THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/1 **PHYSICS 1**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2013**

Instructions

1. This paper consists of sections Section A, B and C with total of fourteen questions.
2. Answer ten questions choosing four questions from section A and three questions from each of section B and C.

1. (a)(i) What is the difference between degree of accuracy and precision?

- Accuracy refers to how close a measured value is to the true value.
- Precision refers to the consistency of repeated measurements, regardless of their accuracy.

(ii) In an experiment to determine Young's modulus of a wooden material the following measurements were recorded.

length $l = 80.0 \pm 0.05$ cm
breadth $b = 28.65 \pm 0.03$ mm
thickness $t = 6.40 \pm 0.03$ mm
slope $G = 0.035 \pm 0.001$ $cmgn^{-1}$

Given that Young's modulus Y is given by:

$Y = (4 / Gb) (l / t)$
Calculate the maximum percentage error in the value of Y.
Taking logarithm and differentiating:

$\Delta Y / Y = \Delta l / l + \Delta t / t + \Delta b / b + \Delta G / G$

Substituting values:
$\Delta Y / Y = (0.05 / 80) + (0.03 / 6.40) + (0.03 / 28.65) + (0.001 / 0.035)$
$\Delta Y / Y = 0.000625 + 0.00469 + 0.001047 + 0.02857$
$\Delta Y / Y = 0.03493$

Percentage error:
% Error = 0.03493 x 100
% Error = 3.49%

(b) Using the method of dimensions, indicate which of the following equations are dimensionally correct and which are not, given that f = frequency, γ = surface tension, ρ = density, r = radius and k = dimensionless constant.

(i) $\rho^2 = k \sqrt{(f / \gamma)}$

Dimensional analysis:
$[\rho]^2 = [M L^{-3}]^2 = M^2 L^{-6}$
$[f] = T^{-1}$
$[\gamma] = M T^{-2}$
$\sqrt{(f / \gamma)} = \sqrt{(T^{-1} / M T^{-2})} = \sqrt{(M^{-1} T)} = M^{-1/2} T^{1/2}$
Since LHS $\neq$ RHS, the equation is incorrect.

(ii) $f = kr^2 \sqrt{(\gamma / \rho^3)}$
Dimensional analysis:
LHS: $[f] = T^{-1}$
RHS: $k r^2 \sqrt{(\gamma / \rho^3)}$
$[r^2] = L^2$
$[\gamma / \rho^3] = (M T^{-2}) / (M^3 L^{-9}) = L^9 M^{-2} T^2$
$\sqrt{(\gamma / \rho^3)} = L^4.5 M^{-1} T$
So RHS = $k L^2 \times L^4.5 M^{-1} T = k L^6.5 M^{-1} T$

Since LHS ≠ RHS, the equation is incorrect.

(iii) $f = ky^2 / \sqrt{(\rho r^2)}$
Dimensional analysis:

LHS: $[f] = T^{-1}$
RHS: $[y^2] / \sqrt{(\rho r^2)}$
$[y^2] = L^2$
$[\rho r^2] = M L^{-3} \times L^2 = M L^{-1}$
$\sqrt{(\rho r^2)} = \sqrt{(M L^{-1})} = M^{1/2} L^{-½}$

So RHS = $L^2 / (M^{1/2} L^{-½}) = L^2 M^{-1/2} L^{1/2} = L^2.5 M^{-1/2}$
Since LHS ≠ RHS, the equation is incorrect.

2. (a)(i) List down two main assumptions in deriving the equation of projectile motion.
- Air resistance is negligible.
- Acceleration due to gravity remains constant and acts vertically downward.

(ii) Why the horizontal motion of a projectile is constant?
- There is no acceleration in the horizontal direction because no external force acts on it after launch.

(b) A ball is thrown horizontally with a speed of 14.0 m/s from a point 6.4 m above the ground.
(i) Calculate the horizontal distance traveled in that time.
Using vertical motion equation:

$h = 1/2 g t^2$
Solving for t:
$t = \sqrt{(2h / g)}$
$t = \sqrt{(2 \times 6.4 / 9.81)}$
$t = \sqrt{(12.8 / 9.81)}$
$t = \sqrt{1.305}$
$t = 1.14$ s

Horizontal distance:

$x = v\,t$
$x = 14.0 \times 1.14$
$x = 15.96$ m

(ii) Its velocity when it reaches the ground.
Vertical velocity:
$v_y = g\,t$
$v_y = 9.81 \times 1.14$
$v_y = 11.18$ m/s

Resultant velocity:
$v = \sqrt{(v_x^2 + v_y^2)}$
$v = \sqrt{(14.0^2 + 11.18^2)}$
$v = \sqrt{(196 + 124.97)}$
$v = \sqrt{320.97}$
$v = 17.92$ m/s
Angle with horizontal:

$\theta = \tan^{-1} (v_y / v_x)$
$\theta = \tan^{-1} (11.18 / 14.0)$
$\theta = \tan^{-1} (0.798)$
$\theta = 38.94°$

(c) A man stands in a lift which is being accelerated upwards at 3.2 m/s^2. If the man has a mass of 65 kg, what is the net force exerted on the man by the floor of the lift?

Normal force N is given by:
$N = m\,(g + a)$

Substituting values:
$N = 65\,(9.81 + 3.2)$
$N = 65\,(13.01)$
$N = 845.65$ N

3. (a) Why is it technically advised to bank a road at corners?
- Banking reduces reliance on friction by providing a component of normal force to act as centripetal force, improving vehicle stability at high speeds.

(b) A wheel rotates at a constant rate of 10 revolutions per second. Calculate the centripetal acceleration at a distance of 0.80 m from the center of the wheel.
Angular velocity:
$\omega = 2\pi \times f$
$\omega = 2\pi \times 10$

$\omega = 62.83$ rad/s

Centripetal acceleration:
$a_c = \omega^2 r$
$a_c = (62.83)^2 \times 0.80$
$a_c = 3946.58 \times 0.80$
$a_c = 3157.27$ m/s²

(c)(i) With the aid of a labeled diagram, sketch the possible orbits for a satellite launched from the earth.
- The possible orbits include geostationary orbit, low Earth orbit, and polar orbit.

(ii) From the diagram in (c)(i) above, write down an expression for the velocity of a satellite corresponding to each orbit.
For a satellite in circular orbit:
$v = \sqrt{GM / r}$
where:
G = gravitational constant
M = mass of the Earth
r = radius of orbit from Earth's center

4. (a)(i) Distinguish surface tension from surface energy.

- Surface tension is the force per unit length acting along a liquid surface to minimize its surface area.
- Surface energy is the energy required to increase the surface area of a liquid by a unit amount.

(ii) Explain the phenomenon of surface tension in terms of the molecular theory.
- Molecules at the surface experience an unbalanced inward force due to the absence of molecules above them, leading to surface contraction.
- This inward force minimizes the surface area, giving rise to surface tension.

(b) A clean open-ended glass U-tube has vertical limbs one of which has a uniform internal diameter of 4.0 mm and the other of 20.0 mm. Mercury is poured into the tube, and it is observed that the height of the mercury column in the two limbs is different.

(i) Explain this observation.
- The height difference occurs due to capillary action, where the liquid level rises more in a narrower tube due to stronger cohesive and adhesive forces.
- Since mercury has strong cohesive forces and weak adhesion to glass, it depresses more in the wider tube than in the narrow tube.

4. (c)(ii) Calculate the difference in levels of mercury in the two limbs of the U-tube.

Given:

Surface tension of mercury, $\gamma = 0.465$ N/m
Density of mercury, $\rho = 13600$ kg/m³
Acceleration due to gravity, $g = 9.81$ m/s²
Contact angle of mercury with glass, $\theta = 140°$
Radius of the narrow tube, $r_1 = 4.0$ mm = 0.004 m
Radius of the wider tube, $r_2 = 20.0$ mm = 0.020 m

Using the capillary rise equation:

$h = (2 \gamma \cos\theta) / (\rho g r)$

First, calculating for the narrow tube (r_1):
$h_1 = (2 \times 0.465 \times \cos140°) / (13600 \times 9.81 \times 0.004)$

$\cos140° = -0.766$
$h_1 = (2 \times 0.465 \times -0.766) / (13600 \times 9.81 \times 0.004)$
$h_1 = (-0.712) / (532.224)$
$h_1 = -0.00134$ m
$h_1 = -1.34$ mm

Now, calculating for the wider tube (r_2):

$h_2 = (2 \times 0.465 \times \cos140°) / (13600 \times 9.81 \times 0.020)$
$h_2 = (-0.712) / (2661.12)$
$h_2 = -0.000268$ m
$h_2 = -0.268$ mm

The difference in levels:
$\Delta h = |h_2 - h_1|$
$\Delta h = |(-0.268) - (-1.34)|$
$\Delta h = 1.072$ mm
The difference in mercury levels in the two limbs is 1.072 mm.

5. (a)(i) Name the temperature of a thermocouple at which the thermo e.m.f changes its sign.
- The temperature of inversion.

(ii) Name the temperature of a thermocouple at which the electric power becomes zero.
- The neutral temperature.

(b)(i) A person sitting on a bench on a calm hot summer day is aware of a cool breeze blowing from the sea. Briefly explain why there is a natural convection.
- The land heats up faster than the sea, warming the air above it.

- The warm air rises, creating a low-pressure area, and cooler air from the sea moves in to replace it, forming a sea breeze.

(ii) A Nichrome-constantan thermocouple gives about 70 μV for each 1°C difference in temperature between the junctions. If 100 such thermocouples are made into a thermopile, what voltage is produced when the junctions are at 20°C and 240°C?

Temperature difference:

$\Delta T = 240 - 20$
$\Delta T = 220°C$

Total voltage:
V = (number of thermocouples) × (voltage per unit temperature) × ΔT
$V = 100 \times 70 \times 10^{-6} \times 220$
$V = 1.54$ V

(c) A black body of temperature θ is placed in a blackened enclosure maintained at a temperature of 10°C. When its temperature rises to 30°C, the net rate of loss of energy from the body was found to be 10 Watts. Find the power generated by the body at 50°C if the energy exchange takes place solely by the process of forced convection.

Using Newton's Law of Cooling:

$P = k (T^4 - T_0^4)$

where:
$P_1 = 10$ W at $T_1 = 30°C = 303$ K
$T_0 = 10°C = 283$ K
$T_2 = 50°C = 323$ K

First, solving for k:
$10 = k (303^4 - 283^4)$

Calculating each term:

$303^4 = (303 \times 303 \times 303 \times 303) = 8.406 \times 10^9$
$283^4 = (283 \times 283 \times 283 \times 283) = 6.398 \times 10^9$

Difference:
$303^4 - 283^4 = 8.406 \times 10^9 - 6.398 \times 10^9$
$= 2.008 \times 10^9$

Solving for k:

$k = 10 / (2.008 \times 10^9)$
$k = 4.98 \times 10^{-9}$

Now, calculating P_2 at $T_2 = 50°C = 323$ K:

$P_2 = k (323^4 - 283^4)$
Calculating each term:
$323^4 = (323 \times 323 \times 323 \times 323) = 1.084 \times 10^{10}$
$283^4 = 6.398 \times 10^9$

Difference:
$323^4 - 283^4 = 1.084 \times 10^{10} - 6.398 \times 10^9$
$= 4.442 \times 10^9$
Now, solving for P_2:

$P_2 = (4.98 \times 10^{-9}) \times (4.442 \times 10^9)$
$P_2 = 22.1$ W

The power generated by the body at 50°C is 22.1 W.
6. (a) compare the law governing the conduction of heat and electricity pointing out the corresponding quantities in each case.

- fourier's law of heat conduction states that the rate of heat transfer through a material is proportional to the temperature gradient and the material's thermal conductivity:
  $q = -k (dT / dx)$
- ohm's law states that the current through a conductor is proportional to the potential difference across it and inversely proportional to its resistance:
  $I = V / R$

corresponding quantities:
- temperature difference (ΔT) corresponds to potential difference (V)
- thermal conductivity (k) corresponds to electrical conductivity (σ)
- heat flux (q) corresponds to current (I)
- thermal resistance corresponds to electrical resistance

(b)(i) write down three laws governing the black body radiation.
- planck's law: describes the spectral density of radiation emitted by a black body at a given temperature.
- wien's displacement law: states that the wavelength at which a black body emits maximum radiation is inversely proportional to its absolute temperature.
- stefan-boltzmann law: states that the total energy radiated per unit surface area of a black body is proportional to the fourth power of its absolute temperature.

(ii) a cup of tea kept in a room with temperature of 22°c cools from 66°c to 63°c in 1 minute. how long will the same cup of tea take to cool from the temperature of 43°c to 40°c under the same condition?

using newton's law of cooling:
$dT / dt = -k (T - T_0)$

where:
$T_0 = 22°c$
initial temperature drop: $T_1 = 66°c$ to $T_2 = 63°c$
second case: $T_1' = 43°c$ to $T_2' = 40°c$

time taken is inversely proportional to the logarithm of the temperature difference:
$t_1 / t_2 = \ln ((T_1 - T_0) / (T_2 - T_0)) / \ln ((T_1' - T_0) / (T_2' - T_0))$

substituting values:
$t_1 / t_2 = \ln ((66 - 22) / (63 - 22)) / \ln ((43 - 22) / (40 - 22))$
$t_1 / t_2 = \ln (44 / 41) / \ln (21 / 18)$
$t_1 / t_2 = \ln (1.0732) / \ln (1.1667)$
$t_1 / t_2 = 0.0706 / 0.1542$
$t_1 / t_2 = 0.4578$
$t_2 = 1 / 0.4578$
$t_2 = 2.18$ minutes

the time required for the tea to cool from 43°c to 40°c is 2.18 minutes.

(c) a lagged copper rod is uniformly heated by a passage of an electric current. show by considering a small section dx that the temperature θ varies with distance x along a rod in a way that,

$k (d^2T / dx^2) = -H$

where k is a thermal conductivity and H is the rate of heat generation per unit volume.
consider a small section of the rod of length dx.
heat flow into the section at x:
$q_{in} = -k (dT / dx)$ at x
heat flow out of the section at x + dx:
$q_{out} = -k (dT / dx)$ at (x + dx)

net heat conducted:

$\Delta q = q_{out} - q_{in}$
$= -k (dT / dx \text{ at } x + dx) + k (dT / dx \text{ at } x)$
$= k (d^2T / dx^2) dx$

heat generated within the volume dx:
heat generation = H dx

since the heat generated within the rod is balanced by the heat conduction,
$k (d^2T / dx^2) dx = -H dx$

dividing by dx:
$k (d^2T / dx^2) = -H$

this equation shows that the temperature distribution along the rod is governed by the rate of heat generation and the thermal conductivity of the material.
7. (a)(i) define the term standing wave
- a standing wave is a wave that remains confined in a fixed region, formed by the superposition of two identical waves traveling in opposite directions.

(ii) state the position in a stationary wave where a man can hear a louder sound
- a louder sound is heard at an antinode, where the amplitude of vibration is maximum due to constructive interference.

(b)(i) what is meant by dispersion of waves?
- dispersion of waves occurs when different frequency components of a wave travel at different speeds, causing the wave to spread out.

(ii) briefly explain if it is possible for dispersion to take place on a wave whose frequency lie in the audible range
- in air, dispersion does not significantly affect audible sound waves because all frequencies travel at nearly the same speed. however, in some media like water or solids, slight dispersion can occur due to frequency-dependent speed variations.

(c) a small speaker emitting a note of frequency 250 hz is placed over the open upper end of a vertical tube which is full of water. when the water is gradually run out of the tube the air column resonates. if the initial and final position of the water surface below the top are 0.31 m and 0.998 m respectively, calculate the speed of sound in air and the end-correction of the tube.
given:
f = 250 hz
first resonance length, $l_1 = 0.31$ m
third resonance length, $l_2 = 0.998$ m

using the resonance condition for an open-closed tube:

$l_2 - l_1 = (\lambda / 2)$
solving for λ:
$\lambda = 2(l_2 - l_1)$

$\lambda = 2(0.998 - 0.31)$
$\lambda = 2(0.688)$
$\lambda = 1.376$ m
speed of sound in air:
$v = f\lambda$
$v = 250 \times 1.376$
$v = 344$ m/s
end correction e is given by:
$e = (l_2 - 3l_1) / 2$
substituting values:
$e = (0.998 - 3 \times 0.31) / 2$
$e = (0.998 - 0.93) / 2$
$e = 0.068 / 2$
$e = 0.034$ m

the speed of sound in air is 344 m/s and the end correction of the tube is 0.034 m.

8. (a) what is meant by "power rating" as regards to a resistor?
- power rating of a resistor is the maximum amount of power that the resistor can dissipate safely without being damaged.

(b)(i) mention two distinct velocities of an electron in a wire.
- drift velocity: the slow net velocity of electrons due to an applied electric field.
- thermal velocity: the random motion of electrons due to thermal energy, much higher than drift velocity.

(ii) a 20 kω resistor is to be connected across a potential difference of 300 v. calculate the required power rating.
power is given by:
$p = v^2 / r$

substituting values:
$p = (300)^2 / 20000$
$p = 90000 / 20000$
$p = 4.5$ w
the required power rating is 4.5 w.

(c)(i) explain the following observation: light in the bulb comes on once the switch is kept on despite the drift velocity of electrons being very low.
- the electric field propagates through the circuit at nearly the speed of light, causing electrons to move collectively, allowing current to establish instantly.

(ii) the potentiometer is said to be a better device for measuring the potential difference (p.d) than a moving coil voltmeter.

- the potentiometer does not draw current from the circuit being measured, providing an accurate measurement of emf, while a voltmeter introduces a small current, causing slight measurement errors.

9. (a)(i) state the laws of electromagnetic induction.
- faraday's law: the induced emf in a circuit is directly proportional to the rate of change of magnetic flux through the circuit.
- lenz's law: the direction of induced current opposes the change that caused it.

(ii) mention the factors which determine the magnitude and direction of the force experienced by a current-carrying conductor in a magnetic field.
- magnitude of current in the conductor
- strength of the magnetic field
- length of the conductor in the magnetic field
- angle between the conductor and the magnetic field

(b)(i) derive the formula for the torque acting on the rectangular current-carrying coil in a magnetic field.
consider a coil of n turns, length l, and width w, carrying current i in a uniform magnetic field b.
force on each side:
$f = bil$
since torque τ is given by:
τ = force × perpendicular distance
for the coil:
$\tau = bil \times w \sin\theta$
for n turns:

$\tau = nbiw \sin\theta$
since area of the coil $a = lw$,
$\tau = nbi\, a \sin\theta$

(ii) what is the maximum torque on a 400-turns circular coil of radius 0.75 m that carries a current of 1.6 a and resides in a uniform magnetic field of 0.4 t?

given:
$n = 400$
$r = 0.75$ m
$i = 1.6$ a
$b = 0.4$ t

area of the coil:
$a = \pi r^2$
$a = \pi \times (0.75)^2$
$a = \pi \times 0.5625$
$a = 1.766$ m²

maximum torque occurs when $\sin\theta = 1$:

$\tau\_max = nbi\ a$
$\tau\_max = 400 \times 1.6 \times 0.4 \times 1.766$
$\tau\_max = 451.6$ Nm
the maximum torque on the coil is 451.6 Nm

10. (a)(i) what is band theory?
- band theory explains the behavior of electrons in solids by grouping energy levels into bands: the valence band, conduction band, and band gap in between.

(ii) how does the band theory explain electrical properties of solids?
- in conductors, the valence and conduction bands overlap, allowing free movement of electrons.
- in semiconductors, a small band gap exists, and electrons can jump to the conduction band with sufficient energy.
- in insulators, the band gap is large, preventing electron flow.

(b) in an intrinsic semiconductor, the energy gap e_g is 1.2 ev, and its hole mobility is very much smaller than electron mobility which is independent of temperature. assuming that the temperature dependence of intrinsic carrier concentration, n_i is expressed as:
$n\_i = n_0 \exp(- e\_g / 2\ k\_b\ t)$
where n_0 and k_b are constants.

(i) what is the ratio between conductivity at 600k and that at 300k?
conductivity is proportional to carrier concentration, so the ratio is given by:
$\sigma\_600 / \sigma\_300 = (n\_600 / n\_300)$

using the given equation:
$n\_600 / n\_300 = \exp[(e\_g / 2\ k\_b)\ (1/300 - 1/600)]$
substituting $e\_g = 1.2$ ev $= 1.2 \times 1.6 \times 10^{-19}$ j, and $k\_b = 1.38 \times 10^{-23}$ j/k:
$n\_600 / n\_300 = \exp[(1.2 \times 1.6 \times 10^{-19}) / (2 \times 1.38 \times 10^{-23}) \times (1/300 - 1/600)]$
$= \exp[(0.96 \times 10^{-19}) / (2.76 \times 10^{-23}) \times (0.00333)]$
$= \exp[(3.48 \times 10^{3}) \times (0.00333)]$
$= \exp(11.6)$
$n\_600 / n\_300 = 1.09 \times 10^{5}$
the ratio of conductivity at 600 k to 300 k is 1.09×10^{5}

(ii) comment on the result obtained in (b)(i).

- the result shows that conductivity increases significantly with temperature in intrinsic semiconductors due to the exponential dependence of carrier concentration on temperature.

(c) study the circuit in figure 1 below then answer the questions that follow.
(i) determine the voltage drop across R_{B2}.

using voltage divider rule:
$V_B = V_{CC} \times (R_{B2} / (R_{B1} + R_{B2}))$

substituting values:
$V_B = 12 \times (2.2\ k\Omega / (18\ k\Omega + 2.2\ k\Omega))$
$= 12 \times (2.2 / 20.2)$
$= 12 \times 0.1089$
$= 1.31$ v

(ii) calculate the emitter current I_E.
assuming $V_{BE} = 0.7$ v:
$V_E = V_B - V_{BE}$
$= 1.31 - 0.7$
$= 0.61$ v
using ohm's law:

$I_E = V_E / R_E$
$= 0.61\ v / 100\ k\Omega$
$= 6.1\ \mu A$
(iii) state the assumption taken to obtain the answer in (c)(ii) above.
- the transistor is in active mode, meaning base-emitter junction is forward biased and base-collector junction is reverse biased.

11. (a)(i) describe coulomb's law and give the dimensions of each quantity.

- coulomb's law states that the force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them:

$$F = k (q_1 q_2 / r^2)$$

where:
F = electrostatic force (dimension: $M L T^{-2}$)
q = charge (dimension: $I T$)
r = distance (dimension: L)
k = coulomb's constant (dimension: $M L^3 T^{-4} I^{-2}$)

(ii) briefly explain how you can demonstrate that there are two types of charges in nature.

- by rubbing a glass rod with silk, it acquires a positive charge, while rubbing an ebonite rod with fur gives it a negative charge. bringing them close to neutral objects or each other shows attraction and repulsion, confirming two types of charges.
(b)(i) define electric potential.
- electric potential at a point is the work done per unit charge in bringing a positive test charge from infinity to that point.
(ii) a radioactive source in the form of a metallic sphere of radius 1.0 cm emits β-particles at the rate of 5.0×10^{10} particles per second. if the source is electrically insulated, how long will it take for its electric potential to be raised by 2.0 volts? (assuming that 40% of the emitted β-particles escape the source.)

charge of one electron: $e = 1.6 \times 10^{-19}$ c

charge escaping per second:
$Q = 40\% \times (5.0 \times 10^{10} \times e)$
$= 0.4 \times (5.0 \times 10^{10} \times 1.6 \times 10^{-19})$
$= 0.4 \times 8.0 \times 10^{-9}$
$= 3.2 \times 10^{-9}$ c/s

capacitance of a sphere:
$C = 4\pi\varepsilon_0 R$
$= (4 \times 3.142 \times 8.85 \times 10^{-12} \times 0.01)$
$= 1.11 \times 10^{-12}$ f

charge required for 2.0 v:
$Q_{total} = C \times V$
$= (1.11 \times 10^{-12}) \times 2.0$
$= 2.22 \times 10^{-12}$ c

time required:
$t = Q_{total}$ / charge per second
$t = (2.22 \times 10^{-12}) / (3.2 \times 10^{-9})$
$t = 6.94 \times 10^{-4}$ s
the time required for the electric potential to be raised by 2.0 v is 0.694 ms.

12. (a)(i) what is an electron microscope?

- an electron microscope is a type of microscope that uses a beam of electrons instead of light to magnify objects with much higher resolution.

(ii) outline three disadvantages of electron microscope.

- requires a vacuum for operation, making sample preparation complex
- specimens must be coated with a conductive material, which can alter their properties

- expensive to maintain and operate compared to optical microscopes

(b)(i) draw a schematic diagram of an electron microscope showing its main parts.

- the diagram should include an electron source, condenser lens, specimen stage, objective lens, projector lens, and screen/detector.

(ii) give the order of resolution of electron microscope in (b)(i) above.

- the resolution of an electron microscope is typically in the range of **0.1 to 0.2 nm**.

(c)(i) briefly explain why cathode ray oscilloscope (c.r.o) is said to be an excellent instrument for measuring the e.m.f.

- a c.r.o provides a visual representation of voltage variations over time, allowing precise measurement of e.m.f., frequency, and waveform characteristics.

(ii) an electron gun fires electrons at the screen of a tv tube. the electrons start from rest and are accelerated through a potential difference of 30 kv. what is the speed of impact of electrons on the screen of the picture tube?

using energy conservation:

$eV = 1/2\ m\ v^2$

solving for v:

$v = \sqrt{(2\ eV / m)}$

substituting values:

$e = 1.6 \times 10^{-19}$ c
$V = 30 \times 10^3$ v
$m = 9.11 \times 10^{-31}$ kg

$v = \sqrt{(2 \times (1.6 \times 10^{-19}) \times (30 \times 10^3) / (9.11 \times 10^{-31}))}$
$v = \sqrt{(9.6 \times 10^{-15} / 9.11 \times 10^{-31})}$
$v = \sqrt{(1.054 \times 10^{16})}$
$v = 3.24 \times 10^8$ m/s

the speed of impact of electrons is **3.24×10^8 m/s**.

13. (a)(i) give a comment on the statement that an electron suffers no force when it moves parallel to the magnetic field, B.

- the force on a charged particle in a magnetic field is given by $F = q v B \sin\theta$. when an electron moves parallel to B, $\theta = 0$ and $\sin 0 = 0$, so no force acts on the electron.

(ii) a 10 ev proton is circulating in a plane at right angles to a uniform magnetic field of magnetic flux density of 1.0×10^{-2} wb/m². calculate the frequency of a proton.

using cyclotron frequency formula:

$f = (q B) / (2\pi m)$

given:
$q = 1.6 \times 10^{-19}$ c
$B = 1.0 \times 10^{-2}$ T
$m = 1.67 \times 10^{-27}$ kg

substituting values:

$f = (1.6 \times 10^{-19} \times 1.0 \times 10^{-2}) / (2\pi \times 1.67 \times 10^{-27})$
$f = (1.6 \times 10^{-21}) / (1.048 \times 10^{-26})$
$f = 1.53 \times 10^{5}$ Hz

the frequency of the proton is 1.53×10^{5} Hz.

(b) an oscilloscope is used to measure the waveform across a 500 Ω resistor in an a.c. circuit as shown in figure 2. given that the time base of the oscilloscope is set at 5 ms/cm, its Y-gain at 0.5 V/cm and the grid has squares of 1.0 cm, calculate:

(i) the period and the frequency.

measuring from the waveform, suppose the wave covers **4 cm** horizontally.

period:

T = time per cm × number of cm
T = 5 ms/cm × 4 cm
T = 20 ms
$T = 20 \times 10^{-3}$ s

frequency:

$f = 1 / T$
$f = 1 / (20 \times 10^{-3})$
$f = 50$ Hz

(ii) the peak voltage and the r.m.s voltage.

measuring from the oscilloscope, suppose the wave has **3 cm** vertical peak displacement.

V_{peak} = Y-gain × number of cm
$V_{peak} = 0.5$ V/cm × 3 cm
$V_{peak} = 1.5$ V

$V_{rms} = V_{peak} / \sqrt{2}$
$V_{rms} = 1.5 / 1.414$
$V_{rms} = 1.06$ V

(iii) the r.m.s current through the resistor.

$I_{rms} = V_{rms} / R$
$I_{rms} = 1.06 / 500$
$I_{rms} = 2.12 \times 10^{-3}$ A

(iv) the mean power dissipated in the resistor.

$P = V_{rms}^2 / R$
$P = (1.06)^2 / 500$
$P = 1.1236 / 500$
$P = 2.25 \times 10^{-3}$ W

14. (a)(i) the main interior of the earth (core) is believed to be in molten form. what seismic evidence supports this belief?

- s-waves cannot travel through the outer core, indicating it is liquid, while p-waves are refracted, confirming the presence of a molten region.

(ii) explain why the small ozone layer on the top of the stratosphere is crucial for human survival.

- the ozone layer absorbs harmful ultraviolet radiation from the sun, preventing it from reaching the earth's surface and reducing the risk of skin cancer and dna damage.

(b)(i) what is the layer composed of and what do you think is the origin of such constituents?

- the ionosphere is composed of ionized gases such as oxygen (O_2^+) and nitrogen (N_2^+), formed by solar ultraviolet radiation and cosmic rays ionizing atmospheric particles.

(ii) mention two uses of the ionosphere.

- enables long-distance radio wave propagation by reflecting shortwave signals
- absorbs and blocks harmful solar radiation that could interfere with communication systems

(c) briefly explain why long distance radio broadcasts make use of short wave bands.

- shortwave bands are reflected by the ionosphere, allowing signals to travel beyond the horizon through multiple reflections between the earth and ionosphere, enabling long-distance communication.

15. (a)(i) briefly explain thermal pollution.

- thermal pollution occurs when industrial activities release excess heat into water bodies or the atmosphere, leading to temperature changes that affect aquatic life and disrupt ecosystems.

(ii) briefly explain water pollution.

- water pollution is the contamination of water bodies by substances such as chemicals, sewage, and plastics, reducing water quality and harming organisms.

(b) describe the soil temperature with regard to agricultural physics which causes lower crop growth at a particular area.

- soil temperature affects enzymatic activities and microbial processes essential for nutrient availability.
- excessively low soil temperatures slow seed germination, root growth, and nutrient absorption, leading to stunted crop growth.
- frost formation can damage plant tissues, reducing productivity.
- prolonged cold conditions limit biological activity in the soil, negatively impacting soil fertility.