Nepal Physics Olympiad - 2020

NePhO-2020 January 25, 2020
Duration: 3 H 15 m Maximum Marks:100

INSTRUCTIONS

- This question paper consists of **Six**(6) 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 subquestions.
- 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.
- Ensure that your diagrams are clear and labelled.
- All numerical answers must have correct units.
- Marks will not be deducted for incorrect answers.

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: 180 m +15m (195m)

TABLE OF INFORMATION

Speed of light in vacuum (c)	=	$3.00 \times 10^{8}\ ms^{-1}$
Planck's constant (h)	=	$6.63 \times 10^{-34}\ Js$
Universal constant of Gravitation (G)	=	$6.67 \times 10^{-11}\ N\text{-}m^{2}\text{-}kg$
Magnitude of the electron charge (e)	=	$1.60 \times 10^{-19}\ C$
Permittivity constant (ε_0)	=	$8.85 \times 10^{-12}\ F\text{-}m^{-1}$
Permeability constant (μ_0)	=	$4\pi \times 10^{-7}$ Henry-meter $^{-1}$
Universal Gas Constant (R)	=	$8.314\ J\ K^{-1}mol^{-1}$
Avogadro's number (N_A)	=	6.023×10^{23} /mole

[Pre-Selection Test for IphO-2020]

Section A: Short Questions

QN1. A. A point mass of 0.5 kg moving with a constant speed of 5 ms^{-1} on an elliptical track experiences an outward force of 10 N when at either endpoint of the major axis and a similar force of 1.25 N at each end of the minor axis. How long are the axes of the ellipse? (2.5)

B. Why would reducing the mass of a bicycle's wheels be more advantageous to the racer than the same mass reduction in the frame? Explain. Also find the direction of earth's angular momentum vector? (2.5)

QN2. A. A fresh-water one liter bottle is dropped from an airplane at 2 km height and stopped abruptly on the ground. Find the change in temperature of the water assuming the bottle absorbs negligible heat.? (2.5)

B. Each section of a long bridge on a highway (maximum allowed speed is 50 km/h) is 30 m long. How wide should the expansion gaps be to allow for changes in temperatures from -5^0c in winter and 40^0C in summer? Is the gap significant ? Explain. (α for the concrete=4.0 x 10^{-6} $^0C^{-1}$) (2.5)

QN3. A. Consider water droplets on a big "KARKALO" leaf. Assuming the droplets are perfectly spherical having radius of curvature R and a refractive index 1.33, where will the image of the sun form? (2.5)

B. An object to the left of a lens is imaged on a screen 30.0 cm to the right of the lens . When the lens is moved 4.00 cm to its right the screen must be moved 4.00 cm to the left to refocus the image. What is the focal length of the lens? (2.5)

QN4. A. The inner surface of two close parallel insulating plates, each having area A and separated by a distance "x" are charged separately by a uniform charge "+Q". Calculate the energy stored and the force required to hold the plates together. (2.5)

B. Work done in moving a charge along a certain path from point A to point B is Zero? What is the potential difference (P. d.) between those two points? Does this mean that $\vec{E}=0$ every where along the path? Explain. (2.5)

QN5. A. A student wants to measure current through and potential difference (P. d.) across 2Ω resistor**.** How should she connect an Ammeter and a Voltmeter to do this? What resistances should these meters have? (2.5)

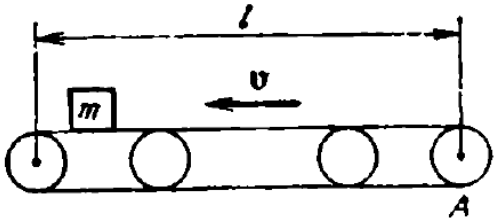
B. How many collisions per second electrons in copper experience if charge carrier density (n) in it is 8.5 x $10^{28}m^{-3}$ and resistivity of Cu is 1.72 x 10^{-8} Ωm. (2.5)

Section B: Long Questions

QN6. A. The masses of two stars are m_1 and m_2 , and their separation is "*l*". Determine the period T of their revolution in circular orbits about a common center. (6.5)

B. An open mery-go-around rotates at an angular velocity ω . A person stands in it at a distance r from the rotational axis. It is raining and the raindrops fall vertically with a velocity $\vec{v}_0$. How should the person hold an umbrella to protect himself from the rain in the best way? (6)

QN7. A. A conveyer belt having a length "*l*" and carrying a block of mass m moves with a velocity v (Fig. a). (i) Determine the velocity v_o with which the block should be pushed against the direction of motion of the conveyer so that the amount of heat liberated as a result of deceleration of the block by the conveyer belt is maximum. (ii) What is the maximum amount of heat Q if the coefficient of friction is μ and the condition $v < \sqrt{2\mu lg}$ is satisfied? (7.5)



(Fig. a)

B. A wire made of a ductile material of density 7.60×10^{-3} kgm^{-3} has an area of cross section 2.50×10^{-7} m^2 and initial length 2.00 m. It is stretched by applying a tensile force to it. The force increases to 48 N. At this value the extension increases from 8.0 mm to 88.0 mm. Calculate

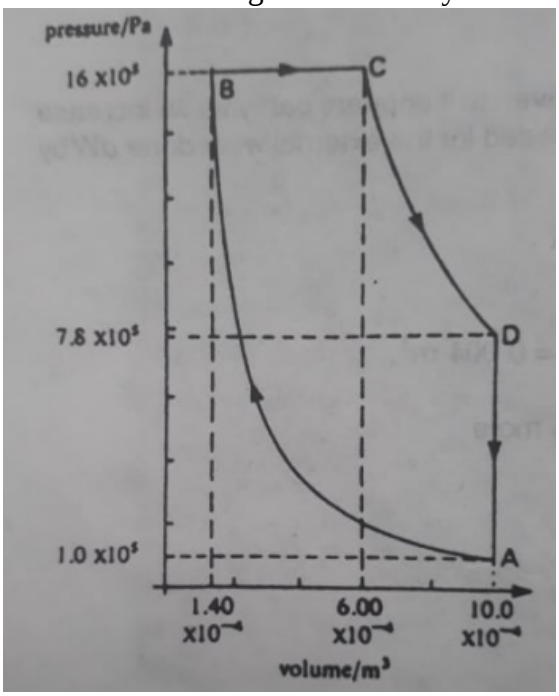
(i) mass of the wire

(ii) the strain in the wire when extension is 8.0 mm

(iii) total work on the wire when extension increases from 0 to 8.0 mm and from 8.0 mm to 88.0 mm. (It is advisable to draw a force vs extension sketch) (5)

QN8. A. A vessel of volume 30 liter contains ideal gas at 0 ^oC . After a portion of the gas has been let out, the pressure in the vessel decreased by ΔP=0.78 atm. at constant temperature. Find the mass of the released gas if density (ρ) of the gas is 1.3 g/*l* at NTP. (5)

B. The gas in the cylinder of a diesel engine can be considered to undergo a cycle of changes in pressure, volume and temperature. For an ideal gas one such cycle is shown in the figure below,



(i) The temperature of the gas at A and at B are 300K and 660K respectively. Find the temperatures at C and D by using ideal gas equation and data from the figure.

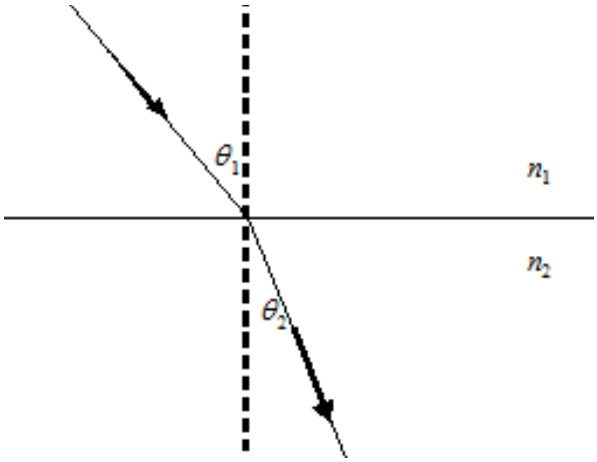
(ii) During each of four sections of the cycle, changes are being made to the internal energy of the gas . Some of the factors affecting these changes are given in the table below

Section of cycle	Heat supplied to gas/J	Work done on gas/J
A to B	0	300
B to C	2580	-740
C to D	0	-440
D to A	-1700	

Explain why the work done on the gas is sometimes negative and find the work done on the gas in section D to A. Calculate the value of increase in internal energy of gas in each section.
(iii) Calculate the total change in internal energy of the gas during complete cycle and net output during a complete cycle. (7.5)

QN9. A. Determine the focal length of a concave mirror if in a certain position of the object the transverse magnification is m_1=0.50 and in another position displaced w. r. t. the former by distance l =5.0 cm the transverse magnification m_2=0.25. The image in both cases are real. (5)

B. If a ray of light traveling from one medium to another , the angle of incidence θ_1 and the angle of refraction θ_2 defined as in figure below, is related to Snell's law as $n_1 \sin\theta_1 = n_2 \sin\theta_2$, where n_1 and n_2 are refractive indices of the respective medium.



The medium 1 is air with n_1 = 1.0 . Result of the several measurements of θ_2 versus θ_1 is listed in table below.

θ_1 ($\pm 0.5^0$) degree	θ_2($\pm 0.5^0$) degree	$\sin\theta_1$	$\sin\theta_2$	n_2
10.0	7.5			
20.0	13.5			
30.0	17.0			
40.0	23.5			
50.0	30.0			

(a) Copy the given table and fill the blank columns using appropriate calculations.

(b) Find the fractional uncertainty in $\sin\theta_1$ and $\sin\theta_2$ in each case;

(c) find the value of mean n_2

(c) Find the fractional uncertainties in n_2 in each case (7.5)

QN10. A. A radioactive substance decays according to the formula $C=C_0\, e^{-\lambda t}$ where C is the count rate at time t, C_0 is the initial count rate and λ is the rate constant. An experimentalist measured the count rate from the sample of radioactive gas which varies with the time as given in table below.

Time (s)	Count rate per second (C/s)	Time(s)	Count rate per second (C/s)
0	86.1	180	9.8
20	67.8	200	8.3
40	52.9	400	3.6
60	45.2	600	2.4
80	33.2	800	2.2
100	24.1	1000	2.6
120	20.1	1200	2.3
140	17.8	1400	2.5
160	13.7	1600	2.4

The count rate from 800s to 1600s are due to background radiation and tells that the gas has become non radiating . Do the following:

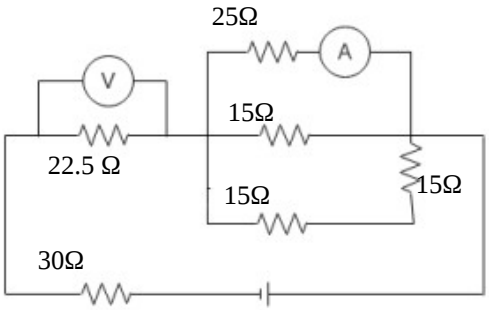
(a) Make a new table with new data set to reflect the linearized formula.

(b) Plot an appropriate linear graph to show the dependence of C on t.

(c) Calculate the slope of the graph and relate it to the rate constant.

(d) Find "y" intercept and relate it to C_o. (7.5)

B. For the circuit shown in the figure below both meters are idealized, the battery has no appreciable internal resistance, and the ammeter reads 0.50 A .



(a) What does the voltmeter read?

(b) What is the emf of the battery? (5)

QN11. A. Calculate the capacitance of an isolated ball-shaped conductor of radius R_1 surrounded by an adjacent concentric layer of dielectric with permittivity (ε) and outer radius R_2. (6.5)

B. Find the interaction force between two copper spheres each of mass 1gm, separated by a distance 1.0 m, if the total number of electron in one sphere is 0.5 % less where as the number of electron in another sphere is 0.5% more than in an electrically neutral copper. (Given atomic mass of the copper is 64 gm/mole and atomic number is 29). (6)

*** ==========Good Luck ==========***