THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

181 ELECTRICAL INSTALLATION

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2011**

Instructions

1. This paper consists of SIXTEEN questions.

2. Answer all questions in section A and B and THREE questions from section C.

(i) If the excitation to the field of the d.c motor is constant, then the torque developed in the motor is proportional to
A. armature current
B. field current
C. rotor speed
D. magnetic flux
E. induced e.m.f

Correct answer: A. armature current
Reason: In a d.c motor with constant field excitation, torque is directly proportional to armature current.

(ii) A.C power is transmitted at high voltage in order to
A. safeguard against losses
B. minimize transmission losses
C. increase tensile strength
D. reduce cost of power generation
E. make the system more reliable

Correct answer: B. minimize transmission losses
Reason: Higher voltage reduces current, which minimizes I^2R losses in transmission lines.

(iii) What is the current rate and the cable size of a domestic ring circuit?
A. 120 A and 1.5 mm^2
B. 30 A and 2.5 mm^2
C. 15 A and 3.5 mm^2
D. 30 A and 1.5 mm^2
E. 8 A and 1.5 mm^2

Correct answer: B. 30 A and 2.5 mm^2
Reason: Standard domestic ring circuits operate at 30 A with 2.5 mm^2 cable in many installations.

(iv) PVC cables can be used in conditions where temperature exceeds
A. 90°C
B. 80°C
C. 60°C
D. 45°C
E. 25°C

Correct answer: C. 60°C
Reason: PVC insulation typically withstands temperatures up to 70°C continuously, with safe usage starting above 60°C.

(v) The best instrument for the measurement of e.m.f of a cell is

A. potentiometer
B. ammeter
C. voltmeter
D. ohmmeter
E. galvanometer

Correct answer: A. potentiometer
Reason: A potentiometer measures e.m.f accurately without drawing current from the cell.

(vi) A circuit is protected by a fuse of rating 5 A. If it has a fusing factor of 1.45, what is the minimum fusing current?
A. 3.45 A
B. 6.25 A
C. 7.25 A
D. 10.0 A
E. 100.0 A

Correct answer: B. 6.25 A
Reason: Minimum fusing current = fuse rating × fusing factor = 5 × 1.25 = 6.25 A

(vii) Which of the following is the most likely source of harmonics in transformer?
A. Poor insulation
B. Over load
C. Core saturation
D. Loose connection
E. Mechanical stress

Correct answer: C. Core saturation
Reason: Harmonics are mostly generated due to non-linearity in magnetic core, especially under saturation.

(viii) The objective of carrying out a polarity test is to verify that
A. lamp holders and switches are correctly earthed
B. final circuits are correctly fused and earthed
C. the circuit is continuous through the installation
D. protective gears are connected to the neutral conductor
E. single pole switches are connected in the live conductor

Correct answer: E. single pole switches are connected in the live conductor
Reason: Polarity tests ensure live wires are correctly connected to switches and fuses for safety.

(ix) Which of the following shows the correct sequence of power connection to a consumer?
A. Supply authority, meter, consumer unit, and cut out

B. Supply authority, circuit breaker, meter and cut out
C. Supply authority, cut out, meter, and consumer unit
D. Supply authority, meter, cut out, and consumer unit
E. Supply authority, consumer unit, cut out and meter

Correct answer: C. Supply authority, cut out, meter, and consumer unit
Reason: Power flows from source to cut-out (protection), then to meter for billing, and then to consumer unit for distribution.

(x) When 10 mA passes through a human body, it will cause
A. mild sensation
B. muscle effects
C. rise in heart beat
D. rise in body temperature
E. death

Correct answer: B. muscle effects
Reason: At around 10 mA, the human body starts experiencing involuntary muscle contractions, which can be dangerous.

2. Explain three factors which determine the seriousness of electric shock.
- Magnitude of Current: The higher the current passing through the body, the more severe the physiological effect, which can range from a tingling sensation to cardiac arrest.
- Duration of Exposure: The longer the time a person is exposed to an electric current, the greater the damage to tissues and the higher the risk of fatality.
- Path of Current Through the Body: If the current path includes vital organs such as the heart or brain, the danger increases significantly compared to paths through extremities.

3. Explain three reasons which make conduit wiring system be mostly recommended in electrical installation works.
- Safety and Protection: Conduit protects conductors from mechanical damage, moisture, and chemical effects, increasing the lifespan and safety of the installation.
- Aesthetics and Neatness: Conduit provides a clean and organized appearance, especially in commercial and institutional buildings.
- Flexibility and Maintenance: Cables can be replaced or added with minimal disruption to the structure, making future maintenance easier.

4. A 4-pole wave connected generator has a useful flux of 0.02 Wb. If the induced e.m.f is 238 V at 1200 r.p.m,
(a) Find the number of conductors in the armature.
$E = (P \times \Phi \times Z \times N) / (60 \times A)$
$P = 4$, $\Phi = 0.02$ Wb, $N = 1200$ rpm, $A = 2$ (wave winding), $E = 238$ V
$238 = (4 \times 0.02 \times Z \times 1200) / (60 \times 2)$

238 = (96 × Z) / 120
Z = (238 × 120) / 96 = 297.5
Z ≈ 298 conductors

(b) If each slot contains 10 conductors, find the number of slots in the armature.
Number of slots = 298 / 10 = 29.8 ≈ 30 slots

5. A three-phase transformer is used to step down the supply voltage from 4000 V to 433 V. The output of the transformer is 150 kVA. Find the secondary and primary currents of the transformer.
S = 150000 VA
Primary voltage = 4000 V, Secondary voltage = 433 V
Primary current = 150000 / (√3 × 4000) = 150000 / 6928 = 21.65 A
Secondary current = 150000 / (√3 × 433) = 150000 / 750.08 = 199.97 A

6. Explain three disadvantages of oil circuit breaker.
- Risk of Fire or Explosion: Oil may catch fire due to arcing inside the breaker.
- Requires Regular Maintenance: Oil needs to be filtered or replaced periodically.
- Bulky in Size: Oil circuit breakers are large and heavy, taking up more space.

7. Suggest three precautions required to be taken to avoid electric shock to a worker.
- Ensure power is disconnected and locked out before maintenance.
- Use insulated tools and wear protective gloves and footwear.
- Always test for voltage before starting work on circuits.

8. A twin copper cable 100 m long has a resistance of 0.1 Ω. Calculate the minimum cross-sectional area of the required conductor.
ρ (resistivity of copper) = 1.7×10^{-8} Ω·m
R = ρ × L / A → A = ρ × L / R
A = $(1.7 \times 10^{-8} \times 100) / 0.1 = 1.7 \times 10^{-5} / 0.1 = 1.7 \times 10^{-4}$ m² = 1.7 mm²

9. Briefly explain the function of the transformer, filter and voltage regulator in a d.c power supply.
- Transformer: Steps down or steps up the input AC voltage to a suitable level.
- Filter: Removes AC ripples from the rectified output to provide smooth DC.
- Voltage Regulator: Maintains a constant output voltage regardless of load changes or input fluctuations.

10. A resistance R is connected in series with a parallel circuit comprising 20 Ω and 48 Ω. If the equivalent resistance of the circuit is 65.2 Ω, calculate the value of R.
Parallel resistance Rp = (20 × 48) / (20 + 48) = 960 / 68 = 14.12 Ω
R = 65.2 - 14.12 = 51.08 Ω

11. Classify d.c motor according to the connections made in the field system.
- Shunt Motor: Field winding connected in parallel with armature.
- Series Motor: Field winding connected in series with armature.

- Compound Motor: Combination of series and shunt field windings (can be short or long compound).

12. (a) Three-phase systems are more economical over single-phase systems. Give four reasons to support this statement.
- Better power transfer efficiency due to constant power flow.
- Lower conductor material required for the same power compared to single-phase.
- Three-phase motors are self-starting and have better performance.
- Reduced voltage drops over long distances, making transmission more economical.

(b) Discuss four factors which make power plants prefer to have several smaller generators running in parallel rather than having a large single unit.
- Reliability: If one generator fails, others continue running, ensuring supply continuity.
- Flexibility: Generators can be turned on or off based on load demand.
- Maintenance: Units can be serviced one at a time without shutting down the whole plant.
- Cost-effectiveness: Smaller units are often cheaper and easier to install and manage.

13. (a) Explain methods of heat transfer from a hot to a cold body.
- Conduction: Transfer of heat through a solid medium without movement of the substance itself.
- Convection: Transfer of heat through fluid motion (liquid or gas).
- Radiation: Transfer of heat via electromagnetic waves without requiring a medium.

(b) Draw a sketch of a non-pressure (free outlet) type water heater and label clearly its parts.
[Sketch expected: water inlet, heating element, thermostat, outlet pipe, tank]

(c) A 4 kW immersion heater is fitted to a tank containing 223.5 litres of water. If the initial temperature of water was 27°C, how long it would take to heat the water and reach a temperature of 87°C? Assume no heat loss and an efficiency of 82%. Take 1 kWh = 3.6×10^6 J and 1 litre of water = 1 kg.
Mass = 223.5 kg
$\Delta T = 87 - 27 = 60°C$
$Q = mc\Delta T = 223.5 \times 4200 \times 60 = 56{,}676{,}000$ J
Effective energy from heater = $0.82 \times 4000 = 3280$ W = 3280 J/s
Time = Q / Power = 56,676,000 / 3280 = 17284.15 s = 4.8 hours

14. (a) Which types of switches will you need to control lights from three different doors? Explain their function.
- 2 two-way switches and 1 intermediate switch.
Two-way switches control lights from two locations; the intermediate switch allows control from a third location by connecting between the two two-way switches.

(b) A bed room has got one lamp which is controlled by two switches. Make a neat circuit diagram when the lamp is switched on and when it is off.
[Diagram expected showing two two-way switches controlling one lamp in a staircase arrangement.]

(c) Two metal filament lamps with intensities 150 cd and 300 cd respectively are fixed 10 m apart on a level bench. A double sided matt white screen is placed on the line between the lamps so that both sides are equally illuminated. Calculate the:
(i) Distance between the screen and the larger lamp
Let x = distance from 300 cd lamp, so (10 - x) from 150 cd lamp
Equal illumination means: $I_1 / (d_1)^2 = I_2 / (d_2)^2$
$150 / (10 - x)^2 = 300 / x^2$
Cross-multiplied: $150x^2 = 300(10 - x)^2 \rightarrow x^2 = 2(100 - 20x + x^2)$
$x^2 = 200 - 40x + 2x^2$
$x^2 - 40x + 200 = 0$
Solving: x = 28.28 or 7.07 → x = 7.07 m from larger lamp

(ii) Illumination on each side of the screen if it were positioned that way
$E = I / d^2 = 300 / (7.07)^2 = 300 / 50 = 6$ lux

15. (a) (i) Differentiate between fixed and running charges in the operation of a power company.
Fixed charges: Costs that remain constant regardless of power consumption (e.g. maintenance, salaries).
Running charges: Costs that vary with energy usage (e.g. fuel, operation).

(ii) Give two expenses which are considered as fixed costs and two as running costs.
Fixed: Depreciation of equipment, staff wages
Running: Fuel cost, repair costs during usage

(b) A 100 MW power station delivers 100 MW for 2 hours, 50 MW for 6 hours and is shut down for the rest of each day. It is also shut down for maintenance for 45 days a year. Calculate its annual load factor.
Energy delivered per day = (100 × 2) + (50 × 6) = 200 + 300 = 500 MWh
Operating days = 365 - 45 = 320 days
Total energy per year = 500 × 320 = 160000 MWh
Max possible = 100 × 24 × 365 = 876000 MWh
Load factor = 160000 / 876000 = 0.1826 = 18.26%

(c) A 415 V 3-phase, 50 Hz induction motor having an output of 74.6 kW runs on full load at 0.7 power factor lagging and 88% efficiency. Find the capacitor per phase of a mesh-connected capacitor necessary to raise power factor to unity.
P = 74600 W, $\eta = 88\%$, $S = P / \eta = 84659$ W
$I = S / (\sqrt{3} \times V \times pf) = 84659 / (\sqrt{3} \times 415 \times 0.7) = 169$ A
Reactive power $Q = S \times \sin\theta = 84659 \times \sin(\cos^{-1}0.7) = 84659 \times 0.714 = 60451$ VAR
Qc per phase = 60451 / 3 = 20150.3 VAR
$C = Q / (2\pi f V^2) = 20150.3 / (2\pi \times 50 \times 415^2) = 20150.3 / 54097000 = 372.4$ μF per phase

16. (a) (i) Differentiate absolute instruments from secondary instruments.
Absolute instruments give measurements based on physical constants (no calibration needed).
Secondary instruments depend on calibration and comparison.

(ii) A moving coil milliammeter has a resistance of 5 Ω and full scale deflection at 20 mA. Determine the resistance of a shunt to read 100 mA.
I = 100 mA, Im = 20 mA → Ish = 80 mA
Rsh = (Im × Rm) / Ish = (0.02 × 5) / 0.08 = 0.1 / 0.08 = 1.25 Ω

(iii) What is the percentage error if the instrument operates up to 80 mA at 40°C?
Error = (80 - 100) / 100 × 100% = -20%

(b) The steady readings of single-phase watt-meter in 3-phase circuit are 35 kW and 14 kW respectively. Calculate the power factor:
Total power = 35 + 14 = 49 kW
$\tan\theta = \sqrt{3}(W1 - W2) / (W1 + W2) = \sqrt{3}(35 - 14)/49 = 21\sqrt{3}/49 = 0.742$
$\theta = \tan^{-1}(0.742) = 36.53° \rightarrow pf = \cos(36.53°) = 0.803$

Apparent power = $\sqrt{3} \times 415 \times I$
S = P / pf = 49000 / 0.803 = 61059 VA