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MECHANICAL SCIENCE AND
ELECTRICAL AND ELECTRONIC
PRINCIPLES
June/July 2023
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN MECHANICAL ENGINEERING
(PRODUCTION OPTION)
(PLANT OPTION)
(WELDING AND FABRICATION OPTION)
DIPLOMA IN AUTOMOTIVE ENGINEERING
DIPLOMA IN WELDING AND FABRICATION
DIPLOMA IN CONSTRUCTION PLANT ENGINEERING

MODULE II

MECHANICAL SCIENCE AND ELECTRICAL AND ELECTRONICS PRINCIPLES

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
> *Answer booklet;*
> *Non-programmable scientific calculator;*
> *Drawing instruments.*
*This paper consists of **EIGHT** questions in **TWO** sections A and B .*
*Answer any **FIVE** questions by choosing at least **TWO** questions in each section.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

This paper consists of 6 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A: MECHANICAL SCIENCE

*Answer at least **TWO** questions from this section.*

1. (a) (i) Define the following terms as applied to dynamics and state their SI units:

    I.   velocity;
    II. acceleration.

    (ii) State Newton's first law of motion.   (6 marks)

    (b) A gear wheel rotating at 3000 rev/min retards to rest in 200 revolution. Determine the:

    (i) angular retardation;
    (ii) time taken.   (7 marks)

    (c) A body of mas 120 kg rests on a plane inclined at 20° to the horizontal. A force P is applied to pull the body up slope at uniform speed. If the coefficient of friction between the body and the plane is 0.54, determine the value of P if it acts parallel to the plane.
                                                            (7 marks)

2. (a) (i) Distinguish between scalar and vector quantities giving one example for each.

    (ii) State the principle of moments.   (6 marks)

    (b) **Figure 1** shows a system of four co-planar forces in a static equilibrium. Construct a polygon of the forces, hence determine the magnitudes of forces P and Q.   (7 marks)
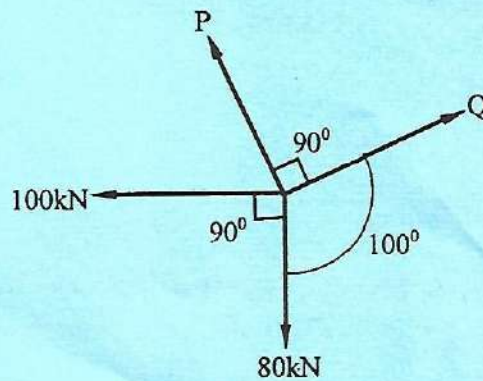

Fig. 1

(c)   (i)   **Figure 2** shows a simply supported plank carrying two loads. Neglecting the mass of the plank, determine the reactions at the supports X and Y.
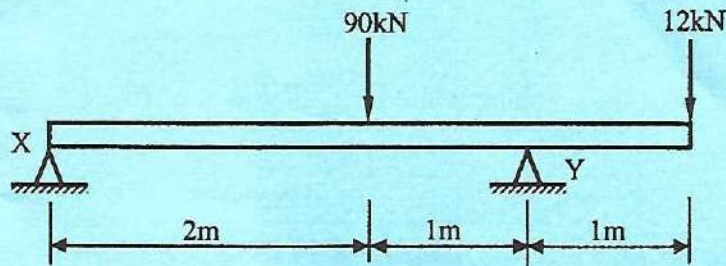

Fig. 2

(ii)   State **two** engineering applications of couples.   (7 marks)

3.   (a)   (i)   Define the following terms and state their SI units:

    I.   density;
    II   pressure.

(ii)   State the Archimedes' principle.   (6 marks)

(b)   With the aid of a labelled diagram, describe the operation of a simple barometer.

    (6 marks)

(c)   A timber block measuring 300 mm x 200 mm x 100 mm floats on a liquid, with its top surface being horizontal and the 100 mm side is vertical. 40 mm height of the block remains above the liquid surface. If the relative density of the timber is 0.74, determine the density of the liquid.   (8 marks)

4.   (a)   Distinguish between the following:

    (i)   mechanical advantage and velocity ratio of a machine;
    (ii)   kinetic and potential energy.   (4 marks)

(b)   A forklift raises a load of mass 2 tonnes vertically through a distance of 1.5 m in 10 seconds. If the efficiency is 78%, determine the:

    (i)   work done;
    (ii)   power developed;
    (iii) energy consumed while raising the load.   (7 marks)

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(c)   A manually operated hoisting pulley system requires an effort of 62.86N to raise a load of 50 kg, and an effort of 145.26 N for a load of 120 kg. If the velocity ratio is 12, determine the:

   (i)   law of the machine;
   (ii)   efficiency of the machine while it raises a load of 85 kg.   (9 marks)

SECTION B: ELECTRICAL AND ELECTRONICS PRINCIPLES

*Answer at least **TWO** questions from this section.*

5.   (a)   With the aid of a labelled circuit diagram, show that the total resistance (R_t) of three resistors connected in parallel across a voltage source is given by the equation:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

(6 marks)

   (b)   An aluminium wire has a resistance of $50\,\Omega$ at $20°C$. If the aluminium's temperature coefficient of resistance at $0°C$ is $0.004/°C$, determine the resistance of the aluminium wire when heated to a temperature of $100°C$.   (4 marks)

   (c)   **Figure 3** shows an electrical circuit. Use Kirchoff's laws to determine the:

   (i)   current flowing through the $20\,\Omega$ resistor;
   (ii)   power dissipated by the $20\,\Omega$ resistor;
   (iii) voltage drop across the $6\,\Omega$ resistor.   (10 marks)
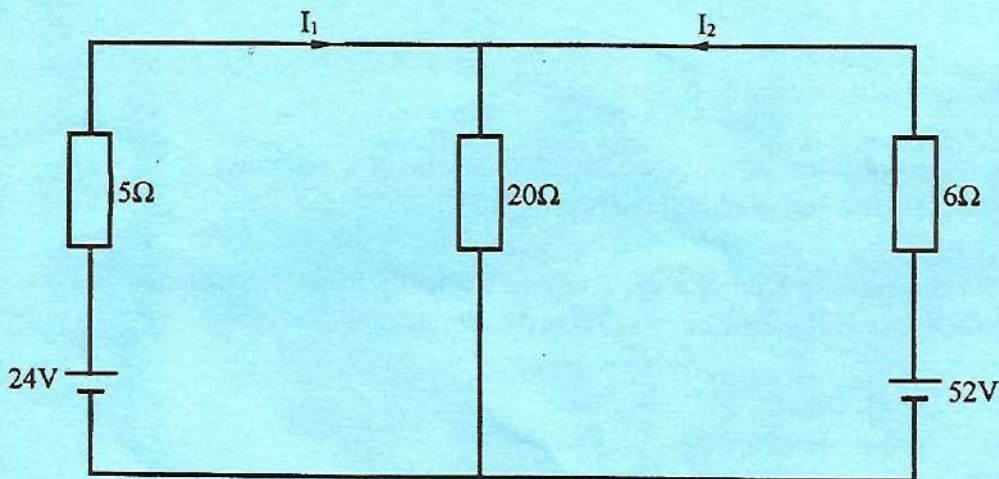
Fig. 3

6. (a) **Table 1** shows magnetic quantities, their symbols and SI units.

Table 1

Magnetic quantities	Symbol	Unit
Magnetic flux		
Magnetic flux density		
		At/ Wb
Permeability		H/M
	F	At

Copy and complete the table. (8 marks)

(b) An alternating voltage $V = 250 \sin 800t$ volts is applied across a series circuit containing a $30\,\Omega$ resistor and $50\,\mu F$ capacitor. Determine the:

(i) circuit impedance;
(ii) current flowing;
(iii) potential difference across the capacitor;
(iv) circuit power factor. (10 marks)

(c) State **two** applications of a silicon controlled rectifier (SCR). (2 marks)

7. (a) Draw the energy- band structure of each of teh following materials:

(i) conductors;
(ii) insulators;
(iii) semi-conductors. (9 marks)

(b) With the aid of a labelled circuit diagram, explain the operation of a transistor series voltage regulator. (8 marks)

(c) List **three** applications of semi-conductor diodes. (3 marks)

8. (a) Explain three methods of minimizing armature reactions in direct current machines. (6 marks)

(b) An alternating voltage given by $V = 200 \sin 100\pi t$ volts is applied across an inductor of inductance 31.83 mH.

(i) Determine the expression for the instantaneous current flowing through the inductor.

(ii) Sketch the waveforms for both the voltage and current on the same axes. (6 marks)

(c) A 4-pole, direct current (d.c) shunt generator with wave-wound armature has 41 slots each having 12 conductors. The armature and shunt field resistances are $0.5\,\Omega$ and $200\,\Omega$ respectively. The flux per pole is 25 mWb. If a load of $10\,\Omega$ resistance is connected across the armature terminals, determine the voltage across the load when the generator is driven at 100 rev/min. (8 marks)

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