THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATION COUNCIL OF TANZANIA

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

035 **ENGINEERING SCIENCE**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2020**

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instructions

1. This paper consists of section A, B and C with a total of **fourteen (14)** questions
2. Answer all questions in section A and B and **three (3)** questions from section C
3. Calculators, cellular phones and any unauthorized materials are **not** allowed in the examination room

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

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

(i) Which electrical component is represented by a symbol shown in Figure 1?
A A capacitor
B A rheostat
C An inductor
D A transformer
E A fixed resistor

Correct answer: E A fixed resistor

Reason: The symbol shown in Figure 1 is a zig-zag line, which universally represents a fixed resistor in electrical circuit diagrams. A rheostat would have an arrow across it, and a transformer has two inductors with a magnetic line between them.

(ii) The depth of a sea can be easily estimated by applying the concept of

A resonance
B reverberation
C audibility range
D ultrasonic waves
E echo

Correct answer: D ultrasonic waves

Reason: Depth of the sea is measured using sonar technology, which works by sending ultrasonic waves and measuring the time taken for the echo to return. This is known as echo sounding.

(iii) Which one is the correct combination of the factors affecting the amount of heat energy required to cause a raise in temperature of a given material?

A Mass, temperature change and the nature of material
B Mass, volume and temperature change
C Mass, density and nature of the material
D Volume, density and nature of the material
E Temperature, volume and density of the material

Correct answer: A Mass, temperature change and the nature of material

Reason: The heat energy required is given by the formula $Q = mc\Delta T$, where m is mass, c is the specific heat capacity (dependent on the nature of material), and ΔT is the temperature change.

(iv) Which list represents examples of the third class levers?

A Scissors, spade and wheelbarrow
B Wire cutter, bottle opener and wheelbarrow
C Wheelbarrow, bottle opener and paper cutter
D Spade, tweezers and broom

E Broom, tweezers and wire cutter

Correct answer: D Spade, tweezers and broom

Reason: In third class levers, the effort is applied between the load and the fulcrum. A spade (when digging), tweezers, and broom are classic examples of third class levers.

(v) What happens when parallel light rays enter a concave mirror?

A The mirror converges rays to principal focus which is virtual.
B The mirror converges rays to principal focus which is real.
C The mirror converges rays to radius of curvature which is virtual.
D The mirror converges rays to radius of curvature which is real.
E The mirror converges rays to principal axis which is real.

Correct answer: B The mirror converges rays to principal focus which is real.

Reason: A concave mirror converges parallel rays to a real focus at the focal point in front of the mirror.

(vi) What does the 'tensile force' do on engineering material?

A It creates pressure on the material.
B It causes decrease in diameter of the material.
C It produces an increase in length of the material.
D It produces decrease in length of the material.
E It enlarges the diameter of the material.

Correct answer: C It produces an increase in length of the material.

Reason: Tensile force stretches the material, causing it to elongate in length.

(vii) If a bucket is filled with water, the pressure at the bottom of a bucket will depend on

1 a density of water.
2 a bottom area.
3 a viscosity of water.
4 a depth of water.

A 1 and 3
B 2 and 4
C 2 and 3
D 3 and 4
E 1 and 4

Correct answer: E 1 and 4

Reason: The pressure at the bottom of a fluid column is given by $P = \rho gh$, where ρ is the density of the fluid and h is the depth. It is independent of the area of the bottom and the viscosity.

(viii) What will happen when the circuit is switched on and the three identical bulbs P, Q and R are connected to a battery as shown in Figure 2?

A Q and R will be brighter than P.
B Q and R will not shine at all.
C All the bulbs will be equally bright.
D P and Q will be brighter than R.
E Q and R will be dimmer than P.

Correct answer: E Q and R will be dimmer than P.

Reason: P is in series with the parallel combination of Q and R. The current through P will be the total current, while Q and R share the remaining current. Hence P is brighter than Q and R, and Q and R will be equally dimmer.

(ix) What does a body of mass 'm' kilograms which is at a height of 'h' metres above the earth surface possess?

A Magnetic energy
B Gravitational energy
C Thermal energy
D Potential energy
E Kinetic energy

Correct answer: D Potential energy

Reason: A body at a height possesses gravitational potential energy given by $PE = mgh$. Magnetic, kinetic, or thermal energy are not involved in this context.

(x) Which of the following instruments would be preferred if an auto-mechanic is required to measure a diameter of a wire to the nearest 0.001 cm?

A Vernier caliper
B Micrometer screw gauge
C Screw gauge
D Vernier gauge
E Micrometer linear gauge

Correct answer: B Micrometer screw gauge

Reason: A micrometer screw gauge can measure small dimensions like wire diameters to a precision of 0.001 cm, which is 0.01 mm. Vernier calipers have a lower precision.

2 (a) Why a ship made of iron floats in sea water while the iron nail sinks? Give two reasons.

A ship made of iron floats because it is hollow and occupies a large volume, which makes its average density less than that of sea water. According to the principle of flotation, an object will float if its average density is less than the fluid it displaces. On the other hand, an iron nail is solid and compact, having a density greater than that of water, so it sinks because the upthrust force acting on it is less than its weight.

2 (b) Why building designers made the wall of a dam much thicker at the bottom than at the top? Briefly explain.

The wall of a dam is made thicker at the bottom because the pressure exerted by water increases with depth. According to the formula pressure = density × gravity × height, as the depth increases, pressure also increases. To withstand this high pressure and prevent collapse, the base of the dam is made thicker.

3. A belt passing round a pulley of a grinding machine has a linear velocity of 44 m/s and the pulley has a radius of 200 mm. If there is no slippage of the belt on the wheel, how many revolutions per second are made by the pulley?

Linear velocity = angular velocity × radius
$44 = (2\pi n) \times 0.2$
$n = 44 / (2\pi \times 0.2)$
$n = 44 / (1.2566 \times 0.2)$
$n = 44 / 1.2566$
$n \approx 35$ revolutions per second.

4. A gun is aimed horizontally at a target 60 m away. The bullet hits a target 0.08 m below the aiming point: Find the time of flight of the bullet and its speed as it emerges from the gun. Take $g = 10\ m/s^2$.

Time of flight:
Using the equation $h = 0.5 \times g \times t^2$
$0.08 = 0.5 \times 10 \times t^2$
$0.08 = 5 \times t^2$
$t^2 = 0.08 / 5$
$t^2 = 0.016$
$t = 0.126$ s

Speed of the bullet:
Speed = distance / time
$v = 60 / 0.126$
$v \approx 476.19$ m/s

5. A stone is allowed to fall freely from the top of a tower 60 m high at exactly the same moment a second stone is thrown vertically upwards from the ground at a speed of 20 m/s. Calculate the required distance in meters above the ground at which the stones will pass each other.

Let the distance from the ground where they meet be x.

Time taken to meet = t seconds.

For falling stone:
Distance fallen = $60 - x = 0.5 \times g \times t^2$
$60 - x = 5 \times t^2$

For rising stone:
Distance risen = $x = u \times t - 0.5 \times g \times t^2$
$x = 20 \times t - 5 \times t^2$

Adding both equations:
$60 = 20 \times t$
$t = 60 / 20$
$t = 3$ s

Now substitute t into one of the equations:
$x = 20 \times 3 - 5 \times 3^2$
$x = 60 - 5 \times 9$
$x = 60 - 45$
$x = 15$ m

So, they will meet 15 meters above the ground.

6 (a) The frictional force acting when a bag of rice is pushed in a wheelbarrow is 50 N. The load moved 25 m in 20.4 seconds. At what rate the work was done?

Work done = force × distance
$W = 50 \times 25$
$W = 1250$ J

Power = work done / time
$P = 1250 / 20.4$
$P \approx 61.27$ W

6 (b) Water is pumped from a stream at the rate of 90 kg in every 30 seconds and sprayed on an orchard from a nozzle at a velocity of 15 m/s. Determine the power of the pump.

Kinetic energy = $0.5 \times m \times v^2$
$KE = 0.5 \times 90 \times 15^2$
$KE = 0.5 \times 90 \times 225$
$KE = 10125$ J

Power = energy / time
$P = 10125 / 30$
$P = 337.5$ W

7 (a) Briefly explain how is heat transmitted by each of the following principal method of heat transmission.
(i) Conduction
Conduction is the transfer of heat through a material without the movement of the material itself. It occurs when fast-moving particles collide with neighboring slower particles, transferring energy to them.

(ii) Convection
Convection is the transfer of heat by the movement of fluids (liquids or gases). When a fluid is heated, it becomes less dense and rises while the cooler, denser fluid sinks, creating a circulation pattern that transfers heat.

(iii) Radiation
Radiation is the transfer of heat through electromagnetic waves, without the need for a medium. Heat from the sun reaches the earth by radiation through the vacuum of space.

7 (b) A glass breaks when cold water in it is suddenly replaced by hot water. Briefly explain by giving three reasons.

When hot water is suddenly poured into a cold glass, the inner surface of the glass expands rapidly while the outer surface remains contracted due to the lower temperature. This uneven expansion creates thermal stress in the glass. If the stress exceeds the strength of the glass, it cracks or breaks. Also, glass is a poor conductor of heat, so it cannot quickly equalize the temperature difference between the inner and outer surfaces, contributing to the breakage.

8 (a) Why strings of different thickness are used on a stringed instrument such as violin or guitar?

Strings of different thickness produce different frequencies when plucked. Thicker strings are heavier and vibrate more slowly, producing lower pitch sounds. Thinner strings vibrate faster and produce higher pitch sounds. This allows the instrument to produce a range of notes.

8 (b) Why the lowest pitch note played on drum is lower than that played on a guitar?

A drum produces sound through the vibration of a stretched membrane, which has a larger surface area and more mass compared to a guitar string. The vibration of this larger area is slower, resulting in lower frequency and hence a lower pitch sound than that produced by the faster vibrating guitar string.

9. Figure 3 shows two co-planar forces 30 N and 50 N act at a point O. By using analytical method, calculate the value of the resultant force.

Let's resolve the forces into horizontal and vertical components.

Horizontal component (x-axis):
$Fx = 50 + 30 \times \cos 60°$
$Fx = 50 + 30 \times 0.5$
$Fx = 50 + 15$
$Fx = 65$ N

Vertical component (y-axis):
$Fy = 30 \times \sin 60°$
$Fy = 30 \times 0.866$
$Fy = 25.98$ N

Resultant force:
$R = \sqrt{(Fx^2 + Fy^2)}$
$R = \sqrt{(65^2 + 25.98^2)}$
$R = \sqrt{(4225 + 675.49)}$
$R = \sqrt{(4900.49)}$
$R \approx 70$ N

10. The following instrument are found in Engineering science laboratory. Identify which class of lever does each belong to?

(a) A bottle opener — Class two lever
(b) A see-saw — Class one lever
(c) A fishing rod — Class three lever
(d) A fire tong — Class one lever
(e) A claw hammer — Class one lever

11. (a) A helical spring shortens by 25 mm when a compressive load of 150 N is applied. Calculate the total shortening if an additional 90 N were applied. (7.5 marks)

From Hooke's law:
Extension or compression is directly proportional to the load applied.

Let the spring constant k be:
$k = F / x = 150 \text{ N} / 25 \text{ mm} = 150 \text{ N} / 0.025 \text{ m} = 6000 \text{ N/m}$

Now, find the total shortening when a total load of (150 + 90) N = 240 N is applied:
$x = F / k = 240 \text{ N} / 6000 \text{ N/m} = 0.04 \text{ m} = 40 \text{ mm}$

Therefore, the total shortening is 40 mm.

(b) A tie bar having a 25 mm square section is 2 m long. When carrying a load of 33 kN its extension is 0.5 mm. Another tie bar of 20 mm square section and of the same material has a length of 1.25 m, and carries a load of 25 kN. What will be the extension of this second tie bar? (7.5 marks)

Using the formula for extension:
$\delta = (F \times L) / (A \times E)$

Since both bars are of the same material, E is constant.
Using the first bar to find $(F \times L) / A$:
$(33000 \text{ N} \times 2 \text{ m}) / (25 \text{ mm} \times 25 \text{ mm}) = \text{constant} \times E$

Now, for the second bar:

Extension δ_2 = (25000 N × 1.25 m) / (20 mm × 20 mm × E)

Now find the ratio of extensions:
δ_2 / 0.5 mm = (25000 × 1.25 × 25 × 25) / (33000 × 2 × 20 × 20)

Calculate step-by-step:
= (31250 × 625) / (66000 × 400)
= 19531250 / 26400000
= 0.739

Now multiply by 0.5 mm:
δ_2 = 0.739 × 0.5 mm = 0.3695 mm ≈ 0.37 mm

Therefore, the extension of the second tie bar is 0.37 mm.

2 (a) A 4 kg block extends a spring by 16.0 cm from its unstretched position. Then a block is removed and a 2.5 kg body is hung from the same spring. If the spring is then stretched and released, what is the time period of oscillation? (5 marks)

Use $T = 2\pi\sqrt{(m / k)}$

First, find k from the 4 kg block:
F = k × x
k = (4 kg × 9.81 m/s²) / 0.16 m
\= 39.24 N / 0.16 m
\= 245.25 N/m

Now, find the time period for 2.5 kg:
$T = 2\pi\sqrt{(2.5 \text{ kg} / 245.25 \text{ N/m})}$
$= 2\pi\sqrt{(0.01019 \text{ s}^2)}$
$= 2\pi \times 0.101$
= 0.635 s
Therefore, the time period of oscillation is 0.635 seconds.

(b) A particle of mass 0.1 kg is suspended by a spring of force constant of 10 N. If the particle is displaced along the direction of the length of the spring, find its frequency of vibration. (2.5 marks)

Use $f = (1 / 2\pi)\sqrt{(k / m)}$
Substituting values:
$f = (1 / 2\pi)\sqrt{(10 \text{ N/m} / 0.1 \text{ kg})}$
$= (1 / 2\pi)\sqrt{(100 \text{ s}^{-2})}$
$= (1 / 2\pi) \times 10$
$= 10 / (2\pi)$
= 1.5915 Hz

Therefore, the frequency of vibration is 1.59 Hz.

(c) A simple pendulum is formed by a bob of mass 2 kg at the end of a cord 600 mm long. Calculate:
(i) an equivalent angular speed
(ii) the period of oscillation and
(iii) number of complete oscillations it will make per second. (7.5 marks)

First convert length:
L = 600 mm = 0.6 m

(i) Equivalent angular speed (ω):
ω = √(g / L)
\= √(9.81 / 0.6)
\= √(16.35)
\= 4.043 rad/s

(ii) Period of oscillation (T):
T = 2π√(L / g)
\= 2π√(0.6 / 9.81)
\= 2π√(0.06117)
\= 2π × 0.2473
\= 1.553 s

(iii) Number of complete oscillations per second (f):
f = 1 / T
\= 1 / 1.553
\= 0.644 oscillations/s

Therefore:
(i) Angular speed is 4.043 rad/s
(ii) Period of oscillation is 1.553 s
(iii) Number of oscillations per second is 0.644 Hz

13 (a) What is the coefficient of friction?

The coefficient of friction is the ratio of the limiting frictional force to the normal reaction force.

(b) A machine of mass 300 kg rests on a plane inclined at 15° to the horizontal. If the coefficient of friction between the machine and the plane is 0.3, by means of calculation determine;
(i) the minimum force parallel to the plane, required to move the machine up the plane at constant speed.
(ii) the minimum force parallel to the plane, required to pull the machine down the plane at constant speed.
(iii) the minimum horizontal force necessary to move the machine up the plane.

Answer:
Given:
m = 300 kg
θ = 15°

$\mu = 0.3$
$g = 9.81\ m/s^2$

First calculate weight:
$W = m \times g = 300 \times 9.81 = 2943\ N$

(i) Minimum force up the plane:
$F = W \sin\theta + \mu W \cos\theta$
$= 2943 \times \sin 15° + 0.3 \times 2943 \times \cos 15°$
$= 2943 \times 0.2588 + 0.3 \times 2943 \times 0.9659$
$= 761.5 + 852.8$
$= 1614.3\ N$

(ii) Minimum force down the plane:
$F = W \sin\theta - \mu W \cos\theta$
$= 2943 \times 0.2588 - 0.3 \times 2943 \times 0.9659$
$= 761.5 - 852.8$
$= -91.3\ N$

(iii) Minimum horizontal force to move up:
$F_{horizontal} = W \sin\theta + \mu W \cos\theta / \cos\theta$
$= (W \sin\theta + \mu W \cos\theta) / \cos\theta$
$= (2943 \times 0.2588 + 0.3 \times 2943 \times 0.9659) / 0.9659$
$= (761.5 + 852.8) / 0.9659$
$= 1614.3 / 0.9659$
$= 1670.9\ N$

14 (a) Sketch the diagram of a plane mirror and label the incident and the reflected rays of light.

A ray diagram would show:

- A plane mirror as a vertical line.
- An incident ray striking the mirror at an angle θ_i.
- A normal drawn at the point of incidence, perpendicular to the mirror surface.
- A reflected ray leaving the mirror at the same angle $\theta_r = \theta_i$.

(b) (i) Calculate the critical angle for a water – air surface, taking refractive index of water as 4/3. (02 marks)

Answer:
$\sin C = 1 / n$
$= 1 / (4/3)$
$= 3 / 4$
$C = \sin^{-1}(0.75)$

= 48.59°

Therefore, the critical angle is 48.59°

(ii) The critical angle of ice was found to be 51°. Calculate its refractive index. (02 marks)

Answer:
n = 1 / sin C
= 1 / sin 51°
= 1 / 0.7771
= 1.287

Therefore, the refractive index is 1.287

(c) By using a simple well labelled diagram, explain how mirage occurs.

Answer:
A ray diagram would show:

- Hot ground surface.
- Layers of air with decreasing density as altitude increases.
- A ray of light from a distant object bending progressively away from the normal due to refraction through air layers of decreasing density.
- At a certain point, total internal reflection occurs, sending the ray upward to the observer's eye.
- Observer perceives an image on the ground.

(d) If the speed of light in glass is 1.97×10^8 m/s and its refractive index is 1.52, calculate the speed of light in air.

n = c_air / c_glass
c_air = n × c_glass
= $1.52 \times 1.97 \times 10^8$
= 2.995×10^8 m/s

Therefore, the speed of light in air is 2.995×10^8 m/s