THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION, 1991

035 **ENGINEERING SCIENCE**

Time: 3 Hours **ANSWERS**

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1. This paper consists of Parts: I and II. Part II consists of Sections; A, B and C.
2. Attempt ALL 20 questions in Part I and any FIVE in part II. You must attempt at least ONE question from section A, B and C.
3. Part I carries 40%

   Part II carries 60%

   Take g = 9.81 m/s^2 and pie = 3.14

4. Write your **Examination Number** on every page of your answer booklet(s).

1. (a) What is meant by the equilibrant of a system of forces?

The equilibrant is a single force that brings a system of forces into equilibrium. It is equal in magnitude but opposite in direction to the resultant of the forces.

(b) State the principle of moments.

The principle of moments states that for a body in equilibrium, the sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments.

2. A car started from rest and was accelerated uniformly. It then maintained a constant speed for some time. The brakes were then applied and the vehicle was uniformly retarded to rest. Sketch a graph which describes the motion of the car.

The velocity-time graph is a trapezium:

* Starts at origin, rises linearly (acceleration),

* Continues horizontally (constant speed),

* Slopes downward linearly to zero (deceleration).

3. (a) State the principle of conservation of energy.

Energy cannot be created or destroyed; it can only be converted from one form to another. The total energy of an isolated system remains constant.

(b) A stone of mass 5 kg is dropped from a height of 5 m. What will be its kinetic energy just before hitting the ground?

Potential energy at height = mgh = $5 \times 9.8 \times 5 = 245$ J

Kinetic energy just before hitting the ground = 245 J (since all potential energy converts to kinetic energy).

4. What is a machine?

A machine is a device that makes work easier by changing the direction or magnitude of a force.

5. A pulley system has velocity ratio of 4 and an efficiency of 75%. Calculate the effort required to lift a load of 400 N at a steady speed.

Mechanical advantage MA = Efficiency × VR = 0.75 × 4 = 3

Effort = Load / MA = 400 / 3 ≈ 133.33 N

6. State Archimedes principle and the law of floatation.

Archimedes' Principle: A body wholly or partially immersed in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced.

Law of Floatation: A floating body displaces its own weight of the fluid in which it floats.

7. Mention the appropriate mode of heat transfer for the following:

(a) From the sun to the earth. – Radiation

(b) From an electric fire to hands held at some distance in front of the fire. – Radiation

(c) From the cylinders of a car to the radiator of a car. – Convection

(d) From a hot plate of an electric cooker to the water in a saucepan in contact with the plate. – Conduction

8. Calculate the heat given out when 0.05 kg of iron cools from 45°C to 15°C.

Take specific heat capacity of iron to be 460 $Jkg^{-1}K^{-1}$

$Q = mc\Delta T = 0.05 \times 460 \times (45 - 15) = 0.05 \times 460 \times 30 = 690$ J

9. State Charles' law of gases.

Charles' law states that for a fixed mass of gas at constant pressure, the volume is directly proportional to its absolute temperature.

10. Give an expression which relates the frequency, wavelength and velocity of a wave.

$v = f\lambda$

Where v is velocity, f is frequency, and λ is wavelength.

11. State the laws of refraction.

12. The incident ray, the refracted ray, and the normal lie in the same plane.

13. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant (Snell's Law).

14. Explain the statement "the refractive index of glass is 1.5".

This means that light travels 1.5 times faster in a vacuum than in glass.

15. If a bar 3 m long is stretched under tension until its length is increased by 0.9 mm, find the tensile strain on the bar.

Strain = extension / original length = $0.9 \times 10^{-3} / 3 = 3 \times 10^{-4}$

16. Define the magnetic poles.

Magnetic poles are the regions at the ends of a magnet where the magnetic force is strongest.

17. Draw electric lines of force due to:

(i) a positive charge Q

– Lines radiate outward from Q.

(ii) two positive charges Q_1 and Q_2 of equal magnitude

– Lines radiate outward from both charges and repel away from each other with a neutral region in between.

16. A certain length of aluminium wire has a resistance of 28.3 ohm at 20°C. What is its resistance at 60°C?

Temperature coefficient $\alpha = 0.0043$ /°C

$R = R_0\[1 + \alpha(T - T_0)] = 28.3\[1 + 0.0043(60 - 20)]$

$\= 28.3\[1 + 0.172] = 28.3 \times 1.172 \approx 33.17\ \Omega$

17. State Faraday's law of electrolysis.

The mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through the electrolyte.

18. What path would be taken by an electron moving perpendicular to:

(i) a uniform electric field – The electron follows a parabolic path.

(ii) a uniform magnetic field – The electron follows a circular path.

19. A bulb is marked 240 Volts, 100 Watts:

(a) The resistance of the bulb when switched ON.

$R = V^2 / P = 240^2 / 100 = 57600 / 100 = 576\ \Omega$

(b) The cost of using the bulb for 24 hours if a kilowatt hour costs a shilling.

Energy used = $100\ W \times 24\ h = 2.4$ kWh

Cost = $2.4 \times 1 = 2.4$ shillings

20. What do you understand by an alternating current?

An alternating current (AC) is an electric current that periodically reverses direction, unlike direct current (DC) which flows only in one direction.

21. (a) State Hooke's law.

Hooke's law states that the extension of a spring or elastic material is directly proportional to the force applied, provided the elastic limit is not exceeded.

(b) Define:

(i) tensile stress = Force / Area

(ii) tensile strain = Extension / Original length

(iii) Young's modulus of elasticity = Stress / Strain

(c) A mild steel rod 4 m long and 30 mm in diameter carries a tensile load of 100 kN. Calculate the extension.

Young's modulus $E = 200 \times 10^9$ Pa

Length $L = 4$ m $= 4000$ mm

Diameter $d = 30$ mm $\Rightarrow$ Radius $r = 15$ mm

Area $A = \pi r^2 = \pi \times (15 \times 10^{-3})^2 = \pi \times 2.25 \times 10^{-4} = 7.0686 \times 10^{-4}$ m²

Stress = Force / Area $= 100{,}000 / 7.0686 \times 10^{-4} \approx 1.414 \times 10^8$ Pa

Strain = Stress / E $= 1.414 \times 10^8 / 200 \times 10^9 = 7.07 \times 10^{-4}$

Extension = Strain × Length $= 7.07 \times 10^{-4} \times 4 = 0.002828$ m ≈ 2.83 mm

22. Fig. 1 is a velocity-time graph for the motion of a body moving in a straight line.

(i) What was the initial velocity of the body?

From the graph, at time $t = 0$ s, the velocity is 0 m/s.

Initial velocity = 0 m/s

(ii) What is the acceleration of the body after the first 4 s, 8 s and 9 s?

Acceleration is the gradient of the velocity-time graph.

From 0 to 4 s:

v = 8 m/s, u = 0, t = 4 s

$a = (v - u) / t = (8 - 0) / 4 = 2\ m/s^2$

From 4 s to 8 s:

Velocity remains constant at 8 m/s

$a = 0\ m/s^2$

From 8 s to 9 s:

v = 0, u = 8, t = 1 s

$a = (0 - 8) / 1 = -8\ m/s^2$

Negative sign indicates deceleration

(iii) What is the acceleration of the body in the Section YZ of the motion? Comment on your answer.

Section YZ is from t = 8 s to t = 11 s.

Initial velocity u = 8 m/s, final velocity v = 0 m/s, t = 3 s

$a = (v - u) / t = (0 - 8) / 3 = -8/3 \approx -2.67\ m/s^2$

The body is uniformly decelerating.

(iv) What is the total distance covered by the body?

Distance is the area under the velocity-time graph.

Area from 0–4 s: triangle = $0.5 \times 4 \times 8 = 16$ m

Area from 4–8 s: rectangle = 4 × 8 = 32 m

Area from 8–11 s: triangle = 0.5 × 3 × 8 = 12 m

Total distance = 16 + 32 + 12 = 60 m

(v) Suppose the body was a car; describe the motion of this car.

The car started from rest and accelerated uniformly for 4 seconds. It then moved at a constant velocity for the next 4 seconds. After that, it decelerated uniformly to rest in 3 seconds.

23. (a) Explain what is meant by the term centre of gravity.

The centre of gravity of a body is the point through which the resultant weight of the body acts, regardless of the body's orientation. It is the average location of the weight distribution.

(b) Fig. 2 below is a section of a composite lamina formed by a square and an isosceles triangle. The material has a uniform density and thickness, so that it has a constant mass per unit area. Determine the centre of gravity of the section.

Divide the shape into two parts:

Rectangle (100 mm × 100 mm)

Triangle (base 100 mm, height 100 mm)

Take the left edge of the square as the origin.

Area of rectangle $A_1 = 100 \times 100 = 10{,}000\ mm^2$

Centre of gravity of rectangle: $x_1 = 50$ mm from left, $y_1 = 50$ mm from bottom

Area of triangle $A_2 = \frac{1}{2} \times 100 \times 100 = 5{,}000\ mm^2$

Centre of gravity of triangle from its base = h/3 = 100/3 ≈ 33.33 mm

So $x_2 = 100 + 100/3 \approx 133.33$ mm, $y_2 = 50$ mm

Total area $A = A_1 + A_2 = 10{,}000 + 5{,}000 = 15{,}000$ mm²

$\bar{x} = (A_1x_1 + A_2x_2) / A = (10{,}000 \times 50 + 5{,}000 \times 133.33) / 15{,}000 \approx (500{,}000 + 666{,}650) / 15{,}000 = 1{,}166{,}650 / 15{,}000 \approx 77.78$ mm

$\bar{y} = (A_1y_1 + A_2y_2) / A = (10{,}000 \times 50 + 5{,}000 \times 50) / 15{,}000 = 750{,}000 / 15{,}000 = 50$ mm

Centre of gravity: (77.78 mm, 50 mm)

24. (a) State two differences between a stationary and a progressive wave.

25. A stationary wave does not transfer energy through the medium, while a progressive wave transmits energy.

26. In a stationary wave, certain points (nodes) remain stationary, while in a progressive wave all particles oscillate with the same amplitude.

(b) A plane progressive wave is represented by the equation:

$y = 0.1 \sin(200\pi t - (20\pi x)/17)$

where y is the displacement in millimetres, t is in seconds and x is the distance from a fixed origin in metres. Find:

(i) the amplitude

Amplitude $A = 0.1$ mm

(ii) wavelength of the wave

From the wave equation, the term $(20\pi x / 17) = 2\pi x / \lambda$

So, $20\pi / 17 = 2\pi / \lambda \Rightarrow \lambda = 17 / 10 = 1.7$ m

(iii) the speed of the wave

Wave speed $v = f \times \lambda$

Angular frequency $\omega = 200\pi = 2\pi f \Rightarrow f = 100$ Hz

$v = 100 \times 1.7 = 170$ m/s

(iv) the frequency of the wave

$f = 100$ Hz

25. (a) Define the coefficient of linear expansion.

It is the increase in length per unit original length per degree rise in temperature.

(b) A thick glass bottle cracks when a hot liquid is poured into it. Explain.

The inside surface of the glass expands faster than the outer surface, causing stress due to uneven expansion, which results in cracking.

(c) An steel tape of correct length at 15°C is used to measure distance when the temperature is 100°C. The result found was 20 m. What is the error in measuring distance of 20 m?

Coefficient of expansion of steel $\alpha = 1.1 \times 10^{-5}$ /°C

$\Delta T = 100 - 15 = 85$°C

Change in length $\Delta L = L \times \alpha \times \Delta T = 20 \times 1.1 \times 10^{-5} \times 85$

$\Delta L = 0.0187$ m ≈ 1.87 cm

Measured distance is 1.87 cm too long

26. (a) What is meant by a focal length of a converging lens?

Focal length is the distance from the optical centre of the lens to the focal point where parallel rays converge after passing through the lens.

(b) An object 1 cm tall stands vertically on the principal axis of a converging lens of focal length 10 cm at a distance of 17 cm from the lens. Find the position, size and nature of the image by graphical construction or calculation.

Using lens formula:

$1/f = 1/v - 1/u$

f = +10 cm, u = -17 cm (object on left)

$1/v = 1/f + 1/u = 1/10 - 1/17 = (17 - 10) / 170 = 7/170$

$v = 170 / 7 \approx 24.3$ cm

Magnification $m = v / u = 24.3 / (-17) \approx -1.43$

Image height = m × object height = -1.43 × 1 = -1.43 cm

Position: 24.3 cm from lens on right side

Nature: Real, inverted, enlarged

27. (a) State two laws of electromagnetic induction.

28. Faraday's First Law: An EMF is induced in a conductor whenever it cuts magnetic flux.

29. Faraday's Second Law: The magnitude of the induced EMF is directly proportional to the rate of change of magnetic flux linkage.

(b) (i) A 10 cm long straight conductor moves perpendicularly both to the field and its own length at 2 m/s in a magnetic field of 0.5 T. Calculate the EMF.

EMF = B × L × v = 0.5 × 0.1 × 2 = 0.1 V

(ii) A copper coil of 200 turns is rotated at 500 rev/min in a uniform field of 0.2 Wb/m². The area of the coil is 0.01 m². Calculate the peak value of the induced EMF.

Angular velocity $\omega = 2\pi n = 2\pi \times 500 / 60 \approx 52.36$ rad/s

E_max = NABω = 200 × 0.01 × 0.2 × 52.36 ≈ 20.94 V

28. (a) Explain the following terms as related to an alternating voltage (emf):

(i) root mean square (r.m.s.) value: It is the value of AC that produces the same heating effect as an equivalent DC value.

(ii) period: The time taken to complete one cycle of the waveform.

(iii) peak value: The maximum value of voltage or current in a cycle.

(iv) mean value: The average value of the waveform over a half cycle.

(v) form factor: Ratio of RMS value to mean value.

(b) Calculate the values in (a) above for a 240 V, 50 Hz sinusoidal supply.

Peak value $E_0 = \sqrt{2} \times RMS = \sqrt{2} \times 240 \approx 339.4$ V

Period $T = 1 / f = 1 / 50 = 0.02$ s

Mean value = $(2 / \pi) \times$ peak = $(2 / \pi) \times 339.4 \approx 216$ V

Form factor = $240 / 216 \approx 1.11$

The result in (v) implies how smooth the waveform is; for sine wave, form factor is always about 1.11

29. (a) State Ohm's law.

Ohm’s law states that the current through a conductor is directly proportional to the potential difference across it, provided temperature remains constant.

V = IR

(b) Calculate the equivalent resistance of the circuit in fig. 3 below.

Start with $R_1 = 2\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 6\ \Omega$, $R_4 = 3\ \Omega$, $R_5 = 3\ \Omega$, $R_6 = 3\ \Omega$, $R_7 = 5\ \Omega$, $R_8 = 3\ \Omega$, $R_9 = 3\ \Omega$, $R_{10} = 2\ \Omega$

Combine:

R_8 and R_9 in series: $R_{89} = 3 + 3 = 6\ \Omega$

R_6 and R_{89} in parallel: $R_{689} = (6\times3)/(6+3) = 18/9 = 2\ \Omega$

$R_5 + R_{689} = 3 + 2 = 5\ \Omega$

R_4 in parallel with $R_5+R_{689} = (3\times5)/(3+5) = 15/8 = 1.875\ \Omega$

R_3 + above = $6 + 1.875 = 7.875\ \Omega$

$R_{11} = 3\ \Omega$

R_{11} in parallel with 7.875: $(3\times7.875)/(3+7.875) = 23.625/10.875 \approx 2.17\ \Omega$

Add $R_{10} = 2\ \Omega$ in series: $2 + 2.17 = 4.17\ \Omega$

$R_{12} = 2\ \Omega$ in series: $4.17 + 2 = 6.17\ \Omega$

Now combine with $R_1 = 2\ \Omega$, $R_2 = 3\ \Omega$ in series = $5\ \Omega$

Total circuit equivalent: 5 (R_1+R_2) in parallel with 6.17, plus $R_7 = 5\ \Omega$

$(5\times6.17)/(5+6.17) \approx 30.85 / 11.17 \approx 2.76\ \Omega$

Total resistance = $2.76 + 5 = 7.76\ \Omega$

(c) If the current in the circuit is 0.5 A, calculate the value of E.

$E = IR = 0.5 \times 7.76 = 3.88$ V