(ii) Power dissipated in 6Ω and 7Ω resistors.

Voltage across the right network $= I \times R2 = 7.47 \times 3.65 = 27.27$ V.

Current in the 6Ω branch $= V/R = 27.27/6 = 4.55$ A.

Power $= I^2R = (4.55)^2 \times 6 = 124.2$ W.

For the 7Ω resistor: Current = 7.47 A (since it is in series).

Power $= I^2R = (7.47)^2 \times 7 = 390.5$ W.

16. (a) Give the units and symbols of the following quantities:

(i) Illumination or illuminance → lux (lx).

(ii) Luminous intensity (candle power) → candela (cd).

(iii) Luminance or brightness → candela per square metre (cd/m^2).

(iv) Luminous flux → lumen (lm).

(b) Two lamps A and B of 200 candela and 400 candela respectively are situated 100 m apart. The height of A above the ground level is 10 m and that of B is 20 m. If a photometer is placed at the centre of the line joining the two lamp posts, calculate its reading.

Illuminance from A: $E = I/d^2$, where $d = \sqrt{(50^2 + 10^2)} = \sqrt{2600} = 50.99$ m.

$EA = 200/(50.99^2) = 200/2600 = 0.0769$ lux.

Illuminance from B: $d = \sqrt{(50^2 + 20^2)} = \sqrt{2900} = 53.85$ m.

$EB = 400/(53.85^2) = 400/2900 = 0.138$ lux.

Total = EA + EB = 0.0769 + 0.138 = 0.215 lux.

(c) The illumination of a drawing office 30 m × 10 m has a value of 250 lux and is to be provided by a number of 300 W filament lamps. If the utilization factor is 0.4 and the depreciation factor is 0.9. Determine the number of lamps required. The efficiency of each lamp is 14 lumens per watt.

Total lumens required = E × A = 250 × (30 × 10) = 250 × 300 = 75,000 lumens.

Corrected lumens required = 75,000 / (0.4 × 0.9) = 75,000/0.36 = 208,333 lumens.

Each lamp lumens = 300 × 14 = 4200 lumens.

Number of lamps = 208,333 / 4200 = 49.6 ≈ 50 lamps.