University of KwaZulu-Natal
School of Electrical, Electronic and Computer Engineering
Main Examination: November 2025

Section 1 – Total Marks: 50 Marks
Instruction: Answer **all four** questions from this section in a separate examination book, and label the front cover of this book clearly as **SECTION 1**

Question 1 [15 marks]

a) State the four (4) components of a power system. **[2]**
b) State one advantage and one disadvantage of the electrical energy. **[2]**
c) The "quality" of power supply must meet certain minimum standards with regards to three factors. State those three factors. **[3]**
d) What is the main purpose of the Energy Control Center (ECC)? **[2]**
e) Explain using schematic diagrams, the working principles of the primary Load Frequency Control (LFC) and the Automatic Voltage Regulator (AVR). **[6]**

Question 2 [12 Marks]

a) A power station has to meet the following demands (see **Table 1**):

Table 1: Energy demand of some selected customers

Group A	200 kW between 8 A.M and 6 P.M.
Group B	100 kW between 6 A.M. and 10 A.M.
Group C	50 kW between 6 A.M. and 10 A.M.
Group D	100 kW between 10 A.M. and 6 P.M. and the between 6 P.M. and 6 A.M.

Find the following:

i. Plot the daily load curve **[3]**
ii. The diversity factor **[1]**
iii. Units generated per day **[1]**
iv. Load factor **[1]**

b) The monthly readings of a consumer's meter are as follows:
Maximum demand = 50 kW
Energy consumed = 36000 kWh
Power factor readings = 0.8384
If the tariff is R 80 per KW of maximum demand plus 8 cents per units plus 0.5 cents per unit for each 1% of power factor below 86 %, calculate the monthly bill of the consumer. **[6]**

Question 3 **[11 Marks]**

a) An overhead single-phase short transmission line delivers 5000 kW at 22 kV at 0.8 p.f. lagging. The resistance and reactance of each conductor is 4 ohm and 6 ohm respectively. Determine its transmission efficiency. **[6]**

b) A three-phase, 5 kW induction motor has a p.f. of 0.75 lagging. A bank of capacitors is connected in delta across the supply terminals and p.f. raised to 0.9 lagging. Determine the kVAR rating of the capacitors connected in each phase. **[5]**

Question 4 **[12 Marks]**

A three-phase, 50 Hz transmission line 100 km long delivers 30 MW at 0.9 pf lagging and at 120 kV. The resistance and reactance of the line per phase are 20 ohm and 52 ohm respectively, while the total phase – neutral admittance is 315×10^{-6} Siemen. Calculate the voltage at the sending end using nominal T method. **[12]**

ANSWER ALL THE QUESTIONS
PLEASE BE ADVISED TO USE BALL PENS ONLY, NO WOOD PENCILS

QUESTION 1 **[9]**

(a) Explain how annual cost of energy affects the current density of a power line conductor. **[2]**
(b) The cost of a 10 km long three-phase overhead line is R (250000a+7500) length where a is the cross-sectional area of the conductor in sq mm. The rate of interest and depreciation per annum is 10%. If the load is supplied for 6800 hours of the year, estimate the most economical current density for the conductor. The cost of energy is Rand 4.5 per kWh and resistivity of conductor material is 1.8 μ ohm-cm. **[7]**

QUESTION 2 **[9]**

(a) Explain how parabolic method is suitable for sag calculation? **[2]**
(b) An overhead transmission line has a span of 200 m between level supports. The conductor diameter is 50 mm while it weighs 2.1 kgf/m and has a working tension of 3500 kgf. The conductors are subjected to a radial ice-covering of 10.5 mm thickness and sag of 7.5 m. Calculate the horizontal wind pressure acting on the ice-covered projected area of the conductor if the weight density of ice is 913.5 kgf/m^3. **[7]**

QUESTION 3 **[10]**

(a) Explain the causes of internal and external inductance of a power line conductor. **[2]**
(b) A three-phase, overhead transmission line uses a bundled conductor of 8 sub-conductors on a circle of radius of 1.5 m. Each sub-conductor of the bundle has a diameter of 50 mm. Each phase group shares the total current and charge equally and the transmission line is completely transposed. Determine the inductance/ph/km of the transmission line. The distance between the phases of the line is 8 m. **[8]**

QUESTION 4 **[10]**

(a) Explain how grading of underground cables can be helpful. **[4]**
(b) The total charging kVA drawn by a three-phase underground cable when connected to three-phase, 50 Hz supply is 220 while the charging current is 11 A per conductor. The capacitance measured for the same cable between one core and the other two connected together to the sheath is 4.5 μF. Calculate (a) line-to-line supply voltage (b) equivalent capacitance of the cable (c) capacitance between any two cores of the cable (d) capacitance between a core and sheath. **[6]**

QUESTION 5 **[12]**

(a) Explain how short-circuit currents can cause equipment damage in electrical power systems. **[3]**
(b) There are five generators (labelled as G1 through G5) in a power station connected to a tie-bus system. Each generator is rated at 30 MVA with a reactance of 0.10 p.u. Each generator bus is connected to the tie-bus through a reactance of 0.1 pu rated at 30 MVA. The generator bus voltage is 33 kV and supplies a load feeder through a circuit breaker. Determine the minimum rating of the circuit breaker installed on each feeder of generator bus considering a three-phase short-circuit fault on any feeder. Also, calculate the fault currents supplied by each of the generators. **[9]**

Formula Sheet – Section 2

Sag & Tension	**Catenary Method**		
	$\delta = \frac{H}{w}(\cosh\left(\frac{wl}{2H}\right) - 1)$	$T_{max} = H\cosh\left(\frac{wl}{2H}\right)$	$L = \frac{2H}{w}\sinh\left(\frac{wl}{2H}\right)$
Transmission Lines	**Inductance**		
	$L = 2x10^{-7}\ln\left(\frac{D_m}{D_s}\right)$	$D_m = (D_{AB}D_{BC}D_{CA})^{1/3}$	$D_S = (D_{SA}D_{SB}D_{SC})^{1/3}$
	Capacitance (Line to neutral)		
	$C_n = \frac{2\pi\varepsilon_0}{\ln(D_m/D_{sc})} = \frac{1}{18\times10^9 ln\left(\frac{D_m}{D_{sc}}\right)}$		
Underground Cables	**Capacitance Grading**	**Voltage Across A Cable**	**Cable Capacitance**
	$C = \frac{2\pi\epsilon_0}{\left(\frac{1}{\epsilon_1}ln\left(\frac{r_1}{r}\right) + \frac{1}{\epsilon_2}ln\left(\frac{r_2}{r_1}\right) + \frac{1}{\epsilon_3}ln\left(\frac{R}{r_2}\right)\right)}$	$V = g_{max}\left(rln\left(\frac{r_1}{r}\right) + r_1 ln\left(\frac{r_2}{r_1}\right) + r_2 ln\left(\frac{R}{r_2}\right)\right)$	$C_o = C_1 + C_S = 3C_c + C_s$ $C_L = C_C + \frac{(C_c + C_s)}{2}$ $C_b = 3\,C_s$ $C_L = \frac{2}{3}(3C_c + C_s)$ $C_L = 2C_c + C_S$
	Thermal Resistance (for each of Single Core) (*thermal ohm*)	**Thermal Resistance(3 Core)** (*thermal ohm*)	**Thermal Resistance of Ground** (*thermal ohm*)
	$R_{\theta D} = \frac{\rho_{\theta D}}{2\pi}\ln\left(\frac{D_s}{d}\right)$	$R_{\theta D} = \frac{\rho_{\theta D}}{6\pi}\left(0.85 + \frac{0.2t_b}{T}\right) ln\left[1 + 2\left(\frac{T+t_b}{d}\right)\left(4.15 - \frac{1.1t_b}{T}\right)\right]$	$R_{\theta G} = \frac{\rho_{\theta G}}{2\pi}\ln\left(\frac{2h}{R_s}\right)$
	Thermal Resistance (Protective Cover)	**Rated Current of Under Ground Cable**	
	$R_{\theta P} = \frac{\rho_{\theta P}}{2\pi}\ln\left(\frac{D_P}{D_s}\right)$	$I = \sqrt{\frac{\theta_m - \theta_a}{nR[R_{\theta D} + (1+\lambda)(R_{\theta P} + R_{\theta G})]}}$	