ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2024
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR ELECTRICAL ENGINEERING

Date : October 5, 2024
Total Marks : 100
Writing Time : 150 minutes (2.5 hours)
Reading Time : 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is provided to check the number of pages of the Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
    - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
      Part II - 4 Short Answer Questions
      All questions under SECTION A are **COMPULSORY**.
    - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part on a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **12 printed pages**, including this instruction page.

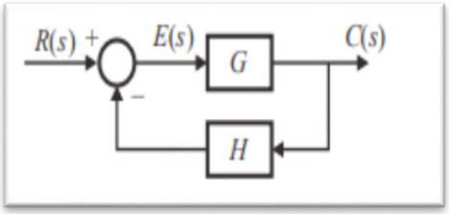
GOOD LUCK

SECTION A

PART I: Multiple Choice Questions [30 marks]

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e. g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. For the closed loop system shown below, the transfer function $\frac{E(s)}{R(s)}$ is:



a) $\frac{G}{1+GH}$

b) $\frac{GH}{1+GH}$

c) $\frac{1}{1+GH}$

d) $\frac{1}{1+G}$

2. Calculate the poles and zeroes for the given transfer function G(s) = $\frac{5(s+2)}{s^2+3s+2}$:
   a) -2, (-1, -2)
   b) 2, (-1, 2)
   c) 2, (1, 2)
   d) -2, (1, -2)

3. The most powerful controller is:
   a) PD controller
   b) PI Controller
   c) PID Controller
   d) None of the above

4. The Nyquist sampling rate is given by:
   a) Fs = 2 Fm
   b) Fs = 3 Fm
   c) Fs = 4 Fm
   d) Fs = Fm

5. In a JK flip-flop, what happens when both J and K inputs are 1?
   a) No change
   b) Set
   c) Reset
   d) Toggle

6. Convert the 127 decimal number into binary:
   a) 1100111
   b) 1111111
   c) 1111011
   d) 111111

7. Charge stores in:
   a) Resistor
   b) Capacitor
   c) Diode
   d) Transistor

8. For a frequency of 200 Hz, the time period will be:
   a) 0.005 S
   b) 0.5 S
   c) 0.0005 S
   d) 0.05 S

9. When the gate signal from a thyristor is removed, it will remain in its forward conduction mode. This characteristics of thyristor is called…:
   a) get-on
   b) off-blocking
   c) ever conducting
   d) latching

10. Which semiconductor power device, out of the following is not a current triggered device:
    a) Thyristor
    b) GTO
    c) TRIAC
    d) MOSFET

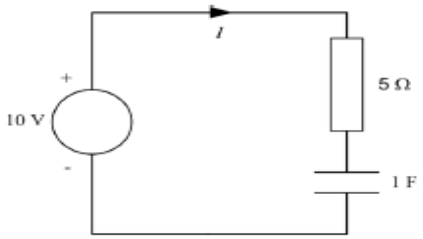
11. You need to design a DC-DC converter to power a 5V microcontroller from a 9V battery. Which type of converter would be most suitable?
    a) Buck Converter
    b) Boost Converter
    c) Buck-Boost Converter
    d) Flyback Converter

12. Linear Variable Differential Transformer has:
    a) One primary coil and two secondary coils
    b) Two primary coils and one secondary coil
    c) One primary coil and one secondary coil
    d) Two primary coils and two secondary coils

13. A voltmeter is connected in a …….with the circuit component across which potential difference is to be measured:
    a) Parallel
    b) Series
    c) Series or parallel
    d) None of the above

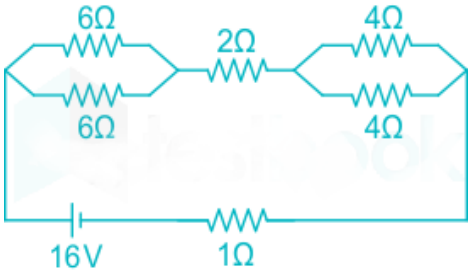
14. Which of the following is a disadvantage of a proportional-only controller?
    a) It cannot respond to changes in the setpoint
    b) It cannot measure the process variable
    c) It can result in a steady-state error
    d) It is too complex to implement

15. For the circuit diagram shown below, determine the current I flowing through 5Ω resistance:



    a) 2 A
    b) 0
    c) 0.5 A
    d) 20 A

16. A network of resistors is connected as shown below. Compute the equivalent resistance of the network:



a) 7 Ω
b) 8 Ω
c) 23 Ω
d) 22 Ω

17. When short circuit occurs, current flow in circuit will be:

a) Zero
b) Very low
c) Normal
d) Infinite

18. For a synchronous generator connected to a power station, increase in excitation will:

a) Decrease reactive power generation
b) Increase reactive power generation
c) Decrease active power generation
d) Increase active power generation

19. Length of the cable is doubled, its capacitance C will be:

a) Doubled
b) One-half
c) One-fourth
d) Unchanged

20. In an interconnected power system, what is the effect of a large increase in load on system frequency?

a) Increase in frequency
b) Decrease in frequency
c) No change in frequency
d) Oscillations in frequency

21. A 800 kV transmission line has a maximum power transfer capacity of P. If it is operated at 400 kV with the series reactance unchanged, the new maximum power transfer capacity is approximately:
    a) P
    b) 2P
    c) P/2
    d) P/4

22. High voltage transmission line are transposed because:
    a) Corona loss can be minimized
    b) Computation of inductance becomes easier
    c) Voltage drop in the lines can be minimized
    d) Phase voltage imbalance can be minimized

23. A transformer has a primary voltage of 110 kV and a secondary voltage of 11kV. If the transformer is supplying 100 A on the secondary side, what is the current on the primary side, assuming no losses?
    a) 10 A
    b) 1000 A
    c) 11 A
    d) 12 A

24. The rating of a circuit breaker is generally determined on the basis of:
    a) Line-to-line fault current
    b) Symmetrical fault current
    c) Single line to ground fault current
    d) Double line to ground fault current

25. Steady state stability of a power system is the ability of a power system to:
    a) Maintain voltage at the rated voltage level
    b) Maintain frequency exactly at 50 Hz
    c) Maintain spinning reserves margin at all time
    d) Maintain synchronism between machines and on external tie lines

26. Buses for load flow studies are classified as (i) load bus, (ii) the generator bus, and (iii) slack bus. The correct combination of the pair of quantities specified having their usual meaning for different buses is:

Load Bus	Generator bus	Slack Bus
a) P, $\|V\|$	P,Q	P, δ
b) P,Q	P, $\|V\|$	$\|V\|$, δ
c) $\|V\|$, Q	P, δ	P,Q
d) P, δ	$\|V\|$, Q	Q, δ

27. A 6 pole, 50 Hz, 3-phase induction motor has a full load slip of 3%, what is the rotor speed at full load?
    a) 950 r.p.m.
    b) 970 r.p.m.
    c) 980 r.p.m.
    d) 1000 r.p.m

28. An under-excited synchronous motor behaves as:
    a) A resistor
    b) An inductor
    c) A capacitor
    d) None of the above.

29. The field winding of an alternator is:
    a) d.c. excited
    b) a.c. excited
    c) both d.c. and a.c. excited
    d) none of the above.

30. The nameplate details of a motor are given as power = 15 kW, efficiency $\eta = 0.9$. Using a power meter the actual three phase power drawn is found to be 8 kW. Find out the loading of the motor.
    a) 48%
    b) 49%
    c) 50%
    d) 55%

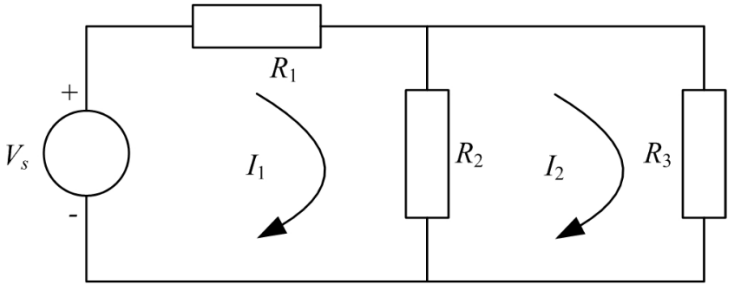
PART II – Short Answer Questions [20 marks]

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks. Mark for each sub-question is indicated in the brackets.

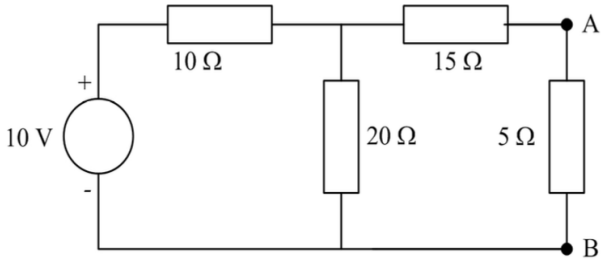
1. Consider a circuit with three inputs (A, B, C) and an output (Y). The circuit uses a combination of an XOR gate and an AND gate, where the XOR gate takes inputs A and B, and the AND gate takes the output of the XOR gate and input C. What will be the output Y for all possible input combinations of A, B, and C? Construct the truth table for the circuit. **(5 marks)**

2. Answer the following questions:

   a) Write the mesh equation using KVL for the circuit shown below **(2 marks)**



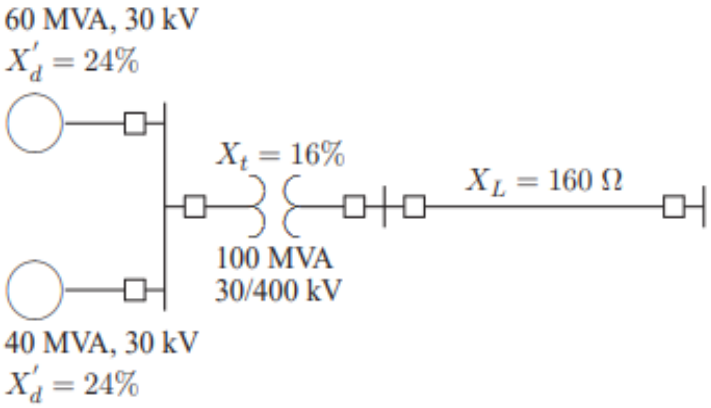
   b) Use Thevenins theorem to find the current through 5Ω resistance in the circuit diagram shown below: **(3 marks)**



3. Answer the following questions.

   a) Write the difference between induction motor and synchronous motor? **(2.5 marks)**
   b) Why 3-phase induction motor cannot run at synchronous motor? **(2.5 marks)**

4. The system shown in figure below is initially on no load with generators operating at their rated voltage with their emfs in phase. The rating of the generators and the transformers and their respective percent reactance are marked on the diagram. All resistances are neglected. The line impedance is j160 Ω. A three-phase balanced fault occurs at the receiving end of the transmission line. Determine the short-circuit current and the short-circuit MVA. **(5 marks)**



SECTION B: CASE STUDY [50 marks]

Choose either CASE I OR CASE II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.

CASE I

You have been recruited as an electrical engineer in the Department of Energy, Ministry of Energy and Natural Resources. As part of the Transformative Initiative under Energy, the Department is undertaking Feasibility Study for the potential development of an Integrated Multipurpose Hydropower Project (IMHP) in Paro Dzongkhag. The Parochhu IMHP is located in Tsento Gewog, with its intake structure planned at about 45-minute walk from the last road head at Shana. The overall salient features of the plant is as shown below:

Sl/No	Parameters	Unit	Value
1	Full Reservoir Level	m	2934
2	Tail Race Channel outfall elevation (TRT)	m	2715
3	River Bed Level (RBL)	m	2929
4	Powerhouse ground elevation	m	2720
5	Height of proposed raised weir	m	5
6	Gross Head of the project	m	219
7	Total Head loss of the project	m	10.95
8	Net Head of the Project	m	208.05
9	Gravity	m/s^2	9.81
10	Combined Efficiency	%	0.906
11	Environmental Flow (E-Flow)	cumec	0.32
12	Design Discharge	cumec	19.55
13	Average lean season flow in 90% Dependable year	cumec	2.53

The power generated from the plant is proposed to be pooled at nearby substation at Olathang, located at 30km away from the pothead yard. Your supervisor has entrusted you with the design of power

evacuation arrangement works for this project. With this task in your hand, please answer the following questions using the data given in the table above:

1. Calculate the installed capacity of the plant. **(2 marks)**
2. Using the installed capacity derived above, calculate the economical transmission voltage if the power is to be evacuated using a 3-phase AC system. Considering technical and economic factors, propose an appropriate voltage level for transmission and justify your choice. **(5 marks)**
3. Global warming is altering the rainfall patterns, which in turn affects power generation. Assuming a catchment area of 613 km², with an average annual rainfall of 100 cm and a 30% evaporation loss, calculate the average power that can be generated **(5 marks)**
4. What do you understand by E-Flow and IMHP? **(3 marks)**
5. If you have chosen a 3-phase overhead transmission line with an ACSR conductor of 15mm diameter spaced at the corner of an equilateral triangle of 1.5m, calculate the inductance and capacitance per phase of the systems **(4 marks).**
6. The Olathang Substation has 2x20 MVA, 66/33 kV transformers. It features three outgoing 33 kV feeders, which are as follows: Feeder-I supplying power to Drugyel, Feeder-II to Shaba, and Feeder-III to Tshongdu. The substation receives its power supply through a 66 kV single-circuit transmission line originating from the Jamjee Substation. Additionally, the power from Parochhu IMHP will be integrated to this substation. Draw the single line diagram of the Olathang substation showing the position of necessary equipment used for protection, measurement and communications. **(10 marks)**
7. Assuming that a MV industries connected to this substation is operating at an average power factor of 0.72 with an average power demand of 627 KW, answer the following questions:
    i. Explain power factor with the help of diagram **(5 marks)**
    ii. What are methods of power factor improvement? **(5 marks)**
    iii. The industries are levied demand charge of Nu. 170/kVA/month. What will be monthly energy cost saving if the power factor is improved to 0.95 and how much kVAr is required? **(5 marks)**
8. Draw the Zero-Sequence equivalent circuit for the following transformers winding arrangement. Also, comments on the zero sequence currents.
    i. Star-Star with isolated neutrals. **(2 marks)**
    ii. Star-Star with any one neutral grounded. **(2 marks)**
    iii. Star-Delta with neutral grounded at Star side. **(2 marks)**

CASE II

Accurate design of electrical installation work in buildings is essential to prevent electrical hazards and ensure occupant safety. Properly designed electrical systems minimize the risk of short circuits, overloading, and other electrical faults that can lead to fires and dangerous situations. This involves selecting appropriate materials, following correct installation procedures, and adhering to safety standards and regulations. By doing so, common electrical hazards such as exposed wires, faulty connections, and inadequate grounding are effectively prevented. In Bhutan, a significant number of house fires are blamed to electrical faults, underscoring the critical need for meticulous electrical planning and installation. Therefore, it is crucial for electrical engineers to prioritize safety in their designs to prevent such incidents and contribute to a safer built environment. As an electrical engineer, please answer the following questions:

1. Name the regulation that governs the electrical wiring system and electrical installations in Bhutan? **(2 marks)**

2. What are the different type of routines inspection and test that needs to be carried out as per the regulation? **(4 marks)**

3. What are the reasons for providing fuse on phase wire? What will be the effect on the wiring, if fuse wire of much higher rating is installed **(3 marks)**

4. It is necessary to break a short circuit current immediately whereas overload current is allowed to persist for some time before it is broken. Give short explanation for this. **(4 marks)**

5. Is it desirable to have low or high value of earthing resistance? What are the different measures that you will adopt to achieve the desired value? **(5 marks)**

6. Explain the importance of load balancing in a three-phase electrical system and the potential consequences of poor load distribution. **(3 marks)**

7. The owner of the building desires electrical connections to be provided in the building with electrical points as under:

Particulars	Lamps (60 W)	Fans (60 W)	Fluorescent (40 W)	Socket (5 Amp,100 W)	Socket (15Amp,1000W)
Verandah	2	1	-	1	-
Room No. 1	1	1	1	-	1
Room No. 2	1	1	1	1	-

   i. Decide the number of final sub circuit **(5 marks)**

ii. Decide the rating of the components to be installed on the main board giving reasons. **(5 marks)**

iii. Write a short note on: Isolator, MCB, RCCB, ELCB, and RCBO **(5 marks)**

iv. What is the standard size of the wire for light points and power points? **(3 marks)**

8. One of the residential consumer has 10 lamps of 40 W each connected at his premises. His demand is as follows:
    - From 12 midnight to 5 AM: 40 W
    - From 5 AM to 6 PM: No load
    - From 6 PM to 7 PM: 320 W
    - From 7 PM to 9 PM: 360 W
    - From 9 PM to 12 midnight: 160 W

    i. Find the average load, maximum load, load factor and electric energy consumption during the day. **(6 marks)**

    ii. The electricity tariff rate in Bhutan is Nu. 1.28/kWh for 0-100 kWh and Nu. 2.66/kWh for consumption >100kWh. Calculate the monthly electrical bill of the given residence **(5 marks)**

TASHI DELEK