Nepal Physical Society

16th Nepal Physics Olympiad (NePhO)-2023/24

[Pre-Selection Test Province Level for IPhO-2024]

NePhO-2023/24 | February 03, 2024
Duration: 3 H 15 m | Maximum Marks:100

INSTRUCTIONS

- This question paper consists of Four (4) pages.
- There are altogether Eleven (11) questions. Section A contains Five (5) short questions and Section B contains Six (6) long questions. Most of them are divided into sub-questions.
- All questions are compulsory. Answer to each question should begin on a new page.
- Permitted materials: a non-programmable, non-graphical calculator, blue and black pens, lead pencils, an eraser, and a ruler.
- A suitable diagram in each question is desirable and ensure that your diagrams are clear and labelled.
- All numerical answers must have correct units and with proper significant figures.
- Marks will not be deducted for incorrect answers but deducted for improper significant figures.

SUGGESTED TIME (3 Hrs. 15 minutes)

Reading Questions and prepare for exam:	15m
Section A: Short Questions Answers types:	36m
Section B: Long Questions Answers types:	144m
Total time:	195m

TABLE OF INFORMATION

Speed of light in vacuum (c)	=	3.00×10^{8} m s^{-1}
Planck's constant (h)	=	6.63×10^{-34} J s
Universal constant of Gravitation (G)	=	6.67×10^{-11} N m^2 kg^{-2}
Acceleration due to gravity (g)	=	9.8 m s^{-2}
Magnitude of the electron charge (e)	=	1.60×10^{-19} C
Permittivity constant (ε_0)	=	8.85×10^{-12} F m^{-1}
Universal Gas Constant (R)	=	8.314 J K^{-1} mol^{-1}
Avogadro's number (N_A)	=	6.023×10^{23} mol^{-1}
Coefficient of volume expansion of diesel	=	9.50×10^{-4}/K
Coefficient of linear expansion for steel truck tank	=	11×10^{-6}/K
Sp. heat capacity of water	=	4200 J kg^{-1} K^{-1}
Sp. heat capacity of Al	=	910 J kg^{-1} K^{-1}
Sp. heat capacity of silver	=	235 J/(kg-K)
Latent heat of fusion of silver	=	105 kJ/kg
Melting point of silver	=	1235 K
Refractive index of glass	=	1.52
Refractive index of diamond	=	2.42
Refractive index of water	=	1.33
Refractive index of oil	=	1.43
Mass of electron me	=	9.11×10^{-31} kg
Mass of proton mp	=	1.67×10^{-27} kg
1 hp	=	746 W
1pc	=	3.26 light years
Hubble constant H_0	=	7.1×10^{4} (m/s)/Mpc.

Section A: Short Questions

QN1. (A) An elevator has mass 600 kg, not including passengers. The elevator is designed to ascend at a constant speed and moves a vertical distance of 20.0 m (five floors) in 16.0 s. It is driven by a motor that can provide up to 40 hp to the elevator. What is the maximum number of passengers that can ride in the elevator? Assume that an average passenger has mass 55.0 kg.

[2.5]

(B) A cricket player hits two identical cricket balls with the same initial speed and from the same initial height but at different initial angles. Show that both balls have the same speed at any height h, if air resistance can be neglected. [2.5]

QN2. (A) An oil truck driver loaded 40000 liters of diesel fuel on a hot day in a city. In another place, where he delivered his entire load, he encountered cold weather; the temperature there was 20.0 K lower than it was in the previous city. How many liters did he deliver? [2.5]

(B) A cylinder contains 10 L of oxygen at 27 ^{o}C and 25 atm. The temperature is raised to 37 ^{o}C, and the volume is reduced to 8.5 L. What is the final pressure of the gas in atmospheres? Assume that the gas is ideal. [2.5]

QN3. (A) An object is placed in front of a converging lens and gives a real image with magnification 5; when the object is moved 6 cm along the axis of the lens a real image of magnification 2 is obtained. What is the focal length of the lens? [2.5]

(B) A ray of light in diamond is incident on an interface with air. What is the largest angle the ray can make with the norma1 and not be totally reflected back into the diamond? [2.5]

QN4. (A) If each of the resistance in the network shown in figure 1 is R, what is the equivalent resistance between terminals A and B. [2.5]

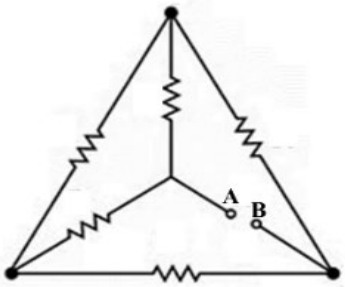


Figure 1: QN4. (A)

(B) Can a charged particle move through a magnetic field without experiencing any force? If not, why not? If so, what is the force? [2.5]

QN5. (A) How many electrons, protons, and neutrons are there in 12 g of $_{6}C^{12}$ and in 14 g of $_{6}C^{14}$?

[2.5]

(B) To fabricate an n-type semiconductor, would you use (i) silicon doped with phosphorus or (ii) germanium doped with aluminum? Explain. The atomic numbers of silicon, germanium, phosphorus, and aluminum are 14, 32, 15, and 13, respectively. [2.5]

Section B: Long Questions

QN6. (A) Two touching bars A and B are placed on an inclined plane forming an angle α with the horizontal (Figure 2). The masses of the bars are equal to m_1 and m_2, and the coefficients of friction between the inclined plane and these bars are equal to k_1 and k_2 respectively, with $k_1 > k_2$. Find:

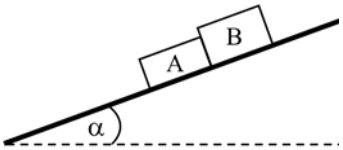


Figure 2: QN6. (A)

(i) the sliding force on the bars in the process of motion;

(ii) the minimum value of the angle α at which the bars start sliding down. [10]

(B) Calculate the work done when one mole of a perfect gas is compressed adiabatically. The initial pressure and volume of the gas are 10^5 N m^{-2} and 6 litres respectively. The final volume of the gas is 2 litres. Molar specific heat of the gas at constant volume is $\frac{3R}{2}$. [5]

QN7. (A) A 0.200-kg frame, when suspended from a coil spring, stretches the spring 0.050 m. A 0.200 kg lump of putty is dropped from rest onto the frame from a height of 30.0 cm as shown in figure 3. Find the maximum distance the frame moves downward from its initial position. [10]

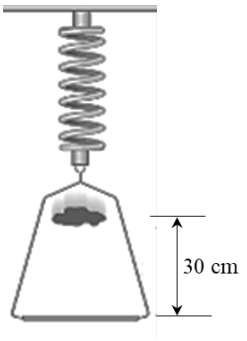


Figure 3: QN7. (A)

(B) Calculate the minimum amount of energy, in joules, required to completely melt 130 g of silver initially at 15 ºC. [5]

QN8. (A) An electrical conductor designed to carry large currents has a circular cross section 2.50 mm in diameter and is 14.0 m long. The resistance between its ends is 0.104 Ω. (i) What is the resistivity of the material? (ii) If the electric-field magnitude in the conductor is 1.28 V m^{-1}, what is the total current? (iii) If the material has 8.5×10^{28} free electrons per cubic meter, find the average drift speed under the conditions of part (ii). [7.5]

(B) A student finds a wire with a resistance of 8 Ω. He melted it and drew it into a wire of half its original length. Calculate the resistance of the new wire. What is the percentage change in its resistance? [5]

QN9. (A) A small lightbulb suspended at distance d_1=250 cm above the surface of the water in a swimming pool where the water depth is d_2 = 200 cm as shown in figure 4. The bottom of the pool is a large plane mirror. How far below the mirror surface is the image of the bulb? You may assume that the rays are close to a vertical axis through the bulb, and the small-angle approximation in which $\sin\theta \approx \tan\theta \approx \theta$. [6.5]

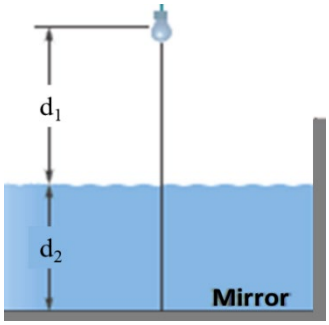


Figure 4: QN9. (A)

(B) A concave shaving mirror has a radius of curvature of 30.0 cm. It is positioned so that the (upright) image of a man's face is 2.50 times the size of the face. How far is the mirror from the face? [3.5]

QN10. (A) As we know, the power P delivered to a resistance R by a current I is given by the relation $P = RI^2$. To check this relation, a student measures the power delivered to an unknown resistance with different currents and listed in Table 1. Plot a graph, including error bars, and decide if this experiment is consistent with the expected proportionality of P and I^2. [7.5]

Table 1: QN10. (A)

Current I (amps) (negligible uncertainty)	Power P (watts) (all ± 70)
1.5	270
2.0	380
2.5	620
3.0	830
3.5	1280
4.0	1600

(B) A physics student measures physical quantities a, b, and c with percentage errors of ±1%, ±2%, and ±3%, respectively, in his novel experiment to find the value of X. These physical quantities, he discovered, are related as $X = \frac{a^2c}{b^3}$. What percentage error will there be in the value of X? [5]

QN11. (A) A hypothetical atom has three energy levels: at 0.00 eV (the ground level), 1.00 eV, and 3.00 eV above the ground level. (i) What are the frequencies and wavelengths of the spectral lines that this atom can emit when excited? (ii) What wavelengths can this atom absorb if it is initially in its ground level? [7]

(B) Using the Hubble Space Telescope, an astrophysicist observed a galaxy and determined that its recession speed was 1.55×10^7 m/s. Find the distance of the galaxy from the earth in meter, according to Hubble law. [3]

**********Good Luck**********