JOINT UNIVERSITIES PRELIMINARY EXAMINATIONS BOARD

AUGUST 2022 EXAMINATIONS

OPTION – D301

PHYSICS **Time Allowed: 3 hours**

SECTION A: MULTIPLE CHOICE QUESTIONS

Answer ALL questions in this section.

Use the OMR answer sheet provided to answer the questions.

Write and shade on your OMR Sheet the OPTION written on your question paper

Follow the instructions on the OMR sheet.

SECTION B: ESSAY QUESTIONS

Answer FOUR Questions in ALL; ONE Question from each course.

Ensure you read and follow all the Instructions on the cover page of the Answer Booklet.

The following constants are given

Acceleration due to gravity, g	$9.8\ m/s^2$
Atomic mass unit, u	$931.5\ MeV = 1.661 \times 10^{-27}\ kg$
Avogadro's number, N_A	$6.02 \times 10^{23}\ mol^{-1}$
Boltzmann constant, k	$1.38 \times 10^{-23}\ J/K$
Density of water, ρ_w	$1000\ kg/m^3$
e/m	$1.76 \times 10^{11}\ C\ kg^{-1}$
Electric charge, e	$1.6 \times 10^{-19}\ C$
Electron rest mass, m_e	$9.11 \times 10^{-31}\ kg$
Electron volt, eV	$1.602 \times 10^{-19}\ J$
Gravitational constant, G	$6.67 \times 10^{-11}\ Nm^2/kg^2$
Mass of Helium nucleus	4.0015u
Mass of neutron	1.0087u
Molar gas constant, R	8.31 J/K/mol
Permeability of free space (μ_0)	$4л \times 10^{-7}\ Hm^{-1}$
Permittivity of free space (ε_0)	$8.85 \times 10^{-12}\ F/m$
Planck's constant, h	$6.6 \times 10^{-34}\ Js$
Proton rest mass, m_p	$1.67 \times 10^{-27}\ kg$
Radius of the earth, R	$6.4 \times 10^{6}\ m$
Refractive index for glass	1.5
Refractive index for water	1.33
Speed of light in vacuum, c	$3.0 \times 10^{8}\ m/s$
Stefan constant, σ	$5.67 \times 10^{-8}\ W/(m^2k^4)$
Wien constant, α	$2.9 \times 10^{-3}\ mK$
$(4\pi\varepsilon_o)^{-1}$	$9.0 \times 10^{9}\ mF^{-1}$
1 atm	$1.105 \times 10^{5}\ Pa$

SECTION A: MULTIPLE CHOICE QUESTIONS.

Answer ALL Questions.

1. If P is the momentum of an object of mass m, then the expression $\frac{p^2}{m}$ has the same unit as
   A. energy.
   B. impulse.
   C. pressure.
   D. force.

2. A ball is thrown vertically upwards. The quantity which remains constant is
   A. displacement.
   B. speed.
   C. kinetic energy.
   D. acceleration due to gravity.

3. The velocity of a moving train is given by $V = \frac{P}{t} + Qt$ where V is the velocity and t is the time. Find the SI unit of P and Q respectively.

A. ms^{-1}, ms^{-3}.

B. ms^{-1}, ms^{-1}.

C. m, ms^{-2}.

D. m, ms^{2}.

4. A train goes into the tunnel at 20m/s and emerges from it at 55m/s. The tunnel is 1500m long, assuming constant acceleration. How long did the train stay in the tunnel?

A. 75s.

B. 40s.

C. 27.3s.

D. 20s.

5. The main source of energy used for satellites is

A. Edison cells.

B. Fuel cells.

C. Solar cells.

D. Cryogenic cells.

6. The gravitational force between two objects of masses 10^{24} kg and10^{27} kg is 6.6 N. Calculate the distance between them.

A. 1.0×10^{19} m.

B. 1.0×10^{-19}m.

C. 1.0×10^{20}m.

D. 1.0×10^{-20}m.

7. The magnetic flux in a coil having 500 turns changes at the time rate of 0.04 Wbs^{-1}. What is the induced e.m.f in the coil?

A. 50 V.

B. 35 V.

C. 20 V.

D. 10 V.

8. What is the r.m.s voltage of a circuit consisting of a 10^{-4} F capacitor connected in series with 1 kΩ resistor operating at $50/\pi$ Hz frequency if the current peaks at 2.0 A?

A. 1.0 kV.

B. 1.2kV.

C. 1.4kV.

D. 2.0kV.

9. The function of an atomiser in the Millikan's oil drop experiment is to

A. introduce oil droplets.

B. impart charges on the droplets.

C. illuminate the chamber.

D. maintain the balancing potential.

10. The energy associated with the photon of a radio transmission at 5×10^5Hz is

A. 3.32×10^{-28}J.

B. 2.32×10^{-28}J.

C. 1.32×10^{-29}J.

D. 3.32×10^{-29}J.

11. Given the following statements:

i. X-rays do not consist of electrically charged particles.

ii. X-rays are not deflected in an electric or magnetic field.

iii. The wavelength of X-rays is longer than that of visible light.

Which of the above statements about X-rays is/are correct?

A. i and ii only.

B. i and iii only.

C. i only.

D. iii only.

12. What power is dissipated in an X-ray tube that takes a current of 5 mA to operate at a potential difference of 30 kV?

A. 150W.

B. 250W.

C. 450W.

D. 350W.

13. Calculate the de Broglie wavelength of an electron with energy 1.0 keV.

A. 3.9×10^{-11} m.

B. 4.5×10^{-11} m.

C. 7.4×10^{-11} m.

D. 9.2×10^{-11} m. [$1eV = 1.6 \times 10^{-19}J$]

14. Which of the following has the most penetrating power?

A. alpha-particles.

B. beta-particles.

C. gamma-rays.

D. X-rays.

15. The stopping potential V_s was plotted against the frequency of radiation f on a Cartesian plane. Determine the intercept.

A. $\frac{h}{e}$.

B. $\frac{w_o}{e}$.

C. $\frac{e}{m}$.

D. E.

16. A rocket of mass 100 kg was lunched from the surface of the earth so that it escaped the gravitational attraction of the earth. Calculate its escape velocity.

A. 1.12×10^4 m/s.

B. 1.11×10^4 m/s.

C. 6.00×10^{27} m/s.

D. 3.84×10^{34} m/s. [$g = 9.8$ m/s^2; $R_E = 6.4 \times 10^6$ m; and $M_E = 6 \times 10^{24}$ kg]

17. A body of mass 10 kg is acted on by a constant force of 8 N for 5 seconds. Calculate the kinetic energy gained by the body at the end of the time.

A. 40.0J.

B. 60.0J.

C. 70.0J.

D. 80.0J.

18. A swinging pendulum has which of the following at the middle of its arc?
    A. maximum potential energy.
    B. maximum kinetic energy.
    C. minimum kinetic energy.
    D. minimum mechanical energy.

19. Passengers on a carnival ride move at constant speed in a horizontal circle of radius 7.0 m, making a complete circle in 4.0 s. What is their acceleration?
    A. 28.0 m/s.
    B. 17.3 m/s.
    C. 11.0 m/s.
    D. 5.5 m/s.

20. An object of mass 25 kg moving at a speed of 5 ms^{-1} requires what amount of centripetal force to keep it in a circular path of radius 5m?
    A. 312.5 N.
    B. 125 N.
    C. 5 N.
    D. 0.2 N.

21. Under a deforming force, tensile stress of 5.0×10^4 N/m^2 produces a linear strain of 1.0×10^2 on a wire. Calculate the energy per unit volume.
    A. 5.0×10^6 J/m^3.
    B. 2.5×10^6 J/m^3.
    C. 5.0×10^5 J/m^3.
    D. 2.5×10^5 J/m^3.

22. In a converging lens, when the object is at infinity, the images formed are
    A. erect and magnified.
    B. real, inverted and smaller than the object.
    C. always virtual.
    D. erect and diminished.

23. A given mass of gas at 40 °C is trapped in a tube. If its volume is reduced by one-third of its initial value by applying a pressure which surpasses its initial pressure by 60%, calculate the new temperature of the gas.

A. 125.2 °C.

B. 60.9 °C.

C. 62.6 °C.

D. 333.9 °C.

24. The fundamental frequency of vibration of a stretched wire is 120Hz. What will be the new fundamental frequency if the tension in the wire is doubled with the length remaining constant?

A. 240Hz.

B. 60Hz.

C. 140Hz.

D. 170Hz.

25. According to Huygens' principle, the position of light wave at any point in time is given by the

A. wavelength.

B. waveguide.

C. wavefront.

D. wave number.

26. Doppler effect can be described as the

A. superposition of sound wave due to relative motion of the source and the observer.

B. change in wavelength due to reflective motion of the source and the observer.

C. change in pitch produced by the relative motion of the source and the observer.

D. change in amplitude produced by the relative motion of the source and the observer.

27. A small spherical ball bearing of radius 5cm is placed in a uniform electric field of 150 N/C. Calculate the maximum electric flux that can pass through it.

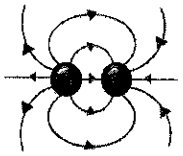
A. 4.7 Nm^2/C.

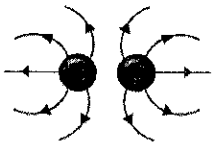
B. 3.0 Nm^2/C.

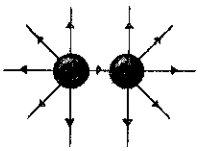
C. 1.5 Nm^2/C.

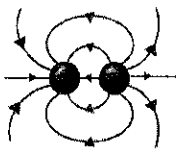
D. 0.1 Nm^2/C.

28. Which of the following BEST represents the field lines due to two equal and opposite charged spheres?

A. 

B. 

C. 

D. 

29. Water in an open container boils at a lower temperature when heated at the top of a mountain than at sea level because at the top of a mountain, the

A. pressure is lower than that at sea level.
B. relative humidity is higher than at sea level.
C. rays from the sun add more heat to the water.
D. temperature is lower than that at sea level.

30. Which of these is most suitable for measuring fluid flow velocity?

A. Open-tube manometer.
B. Mercury barometer.
C. Hydraulic lift.
D. Pitot-static tube.

31. Which of the following is the best condition for a soap bubble to remain intact?

A. The external pressure must be greater than the internal pressure.
B. The internal pressure must be greater than the external pressure.
C. There must be capillary effect and is directed towards the centre.
D. The surface must be held together by gravitational forces.

32. According to the Stefan-Boltzmann law of thermal radiation for a perfect radiator, the rate of radiant energy per unit area is proportional to the

A. temperature of that radiator.
B. square of the temperature of that radiator.
C. cube of the temperature of that radiator.
D. fourth power of the absolute temperature of that radiator.

33. The instrument used in marking the upper fixed point of thermometer is known as
    A. thermometer.
    B. manometer.
    C. spectrometer.
    D. hypsometer.

34. A pair of eyeglasses frame is made of epoxy plastic. At room temperature (20.0 °C), the frame has circular lens holes 2.20 cm in radius. To what temperature must the frame be heated if lenses 2.21 cm in radius are to be inserted in them? The average coefficient of linear expansion for epoxy is $1.30 \times 10^{-4}\ ^{o}C^{-1}$.
    A. 58 °C.
    B. 56 °C.
    C. 55 °C.
    D. 57 °C.

35. Latent heat of vaporization is the amount of heat required to
    A. change phase of a substance from solid to liquid without any change in temperature.
    B. change phase of a substance from liquid to gas without any change in temperature.
    C. raise temperature of a 1 kg of a substance by 1 K.
    D. raise temperature of a substance by 1 K.

36. The temperature of a wire of length 10m is 15°C. If the wire is heated to 65°C, calculate the new length of the wire correct to 3 decimal places.
    A. 10.023 m.
    B. 10.012 m.
    C. 10.050 m.
    D. 10.025 m. [Linear expansivity of the wire is $1.0 \times 10^{-4}\ K^{-1}$]

37. A Carnot engine operates between temperature limits of 473K and 293K. What is its maximum possible efficiency?
    A. 38%
    B. 72%
    C. 90%
    D. 100%

38. When a system expands adiabatically, the work done by the system on its surroundings is
    A. zero.
    B. negative.
    C. constant.
    D. positive.

39. In the electromagnetic spectrum, the highest energy and lowest energy components respectively are:
    A. gamma rays; radio waves.
    B. radio waves; x-rays.
    C. x-rays; microwaves.
    D. microwaves; ultraviolet.

40. I. Rays of light must travel from a less dense medium to a denser medium.
    II. Rays of light must travel from a denser medium to a less dense medium.
    III. The angle of incidence must be greater than the critical angle.

    Which of the statements above is/are condition(s) for total internal reflection to occur?
    A. I & II only.
    B. I & III only.
    C. II & III only.
    D. II only.

41. A man stands 50cm from a concave mirror with radius of curvature 10cm. Find the position and magnification of the image.
    A. 7.55cm, 0.11
    B. 7.89cm, 0.14
    C. 5.56cm, 0.11
    D. 5.56cm, 0.12

42. What is the total charge stored by two 3.5 μF capacitors connected in parallel when a potential difference of 24 V is applied?
    A. 4.20×10^{-6} C.
    B. 1.80×10^{-5}C.
    C. 1.68×10^{-4} C.
    D. 1.20×10^{-4}C.

43. An electric iron is rated 1 kW, 230 V. What is the resistance of its element?

A. 18.9 Ω.

B. 4.3 Ω.

C. 52.9 Ω.

D. 55.9 Ω.

44. Which of the following does not correctly defines dielectric strength? It is the

A. maximum electric field intensity that a pure material can withstand under ideal conditions without breaking down.

B. measure of the electrical strength of an insulator.

C. maximum voltage that can be applied to a given material without causing it to break down.

D. ratio of the permittivity of free space to the permittivity of the dielectric material.

45. A lithium nucleus ${}^{7}_{3}Li$ travelling at 2.0×10^{5} m/s enters a region of uniform magnetic field of flux density 0.10 T. What is the maximum magnetic force experienced by this nucleus?

A. 3.2×10^{-15}N.

B. 2.2×10^{-14} N.

C. 3.2×10^{-14}N.

D. 9.6×10^{-15}N.

46. Two straight parallel conductors carry equal currents in the same direction. The force between them is

A. zero.

B. equal.

C. repulsive.

D. attractive.

47. What resistance is required to convert a galvanometer of internal resistance 10 Ω and full scale deflection of 20 mA to a voltmeter that can measure up to 15 V?

A. 750 Ω.

B. 740 Ω.

C. 200 Ω.

D. 75 Ω.

48. An N-type semiconductor is obtained by doping an intrinsic semiconductor with a
    A. trivalent atom.
    B. tetravalent atom.
    C. pentavalent atom.
    D. monovalent atom.

49. When the forward bias is applied to a junction diode, it
    A. increases the potential barrier.
    B. decreases the potential barrier.
    C. reduces the majority carrier current to zero.
    D. reduces the minority carrier current to zero.

50. For an ultrasound wave, the product of the density of a medium and the speed of the wave in the medium is known as
    A. acoustic impedance.
    B. reactive capacitance.
    C. very high resistance.
    D. power product.

SECTION B: ESSAY QUESTIONS

Answer FOUR Questions in ALL; ONE Question from each Course.

PHY 001: MECHANICS AND PROPERTIES OF MATTER

1. (a) (i) Define the following terms:

Young modulus, Bulk modulus; and Shear modulus. **[3 Marks]**

(ii) Two parallel oppositely directed forces, each 3500 N, are applied tangentially to the upper and lower faces of a cubical metal block 25 cm on a side. Find the angle of shear and displacement of the upper surface relative to the lower surface if the shear modulus for the metal is 80 GPa.

[3 Marks]

(b) An airplane is travelling horizontally at a speed of 60 m/s and drops a crate of emergency supplies. To avoid damage, the maximum vertical speed of the crate on landing is 30 m/s. Assuming air resistance is negligible,

(i) calculate the maximum height of the airplane when the crate is dropped;

(ii) calculate the time taken for the crate to reach the ground from this height.

(iii) If the airplane is travelling at the maximum permitted height, calculate the horizontal distance travelled by the crate after it is released from the airplane.

[4 Marks]

2. (a) Define the following:

(i) terminal velocity, (ii) viscosity, (iii) surface tension. **[3 Marks]**

(b) State the following:

(i) Stokes' law, (ii) law of conservation of angular momentum. **[3 Marks]**

(c) A mass of 2 kg attached to the end of a vertical wire of length 2 m and diameter 2 mm extended the wire by 1 mm. Calculate the

(i) Young's modulus of the wire,

(ii) energy stored in the wire. **[4 Marks]**

3. (a) Define the following terms and state their units:

(i) specific heat capacity **[2 Marks]**

(ii) specific latent heat **[2 Marks]**

(b) A plane progressive wave is represented by the equation $y = 0.3 \sin\left(\frac{20\pi x}{3} + 100\pi t\right)\ m$. Calculate the following:

(i) amplitude; (ii) frequency; (iii) wavelength; (iv) velocity of the wave.

[4 Marks]

(c) The length of a test-tube is 15.0 cm. Calculate the two lowest frequency for the sound emitted when the open end of the tube is blown. Take the speed of sound in air as 330m/s.

[2 Marks]

4. (a) Define the following:

(i) Optical path (ii) Coherent sources **[2 Marks]**

(b) (i) A sound wave has an amplitude of 8.5μm when it is a particular distance away from the source. Calculate the amplitude when this distance is increased by 90%.

(ii) State **TWO** uses of ultrasonics.

[4 Marks]

(c) A parallel beam of sodium light is incident normally on a diffraction grating. The angle between the two first-order spectra on either side of the normal is 38°. If the wavelength of the light is 0.859μm, find the

(i) number of rulings per mm on the grating.

(ii) greatest number of bright images obtained.

[4 Marks]

5. (a) Explain the following terms:

(i) Electric flux (ii) Equipotential surface. **[2 Marks]**

(b) (i) State the condition for resonance in RLC circuits. **[1 Mark]**

(ii) A series RLC circuit with $R = 425\Omega$, $L = 1.25H$, and $C = 3.50\mu F$, is connected to a maximum voltage supply, $V = 150V$, with $\omega = 377\ s^{-1}$. Determine the impedance and maximum current in the circuit.

[5 Marks]

(c) The maximum power dissipated in a $5k\Omega$ resistor is 15W. What is the maximum current?

[2 Marks]

6. (a) Explain the statement: "The capacitance of a capacitor is 5 farads." **[2 Marks]**

(b) A capacitor consisting of 2 parallel plates separated by oil of dielectric constant 1.5, each plate having an effective area of $1000cm^2$ and spaced 0.1cm apart, is connected across a constant voltage source of 5000V. Calculate:

(i) the capacitance of the capacitor, **[1 Mark]**

(ii) the charge of the capacitor, **[1 Mark]**

(iii) the energy stored in the capacitor, and **[1 Mark]**

(iv) If the voltage source was doubled, while the capacitance was kept constant, what would be the new amount of energy stored?

[2 Marks]

(c) Two charges $Q_1 = +200\ \mu C$ and $Q_2 = -100\mu C$ are separated by a distance of 100cm, with Q_1 located at the origin. How much work must be done to transfer a charge $Q_3 = +500\mu C$ from a point x = 80cm to a point x = 20cm?

[3 Marks]

7. (a) (i) State three differences between intrinsic and extrinsic semiconductors. **[3 Marks]**

(ii) Explain the term "doping" in semiconducting material. **[2 Marks]**

(b) (i) State Einstein's photoelectric equation and define the terms in the equation.

[2 Marks]

(ii) Calculate the mass-energy equivalence of a neutron in eV.
(Take 1amu as 1.66×10^{-27}kg; mass of neutron = 1.67493×10^{-27}kg; c = 3×10^{8}m/s, e = 1.6×10^{-19}c).

[3 Marks]

8. (a) (i) State **FOUR** shortcomings of Bohr's atomic theory. **[2 Marks]**

(ii) State any **TWO** properties each of alpha (α), beta (β) and gamma (γ) rays emitted by radioactive atoms. **[3 Marks]**

(b) The wavelength of Balmer first line is 6563 Å. Calculate the wavelength of the second line.

[5 Marks]