THE UNIVERSITY OF ZAMBIA

IN ASSOCIATION WITH

THE TECHNICAL AND VOCATIONAL TEACHERS' COLLEGE

DECEMBER 2022 FINAL EXAMINATION

PHYSICS THEORY (PH 335) QUESTION PAPER

DURATION: THREE HOURS **TOTAL MARKS**: 100

INSTRUCTIONS AND INFORMATION

1. All questions carry equal marks.
2. The marks are shown in brackets.
3. Section A is compulsory and has **20** questions. For each question there are four possible answers A, B, C and D. Choose the one you consider correct and record your choice in pen on the separate Answer Booklet provided.
4. Section B has **2** compulsory questions.
5. Section C has **3** questions. Answer any **2** of your choice.
6. Show clearly all the necessary calculations.
7. Marks will be awarded for neat and well-drawn diagrams.
8. Clearly indicate on the answer booklet cover page which questions you have attempted.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO

WHEREVER NECESSARY USE:

$g = 9.81 m/s^2$

$P_A = 1.01 \times 10^5 Pa$

$1cal = 4.184 J$

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

$1Ci = 3.7 \times 10^{10} Bq$

$\mu_0 = 4\pi \times 10^{-7} Tm/A$

$\varepsilon_0 = 8.85 \times 10^{-12} F/m$

$m_e = 9.11 \times 10^{-31} kg$

$k_e = 8.99 \times 10^9 Nm^2/C^2$

$e = 1.60 \times 10^{-19} C$

$\hbar = 1.05 \times 10^{-34} Js$

$R_H = 1.097 \times 10^7 m^{-1}$

$\sigma = 5.669 \times 10^{-8} W/m^2 K^4$

$h = 6.626 \times 10^{-34} Js$

SOME EQUATIONS YOU MAY FIND USEFUL:

1. $mu_1 + mu_2 = mv_1 + mv_2$
2. $\frac{F_1}{A_1} = \frac{F_2}{A_2}$
3. $F_B = \rho_{fluid} v_{fluid} g$
4. $\frac{\rho_{object}}{\rho_{fluid}} = \frac{v_{fluid}}{v_{object}}$
5. $J = A_1 v_1 = A_2 v_2$
6. $F_g = G\frac{m_1 m_2}{r^2}$
7. $\frac{1}{2}kx_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$
8. $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$
9. $f_o = f_s \frac{v + v_o}{v - v_s}$
10. $F_e = k_e \frac{|q_1||q_2|}{r^2}$
11. $E = k_e \frac{|q|}{r^2}$
12. $R_{eq} = R_1 + R_2$

13. $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$
14. $C_{eq} = C_1 + C_2$
15. $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$
16. $F = qvBsin\theta$
17. $F = ILBsin\theta$
18. $B = \frac{\mu_0 I}{2\pi\pi}$
19. $\Phi_B = BAcos\theta$
20. $\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$
21. $L = \mu_0 n^2 Al$
22. $I = \frac{\varepsilon}{R}\left(1 - e^{-Rt/L}\right)$
23. $q = Q\left(1 - e^{-t/RC}\right)$
24. $I(t) = -\frac{Q}{RC}\left(e^{-t/RC}\right)$
25. $\tau_{max} = BIANsin\theta$
26. $R = \frac{\Delta N}{\Delta t} = \lambda N$
27. $N = N_0 e^{-\lambda t}$
28. $T_{1/2} = \frac{In2}{\lambda} = \frac{0.693}{\lambda}$
29. $N = N_0\left(\frac{1}{2}\right)^n$

SECTION A (20 MARKS)

1. What is the ground state electron configuration of Iron, Fe (Z = 26)?

A. $1s^2\ 2s^2\ 3s^2\ 3p^6\ 3d^6$

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4d^6$

2. The Heisenberg Uncertainty Principle

A. assumes that the electrons take positions predicted by Bohr's theory.

B. states that the position of an electron can be found by measuring its momentum.

C. states that the position and momentum of an electron in an atom cannot be found precisely because measuring the electron changes its momentum.

D. both A and B.

3. At a maximum, an f-orbital can hold _____ electrons, a p-orbital can hold _____ electrons and a d-orbital can hold _____ electrons.

A. 14, 6, 10 **B.** 2, 8, 18 **C.** 14, 8, 2 **D.** 2, 12, 21

4. Newton's second law of motion says that the mass of an object times its acceleration is equal to the net force on the object. Which of the following gives the correct units for force?

A. kgm/s^2 **B.** kgm^2/s^2 **C.** kg/ms^2 **D.** *none these*

5. Decimal sub-multiples and multiples of units are indicated using a prefix to the unit. For example, the prefix milli (m) represents 10^{-3}

Which row gives the sub-multiples or multiples represented by pico (p) and giga (G)?

	pico (p)	**giga (G)**
A.	10^{-9}	10^{9}
B.	10^{-9}	10^{12}
C.	10^{-12}	10^{9}
D.	10^{-12}	10^{12}

6. A wire of resistance 9.55Ω has a diameter of 0.280mm. It is made of metal of resistivity $4.90\times10^{-7}\Omega$m. What is the length of the wire?

A. 1.20m **B.** 4.80m **C.** 19.0m **D.** 76.8m

7. The nuclei of the isotopes of an element all contain the same number of a certain particle. What is this particle?

A. Electron

B. Neutron

C. Nucleon

D. Proton

8. What is the correct statement of Ohm's law?

A. The potential difference across a component equals the current providing the resistance and other physical conditions stay constant

B. The potential difference across a component equals the current multiplied by the resistance.

C. The potential difference across a component is proportional to its resistance.

D. The potential difference across a component is proportional to the current in it providing physical conditions stay constant.

9. Which statement about alpha, beta and gamma radiation is correct?

A. Alpha radiation has the greatest ionising power.

B. Beta radiation has the greatest ionising power.

C. Gamma radiation has the greatest ionising power.

D. Alpha, beta and gamma radiation have nearly equal ionising powers.

10. What is the unit of resistivity?

A. Ω/m^2 **B.** Ω/m **C.** Ω **D.** Ωm

11. There is a current of 10 mA in a conductor for half an hour. How much charge passes a point in the conductor in this time?

A. 0.3 C **B.** 5 C **C.** 18 C **D.** 300 C

12. Induced electric currents can be explained using which of the following laws?

A. Gauss's Law

B. Faraday's Law

C. Ohm's Law

D. Ampere's Law

13. At a point halfway between two identical point charges, the electric field is equal to:

A. zero

B. half its maximum value

C. its maximum value

D. pointing away from the two charges

14. The terminal voltage of a cell supplying energy to a circuit is usually less than its emf because of the cell's:

A. size

B. internal resistance

C. mass

D. energy

15. Which of the following is not a characteristic of a series circuit?

A. The current is the same throughout.

B. The total resistance is the sum of the individual resistance.

C. The voltage of the source equals the sum of the circuit's individual voltage drops.

D. The total resistance is the sum of the reciprocals of the individual resistances.

16. For a parallel-plate capacitor with plate area 'A' and separation 'd', the capacitance is proportional to which of the following?

A. A divided by d squared
B. A times d
C. A divided by d
D. d divided by A

17. What are the correct descriptions of a γ-ray and a β-particle?

	γ-ray	β-particle
A.	High-speed electron	Electromagnetic radiation
B.	Electromagnetic radiation	Helium-4 nucleus
C.	Electromagnetic radiation	High-speed electron
D.	High-speed electron	Helium-4 nucleus

18. Energy is dimensionally represented as:

A. $M^1L^2T^{-2}$ **B.** $M^1L^{-2}T^{-2}$ **C.** $M^2L^2T^{-2}$ **D.** $M^1L^2T^2$

19. In N-type semiconductors the majority of the carriers are:

A. Holes **B.** Electrons **C.** Protons **D.** neutrons

20. The force acting between two point charges can be computed using which of the following laws?

A. Coulomb's Law **B.** Ampere's Law **C.** Newton's Second Law **D.** Ohm's Law

SECTION B (40 MARKS)

Question One

a. The kilogram, metre, second, etc. are base units. State two other base SI units. [2 marks]

b. State the factor (number) represented by the following prefixes;

i. Centi [1 mark]
ii. Milli [1 mark]
iii. Nano [1 mark]
iv. Mega [1 mark]
v. Pico [1 mark]

c. Write the electronic configuration for the following atoms.

i. Iron (26 electrons) [1 mark]
ii. Gallium (31 electrons) [1 mark]
iii. Aluminium (13 electrons) [1 mark]
iv. Calcium (20 electrons) [1 mark]
v. Boron (5 electrons) [1 mark]
vi. Carbon (6 electrons) [1 mark]

d. Suppose that the acceleration a of a particle moving with uniform speed v in a circle of radius r is proportional to some power of r, say r^n, and some power of v, say v^m. Determine the values of n and m and write the simplest form of an equation for the acceleration. [7 marks]

Question Two

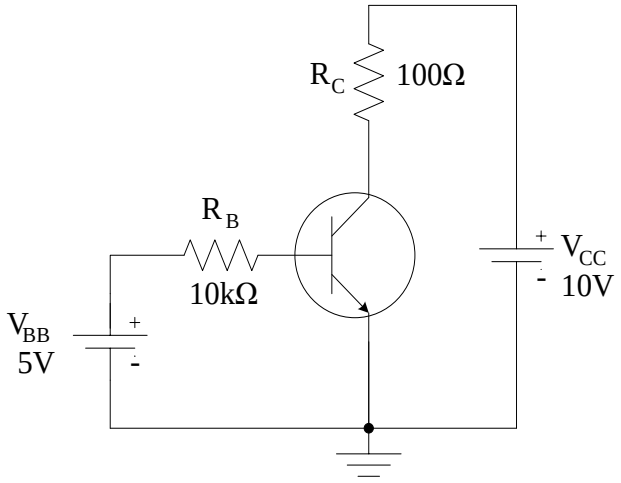
a. State three (3) factors that affect the capacitance of a capacitor. [3 marks]

b. The table below summarises the properties of Alpha, Beta and Gamma radiation. Complete the table by filling in the correct information.

Property	**α ray**	**β ray**	**γ ray**
Nature	**i.** _____	Negatively charged particles (electrons)	Uncharged electromagnetic radiation
Charge	+2e	-e	**ii.** _____
Penetrating power	Low. Can be stopped by a thin sheet of paper	Moderate. Can be stopped by an aluminium sheet	**iii.** _____
Deflection by magnetic field	They are deflected less than beta particles because they have a higher mass	**iv.** _____	They are not deflected by magnetic field.
Ionizing ability	**v.** _____	Medium	0

[5 marks]

c. Determine I_B, I_C, I_E, V_{BE}, V_{CE} and V_{CB} in the circuit below. The transistor is made from silicon and has $\beta_{DC} = 150$.



[12 marks]

SECTION C (40 MARKS)

Question One

a. State two requirements for the forward bias of the pn junction diode. [2 marks]

b. Convert the following binary numbers to decimal.

i. 10011010 [2 marks]

ii. 11001.011 [2 marks]

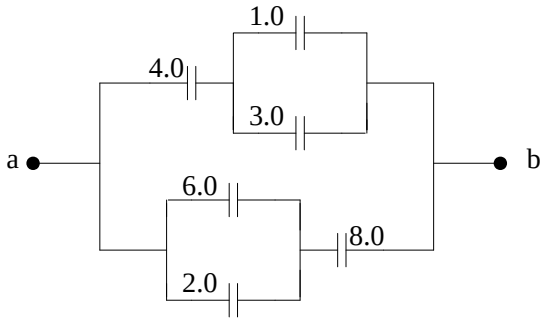
c. Three resistors having resistances of 1.60 Ω, 2.40 Ω, and 4.80 Ω are connected in parallel to a 28.0 V battery that has negligible internal resistance. With the aid of a well-drawn diagram, find:

i. The equivalent resistance of the combination. [2 marks]

ii. The total current through the battery. [2 marks]

iii. The power dissipated in each resistor. [3 marks]

d. The figure below shows a combination of series and parallel capacitors.



Calculate the equivalent capacitance between a and b for the combination of capacitors shown. [7 marks]

Question Two

a. What is frequency modulation? [2 marks]

b. De Morgan's theorem represents two of the most powerful laws in Boolean algebra. State and explain the two laws of De Morgan's theorem. [4 marks]

c. Apply De Morgan's theorem to the following

i. $\overline{\overline{AB}(CD+EF)(\overline{AB}+\overline{CD})}$ [3 marks]

ii. $\overline{(A+\overline{B})(C+\overline{D})}$ [3 marks]

d. Explain four advantages of frequency modulation over amplitude modulation. [8 marks]

Question Three

a. State the three observations that were made in the Rutherford's α-particle Scattering Experiment. [3 marks]

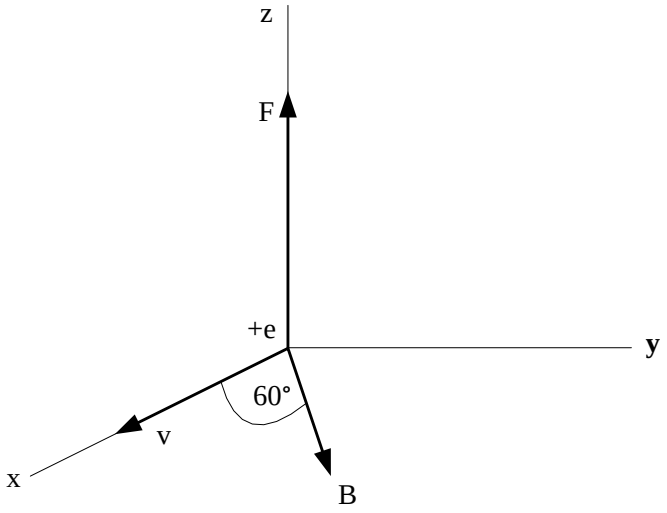
b. With the aid of neat diagrams, show some representative electric field lines for:

i. A single positive charge. [2 marks]

ii. A single negative charge [2 marks]

c. Starting from the equation $N = N_0 e^{-\lambda t}$, derive the expression for the half-life of a radioactive element. [6 marks]

d. A proton moves at 8.00×10^6 m/s along the x-axis. It enters a region in which there is a magnetic field of magnitude 2.50 T, directed at an angle of 60.0° with the x-axis and lying in the xy-plane as shown in the below.



i. Find the magnitude and direction of the magnetic force on the proton. [4 marks]

ii. Calculate the proton's initial acceleration. [3 marks]

END OF EXAMINATION