

Physics
PHY 04

24/07/2024 08:30 AM – 11:30 AM



ADVANCED LEVEL NATIONAL EXAMINATIONS, 2023-2024

SUBJECT: PHYSICS IV

PAPER II : THEORY

COMBINATION: ASSOCIATE NURSING PROGRAM: ANP

DURATION: 3 HOURS

Instructions to candidates:

- 1) Write your names and index number on the answer booklet as written on your registration form and **DO NOT** write your names and index number on additional answer sheets if provided.
- 2) Do not open this question paper until you are told to do so.
- 3) This paper consists of **two** sections **A** and **B**.

Section A: Attempt **ALL** questions. **(70 marks)**

Section B: Attempt any **THREE** questions. **(30 marks)**

- 4) Scientific calculator and mathematical set may be used.
- 5) **Useful constants**

Mass of the Earth $M = 6.0 \times 10^{24}$ kg

Mean radius of the Earth = 6 400 km.

Speed of light in air $C = 3 \times 10^8$ m/s.

Universal gravitational constant $G = 6.67 \times 10^{-11}$ N m²/kg²

Acceleration due to gravity $g = 9.81$ m/s²

The ideal gas constant $R = 8.314$ J/K.mol

Planck constant $h = 6.63 \times 10^{-34}$ Js

Mass of electron $m_e = 9.1 \times 10^{-31}$ kg

Charge of electron $e = 1.6 \times 10^{-19}$ C

Section A: Attempt all questions (70 marks)

1) Select the option that best completes the statement or answers the question.

a) Which of the following are the properties of LASER light?

- i) Directionality and chromaticity ii) Directionality and monochromaticity
- iii) Chromaticity and high intensity iv) Monochromaticity and divergence

(1 mark)

b) LASER light is considered to be coherent because it consists of waves of exactly

- i) the same wavelength and maintain constant phase difference.
- ii) the same amplitude and phase.
- iii) the same intensity and maintain constant phase difference.
- iv) the same frequency.

(1 mark)

c) The following graph (figure 1) is pictorial representation of:

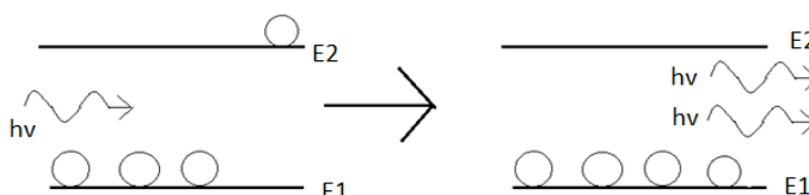


Figure 1

- i) spontaneous emission ii) spontaneous absorption
- iii) stimulated emission iv) stimulated absorption

(1 mark)

d) If N_1 , N_2 be the number of atoms in energy states/levels E_1 , E_2 ($E_2 > E_1$) respectively, then the condition of inverse population is

- i) $N_1 > N_2$ ii) $N_1 < N_2$
- iii) $N_1 = N_2$ iv) $N_1 \geq N_2$

(1 mark)

e) What does the acronym LASER stand for?

- i) Light Absorption by Stimulated Emission of Radiation
- ii) Light Alteration by Storing Emission of Radiation
- iii) Light Alteration by Stimulated Emission of Radiation
- iv) Light Amplification by Stimulated Emission of Radiation

(1 mark)

2) Select the option that best completes the statement or answers the question.

a) The characteristic of the final image formed by a simple microscope is

- i) virtual, erect, and magnified ii) real, erect, and magnified
- iii) real, inverted, and magnified iv) virtual, inverted and magnified

(1 mark)

b) What eye defect can be corrected using a concave lens?

- i) Astigmatism
- ii) Hypermetropia/Farsightedness
- iii) Myopia/Nearsightedness
- iv) Presbyopia

(1 mark)

c) Which one of the following instruments would you use to see a plant cell?

- i) Periscope
- ii) Compound microscope
- iii) Simple microscope
- iv) Telescope

(1 mark)

d) The astronomical telescope consists of objective and eyepiece.

The focal length of the objective is

- i) equal to that of the eyepiece.
- ii) greater than that of the eyepiece.
- iii) shorter than that of the eyepiece.
- iv) five times shorter than that of the eyepiece.

(1 mark)

3) Select the option that best completes the statement or answers the question.

a) Choose a set of renewable energy resources.

- i) Solar energy- natural gas
- ii) Solar energy-geothermal energy
- iii) Coal- hydroelectric power
- iv) Uranium/Nuclear energy-wind energy

(1 mark)

b) Which of the following is a disadvantage of using solar power?

- i) It is not reliable in all weather conditions.
- ii) Maintenance cost of solar energy is very high.
- iii) It emits pollutants.
- iv) The coating materials used in solar absorber possess low emissivity.

(1 mark)

c) Which of the following energy resources releases greenhouse gases?

- i) Hydro-electric power
- ii) Coal
- iii) solar energy
- iv) Geothermal energy

(1 mark)

d) Which of the following is a fossil fuel?

- i) Oil
- ii) Wood
- iii) Natural uranium
- iv) Hydrogen

(1 mark)

4) Fill in the blank with appropriate term from the box. The symbols have their usual meanings. You may use any key word once or not at all.

$U = k \frac{Q_1 Q_2}{r^2}$	$U = k \frac{Q_1 Q_2}{r}$	electric dipole moment
positive	$a = \frac{E}{ e m}$	straight line
electric dipole	negative	parabola
		$a = \frac{ e E}{m}$

- a) Electrical potential energy between two electric charges is given by the formula **(1 mark)**
- b) The direction of an electric field at any point, by convention, is the direction of the electrical force on a small test charge, placed at that point. **(1 mark)**
- c) The trajectory of an electron in an electric field is a..... **(1 mark)**
- d) Acceleration of an electron from rest in the electron gun of a cathode ray oscilloscope is given by **(1 mark)**
- e) Electric potential due to a dipole at any point is directly proportional to **(1 mark)**
- 5) Write **true** if the statement is correct and **false** if the statement is wrong.
- a) The velocity of sound in a gas is directly proportional to square root of its absolute temperature. **(1 mark)**
- b) The speed of a wave within a guitar string is inversely proportional to the square root of the tension in the string. **(1 mark)**
- c) As the sound of a car's horn passes and moves away from you, frequency of the horn increases. **(1 mark)**
- d) The pitch of the sound wave depends on its frequency. **(1 mark)**
- e) The intensity of sound is measured in W/m². **(1 mark)**
- 6) Match the particle or class of particles to the correct description

Particle/class of particles	Description
a) Quarks	i) Matter particles
b) Gluons	ii) Elementary particles that are the building blocks for protons and neutrons
c) Fermions	iii) Force carrying particles
d) Bosons	iv) Elementary particles that create the strong force between quarks
e) Hadrons	v) They are made of quarks held together by the strong force

(5 marks)

7) The diagram below (figure 2) shows the main parts of a nuclear reactor

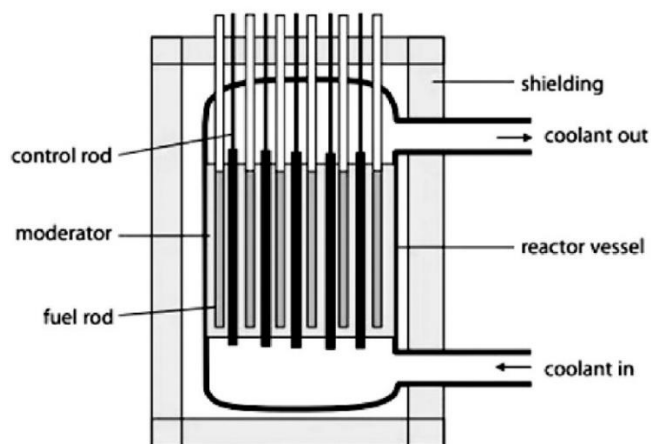


Figure 2

Copy the table below and draw a line linking each part of the reactor with its main function.

Part of reactor	Main function
A) Control rod	i) Removes energy from the reactor
B) Coolant	ii) Controls the rate of fission
C) Fuel rod	iii) Absorbs dangerous radiation
D) Shielding	iv) Contains uranium for fission

(4 marks)

a) Which of the following is the correct energy change taking place in a nuclear power plant?

i) Nuclear energy → Heat energy → Mechanical energy → Electrical energy

ii) Heat energy → Nuclear energy → Mechanical energy → Electrical energy

iii) Potential energy → Kinetic energy → Mechanical energy → Electrical energy

iv) Kinetic energy → Potential energy → Mechanical energy → Electrical energy

(1 mark)

8) a) With the help of a diagram, explain the term couple of forces.

(2 marks)

b) The system below is formed by a mass m that hangs from the end of the uniform strut whose mass is M as shown in the figure 3.

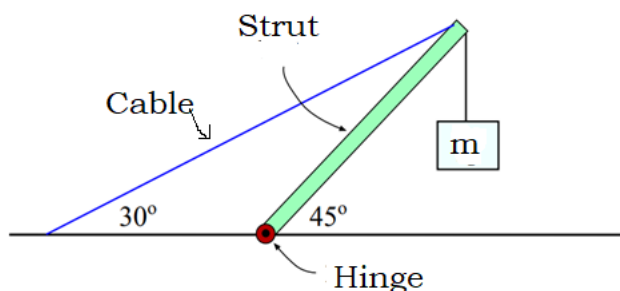


Figure 3

- i) Copy the above system and draw a free body diagram. **(2 marks)**
 - ii) Is the above system in equilibrium? **(1 mark)**
- 9) Biological half-life and physical half-life are commonly used in radiation and medicine.
- a) What is one-way radioactive material can be eliminated from inside the human body? **(1 mark)**
 - b) Differentiate between biological half-life and physical half-life. **(2 marks)**
 - c) i) What is effective half-life? **(1 mark)**
 ii) How does the effective half-life take into account the biological and physical half-lives? **(1 mark)**
- 10) Select the correct option among the given alternatives.
- a) The main objective of cell in a cellular mobile system is

i) higher bandwidth	ii) handoff
iii) frequency re-use	iv) simple modulation techniques

(1 mark)
 - b) Why neighbouring stations are assigned different frequencies in cellular system?

i) To minimize interference	ii) To minimize area
iii) To maximize throughput	iv) To maximize capacity

(1 mark)
 - c) Which of the following is a device that turns information or data into electromagnetic waves that may be delivered wirelessly?

i) Transmitter	ii) Channel
iii) Antenna	iv) Transducer

(1 mark)
 - d) Which of the following characteristics of a cellular system guarantees that the call is neither interrupted nor dropped when the user switches between cells?

- i) Cell ii) Wi-Fi iii) Cell splitting iv) Handoff
(1 mark)

e) The frequency and the phase of the carrier in AM

- i) varies, varies
ii) varies, remains constant
iii) remains constant, varies
iv) remains constant, remains constant

(1 mark)

11) Particles carry momentum as well as energy. Despite photons having no mass, there has long evidence that electromagnetic radiation carries momentum and energy.

a) Calculate the momentum of a visible photon that has a wavelength of 500 nm.

(2 mark)

b) i) What is the energy of this photon in joules?

(2 marks)

ii) Express this energy in electronvolts.

(1 mark)

12) A football is kicked at an angle $\theta = 37.0^\circ$ to the horizontal with an initial velocity of 20.0 m/s.

a) Calculate the maximum height attained by the football.

(2 marks)

b) How far away it hits the ground?

(2 marks)

13) The Global Positioning System (GPS) is a system of satellites that transmit radio signals which can be used to locate the position of a receiver anywhere on Earth. *Figure 4* shows the position of a geostationary satellite with respect to the Earth.

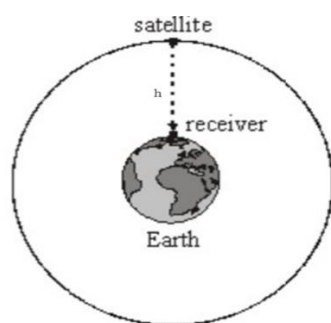


Figure 4

a) A receiver at sea level detects an electromagnetic signal from a satellite in a circular orbit when it is passing directly overhead as shown in the figure above.

i) The microwave signal is received 68 ms after it was transmitted from the satellite. Calculate the height of the satellite.

(1 mark)

ii) Show that the gravitational field strength of the Earth at the position of the satellite is 0.56 N kg^{-1} .

(2 marks)

b) For the satellite in this orbit, calculate its speed. **(2 marks)**

14) Theoretically speaking, what would happen if the Earth's gravity suddenly disappeared? **(4 marks)**

15) Digital technology is always better than analog technology. Do you agree with this statement? Justify your answer. **(4 marks)**

Section B: Attempt any three questions (30 marks)

16) In the last decades, medical imaging has significant advancements in Healthcare. It has greatly improved patient outcomes and supported Doctors in achieving better results. Use essay form to discuss the physics concepts and advantages of medical imaging techniques. **(10 marks)**

17) Use Kirchhoff's rules to determine the values of unknown physical quantities shown in the electric circuit below.

a) A battery of electromotive force (e.m.f) E and internal resistance r is connected to a variable resistor of resistance R , as shown in *figure 5*

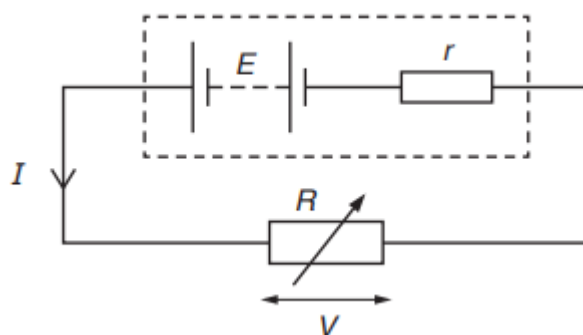


Figure 5

The resistance R of the variable resistor is varied. The variation of V with I is shown in *figure 6*

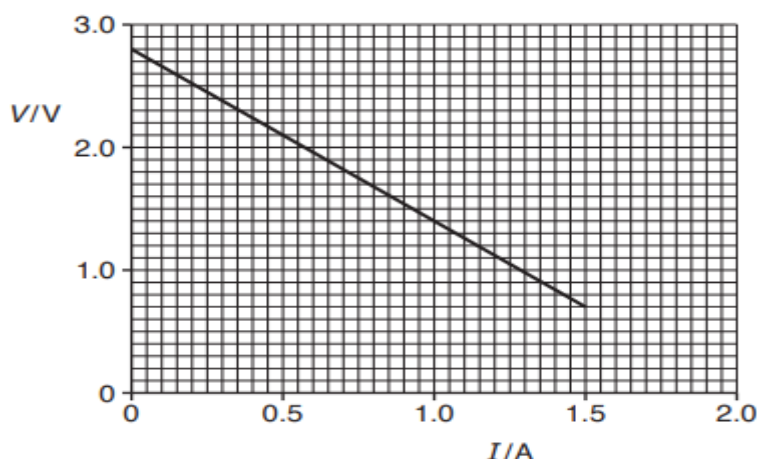


Figure 6

- i) Use the above figures to calculate the internal resistance r . **(2 marks)**
 - ii) Calculate the resistance R if the variable resistor is adjusted so that $V = 2.1$ V. **(2 marks)**
- b) Consider the diagram below (figure 7) of a complex electric circuit.

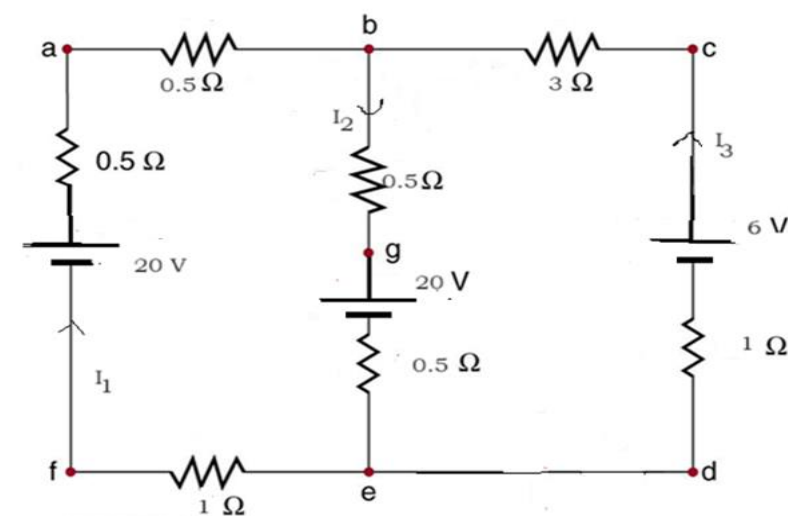


Figure 7

Find the three electric currents I_1 , I_2 and I_3 shown in figure 7.

(6 marks)

- 18) One mole of an ideal monatomic gas is taken through a thermodynamic cycle $abca$ consisting of three processes. The processes are:

Process $a-b$: constant pressure expansion

State a has volume $V_a = 17 \times 10^{-3} \text{ m}^3$ and pressure $P_a = 1.2 \times 10^5 \text{ Pa}$

Process $b-c$: constant volume

State c has volume $V_c = 51 \times 10^{-3} \text{ m}^3$ and pressure $P_c = 0.4 \times 10^5 \text{ Pa}$

Process $c-a$: constant temperature compression

It lies along the 250 K isotherm

- a) Sketch the cycle path on a PV diagram. **(3 marks)**
- b) Find i) The temperature T_b of state b. **(1 mark)**
 ii) Calculate the net work done in this cyclic process. **(3 marks)**
 The work for the cycle is the sum of the work for each step.
- iii) Is the net heat added to the gas for the entire cycle or removed from the gas? Justify your answer. **(2 marks)**
- c) Calculate the efficiency of a Carnot engine that operates between the maximum and minimum temperatures in this cycle. **(1 mark)**

19) In the real world, oscillations rarely follow true simple harmonic motion.

Friction of some sort usually acts to dampen the motion so it dies away or needs more force to continue.

- a) The diagram below (*figure 8*) shows the motion of a 2.00 kg mass on a vertical spring.

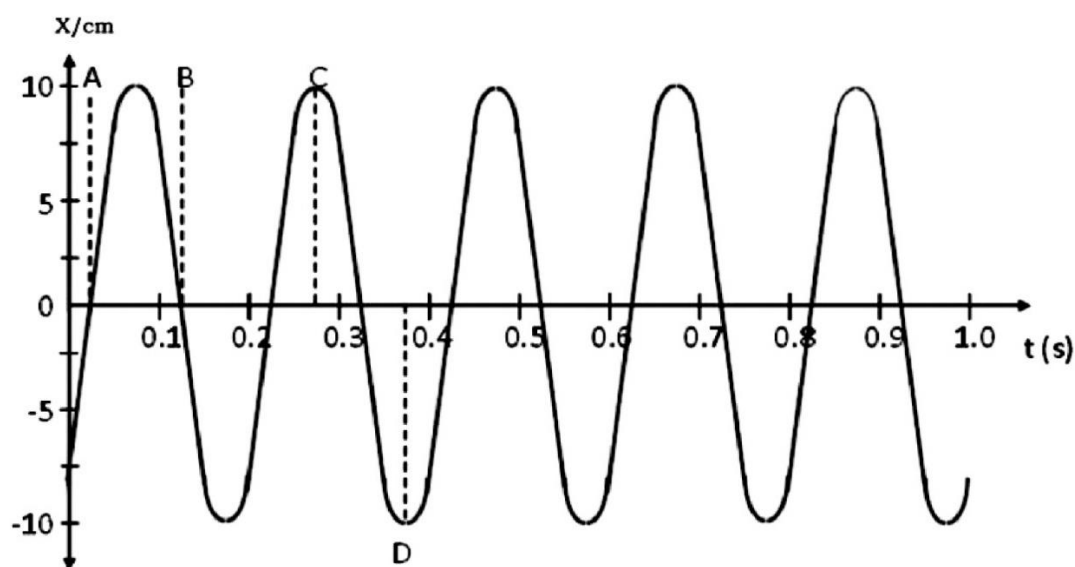


Figure 8

- i) Find the phase constant (initial phase) of this motion. The projection of the corresponding uniform circular motion was done along x-axis (horizontal axis).
 Hint: The correct answer is in the third quadrant and it is 360° or 2π rad minus the calculated value. **(1 mark)**
- ii) Write down the equation (including all constants) of the displacement x as a function of time.
 Phase constant must be in radians. **(2 marks)**
- iii) What is the total energy of the system? **(2 marks)**
- iv) Use your results to draw, not to scale, on the same diagram the variation of kinetic energy, potential energy and total mechanical

energy of the system with displacement.

(2 marks)

- b) An object of mass $m=0.2$ kg that is hung from a spring whose spring constant is 80 N/m. The body is subjected to a resistive force given by $-bv$ where v is its velocity and $b = 4 \text{ Nm}^{-1}\text{s}$.

i) Set up the differential equation of motion for the oscillations of this system.

(1 mark)

ii) Show that these oscillations are overdamped or not.

(2 marks)

20) Radioactive decay is the process by which unstable atomic nucleus losses energy by radiation.

- a) Determine which of the following sources shown in *figure 9* is beta source.

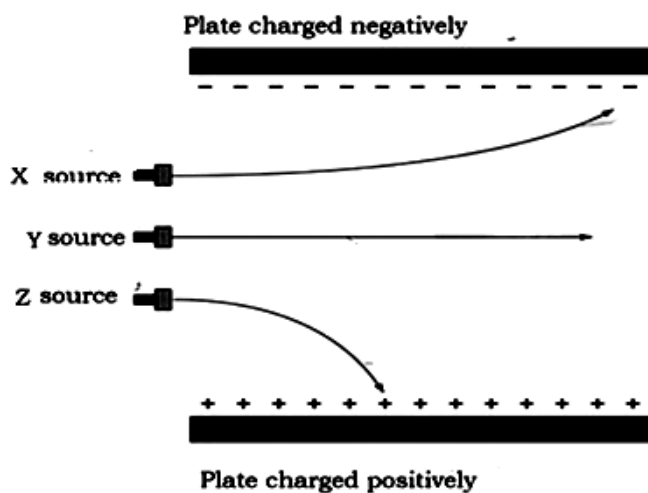
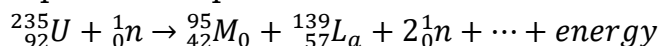


Figure 9

(1 mark)

- b) One nuclear reaction that can take place in a nuclear reactor may be represented, in part, by the equation shown below.

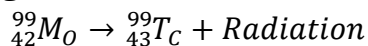
Complete the equation.



Show your working.

(2 marks)

- c) When the nucleus of a molybdenum-99 atom decays, it emits radiation and changes into a nucleus of technetium-99.



i) What type of radiation is emitted by molybdenum-99?

(1 mark)

ii) Give a reason for your answer.

(1 mark)

d) Technetium-99 is used by Doctors as a medical tracer. In hospitals it is produced inside a technetium generator by the decay of molybdenum-99 nuclei.

i) *Figure 10* below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.

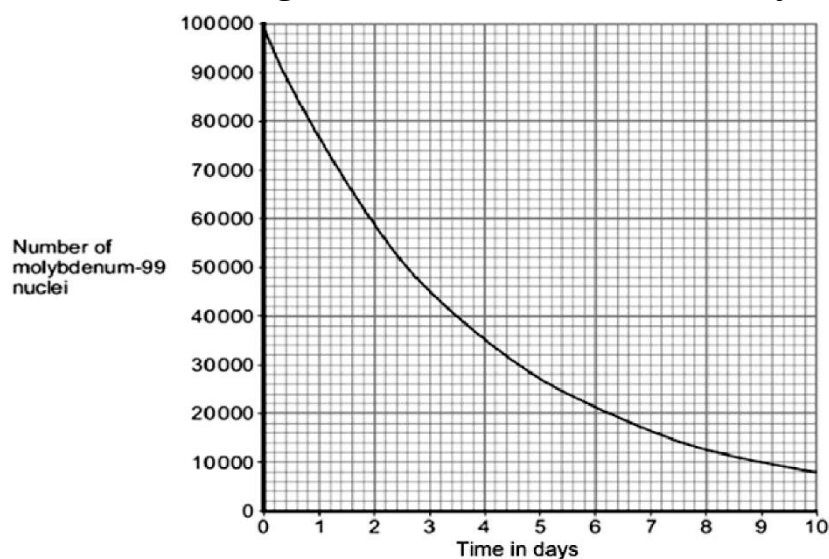


Figure 10

A technetium generator will continue to produce sufficient technetium-99 until 80% of the original molybdenum nuclei have decayed. After how many days will a source of molybdenum-99 inside technetium-99 generator need replacing?

(2 marks)

ii) Find the initial activity of this radioactive sample.

(3 marks)

-END-