दिसंबर 2024 परीक्षा : DECEMBER 2024 EXAMINATION
1 वर्ष बी.टेक. (सभी शाखाएँ) : I Yr. B.TECH. (ALL BRANCHES)
PH10018/PH10017: PHYSICS

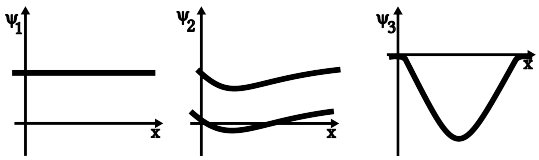
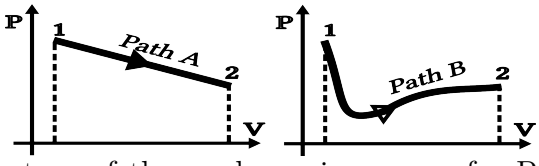
Time : 3 hours Max Marks : 70

इस पेपर में अनुभागों की कुल संख्या - ०५. TOTAL NUMBER OF SECTIONS IN THIS PAPER - 05.

ध्यान दें: गुम डेटा यदि कोई हो, तो उचित रूप से माना जा सकता है।
NOTE: Missing data if any, may be assumed appropriately.

दिया गया:/ Given: $\hbar = 1.054 \times 10^{-34} Js$, $k_B = 1.38 \times 10^{-23} J/K, c = 3 \times 10^8 m/s$.

Q. No. : सवाल/ Question			अंक	CO	BL	PI
1	(a)	Discuss conditions for sustained interference.	2	1	1	1.2
	(b)	Match the following: (p) Division of Amplitude (i) far field approximation (q) Division of Wavefront (ii) Young's double slit (r) Fresnel Diffraction (iii) colored fringes from thinfilms (s) Fraunhofer Diffraction (iv) near field approximation	2	1	3,4	2.1
	(c)	What are Fresnel and Fraunhofer class of diffraction?	3	1	1	2.2
	(d)	(i) Find an expression for diffracted intensity distribution from a N-Slit grating. (ii) Also reduce the expression for intensity distribution when $N = 1$ and $N = 2$ and discuss. या / OR	5+2	1	2,5	1.2
	(e)	(i) As shown in figure, a small metal disc of thickness 5mm is added between lens and glass plate of Newtons Rings setup. When the temperature of the disc is increased the 25th ring moves to the location of 5th ring. Calculate the change in thickness of the metal disc. ($\lambda = 5900$Å)  (ii) Show that the angular distance between a principal maxima of order n and either adjacent minima is given by $\Delta\theta_n = \lambda/(Nd\cos\theta_n)$, where d is grating element.	4+3	1	2-5	2.3
2	(a)	Match the following: (i) Lasers (m) Al_2O_3crystal (j) Optical Fiber (n) Population inversion (k) Ruby laser (o) step-index profile only (l) Single mode fiber (p) Total Internal Reflection	2	2	2,3	
	(b)	Provide a block diagram of Fiber optic communication system and briefly explain all components.	2	2	1	1.1
	(c)	With neat sketch, discuss various light-matter interaction processes.	3	2	2,2	1.3
	(d)	Obtain an expression for relation between Einstein's A and B coefficients. Also, discuss how does it help designing of lasers? या / OR	5+2	2	1,4	2.5
	(e)	(i) A step-index optical fiber has core and cladding refractive indice given by 1.5025 and 1.4975 respectively. Find the numerical aperture and acceptance angle. (ii) If the cladding is replaced with air find the NA and acceptance angle and (iii) discuss the results.	4+2+1	2	1,4,5	2.4
3	(a)	What are postulates of special theory of relativity?	2	3	2	1.2
	(b)	An electron ($m = 0.511$MeV/c^2) and a photon ($m = 0$), both have momentum of 2MeV/c. Find the total energy for each particle in MeV.	2	3	4	1.4

	(c)	Obtain an expression for relativistic length contraction using the Lorentz transformation equations.	3	3	2,3	
	(d)	(i) What is a frame of reference? When will it be called as inertial frame of reference?(ii) The relativistic form of Newton's second law is given as $\vec{F} = \gamma m\vec{a}$. Find an expression for γ.	2+5	3	2,6	2.1
		या / OR				
	(e)	(i) Obtain relativistic relation between mass and energy.(ii) A head on collision between a fast moving proton (p) and antiproton ($\bar{p}$) completely destroys both the particles and generate two new particles t and $\bar{t}$ as given by $p + \bar{p} = t + \bar{t}$ The mass of t or $\bar{t}$ is given by $m_t = 175m_p$. Find the speed of protons just before the collision, if the rest mass of proton is m_p =1GeV/c^2.	3+4	3	2-6	2.2
4	(a)	Briefly discuss on ultraviolet catastrophe.	2	4	3	
	(b)	Using de-Broglie hypothesis, prove that the kinetic energy of a particle is $E = h^2/(2m\lambda^2)$.	2	4	6	1.1
	(c)	Three wavefunctions are shown in the following figure. Find and justify well behaved wavefunction(s). 	3	4	3,4	1.2
	(d)	(i) What do you understand by normalization? Wavefunction for a particle existing in the region $0 \leq x \leq L$, is defined as $\psi(x) = A\sin(\frac{n\pi x}{L})$, find A.(ii) Give your explanation: If photons are particles, why gravity should not pull them downwards on earth?	4+3	4	2,4	1.3
		या / OR				
	(e)	Describe Compton effect. Obtain an expression for the change in wavelength of scattered light in Compton effect. Also discuss on how the results leads to the foundations of quantum mechanics.	2+3+2	4	2,4	2.1
5	(a)	State second law of thermodynamics.	2	5	1	2.1
	(b)	What is a reversed heat engine?	2	5	5	
	(c)	How do you understand the following (i) Free energy (ii) Internal Energy and (iii) Enthalphy.	3	5	2	1.3
	(d)	P-V diagram of two process are shown in figure.  (i) Discuss the nature of thermodynamic process for Path A and B.(ii) Find the workdone in each case and (iii) which process consumes more energy? Why?	3+2+2	5	3-5	2.3
		या / OR				
	(e)	Measured P−V data for an internal combustion engine is given in the following table. Estimate the work.	7	5	2-5	2.4

P(bar)	20.0	16.1	12.2	9.9	6.0	3.1
V (cm^3)	454	540	668	780	1175	1980

CO-Course outcome, BL-Bloom's Taxonomy Level 1-Remember, 2-Understand, 3-Apply, 4-Analyze, 5-Evaluate, 6-Create, PI-Performance Indicator.

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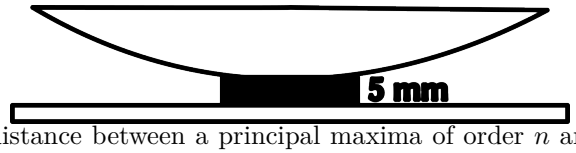
PH10018/PH10017: PHYSICS

ANSWER KEYS and RUBRICS FOR Q. No. 1 Max Marks: 14

Q.No.	Question / Answers / Rubrics	Mark
1a	Discuss conditions for sustained interference.	
	Two coherent sources mentioned	1
	of same wavelength, frequency and amplitude mentioned	1
1b	Match the following:	
	(p) Division of Amplitude (i) far field approximation	
	(q) Division of Wavefront (ii) Young's double slit	
	(r) Fresnel Diffraction (iii) colored fringes from thinfilms	
	(s) Fraunhofer Diffraction (iv) near field approximation	
	(p)→(iii)	½
	(q)→(ii)	½
	(r)→(iv)	½
	(s)→(i)	½
1c	What are Fresnel and Fraunhofer class of diffraction?	
	Fresnel class of diffraction occurs when source to obstacle and observer to obstacle is finite.	1
	Fraunhofer class of diffraction occurs when source to obstacle and observer to obstacle is at infinite.	1
	Pictorial explanation given or use of lens to bring infinite to finite distance mentioned.	1
1d	(i) Find an expression for diffracted intensity distribution from a N-Slit grating. (ii) Also reduce the expression for intensity distribution when $N = 1$ and $N = 2$ and discuss.	
(i)	Ray diagram for N-slit diffraction	2
	Obtained complete derivation and obtained $I = I_0 \frac{\sin^2\beta}{\beta^2} \frac{\sin^2 N\gamma}{\sin^2\gamma}$	2
	Graphical representation of Intensity distribution	1
(ii)	reduction of expression for $N = 1$	1
	reduction of expression for $N = 2$	1
1e	(i) As shown in figure, a small metal disc of thickness 5mm is added between lens and glass plate of Newton's rings setup. When the temperature of the disc is increased the 25th ring moves to the location of 5th ring. Calculate the change in thickness of the metal disc. ($\lambda = 5900$Å)  (ii) Show that the angular distance between a principal maxima of order n and either adjacent minima is given by $\Delta\theta_n = \lambda/(Nd\cos\theta_n)$, where d is grating element.	
(i)	$2\mu t_n = n\lambda$	1
	$2\mu\delta t = p\lambda$	1
	$\delta t = \frac{(25-5)\times 5900\times 10^{-10}}{2\times 1}$	1
	$\delta t = 0.0059$mm or 5.9μm or equivalent	1
(ii)	$d\sin\theta_n = n\lambda$	1
	$d\sin(\theta_n + \Delta\theta_n) - d\sin\theta_n = \lambda/N$	1
	After simplification result obtained / proved.	1

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ANSWER KEYS and RUBRICS FOR Q. No. 2 Max Marks: 14

2a	Match the following: (i) Lasers (m) Al_2O_3 crystal (j) Optical Fiber (n) Population inversion (k) Ruby laser (o) step-index profile only (l) Single mode fiber (p) Total Internal Reflection	
	(i)→(n)	½
	(j)→(p)	½
	(k)→(m)	½
	(l)→(o)	½
2b	Provide a block diagram of Fiber optic communication system and briefly explain all components.	
	Correct block diagram with Source→modulator→OF→demod→reciever.	1
	Discussion on components	1
2c	With neat sketch, discuss various light-matter interaction processes.	
	Sketch for each process	3×½
	Explanation of all three processes	3×½
2d	Obtain an expression for relation between Einstein's A and B coefficients. Also, discuss how does it help designing of lasers?	
	Absorption and emission processes discussed	2
	N_1, N_2, t_{sp}, t, $A - B_{12,21}$ defined properly	1
	Expression for A/B obtained	2
	Relation between N_1, N_2, A, B and population inversion is discussed and explained.	2
2e	(i) A step-index optical fiber has core and cladding refractive indice given by 1.5025 and 1.4975 respectively. Find the numerical aperture and acceptance angle. (ii) If the cladding is replaced with air find the NA and acceptance angle and (iii) discuss the results.	
(i)	$n_1 = 1.5025$ and $n_2 = 1.4975$	1
	NA= $\sqrt{n_1^2 - n_2^2}$	1
	Acceptance angle $= \sin^{-1}(NA/n_0)$	1
	NA=0.122 and acceptance angle=7.013°	1
(ii)	In the absence of cladding $n_1 = 1.5025$ and $n_2 = 1$	1
	NA= $\sqrt{1.5025^2 - 1^2}$=1.1214 > 1	1
(iii)	NA>1, no mode will be guided, no TIR, no guided wave, ...	1

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ANSWER KEYS and RUBRICS FOR Q. No. 3 Max Marks: 14

3a	What are postulates of special theory of relativity?	
	both postulates given	1
	in all inertial frame of reference mentioned	1
3b	An electron ($m = 0.511\text{MeV}/c^2$) and a photon ($m = 0$), both have momentum of $2\text{MeV}/c$. Find the total energy for each particle in MeV.	
	$E = \sqrt{m^2c^4 + p^2c^2}$ and for massless particle $E = pc$ are given	1
	$E(electron) = 2.064\text{MeV}$ and $E(Photon) = 2.00\text{MeV}$, without units 0 marks	1
3c	Obtain an expression for relativistic length contraction using the Lorentz transformation equations.	
	Defined Lorentz transformation equation for x'	1
	Defined $L = x'_2 - x'_1, x'_2$ and x'_1	1
	Showed that $L = L_0\sqrt{1 - v^2/c^2}$. For more details refer to 1.4 of CMP, A Beiser	1
3d	(i) What is a frame of reference? When will it be called as inertial frame of reference?(ii) The relativistic form of Newton's second law is given as $\vec{F} = \gamma m\vec{a}$. Find an expression for γ.	
(i)	A FOR is part of the description of motion where x, y, z, t involves	1
	in i-FOR, Newtons first law holds true	½
	and the body is at rest or moves at constant velocity	½
(ii)	Mentioned Newton's Second law in the form $\vec{F} = \frac{d}{dt}(m(v)\vec{v})$	1
	Mentioned relativistic mass $m(v) = m_0/\sqrt{1 - v^2/c^2}$	1
	After differentiation found $F = m_0a/(1 - v^2/c^2)^{3/2}$	2
	Represented $\gamma = (1 - v^2/c^2)^{-3/2}$	1
3e	(i) Obtain relativistic relation between mass and energy.(ii) A head on collision between a fast moving proton (p) and antiproton ($\bar{p}$) completely destroys both the particles and generate two new particles t and $\bar{t}$ as given by $$p + \bar{p} = t + \bar{t}$$ The mass of t or $\bar{t}$ is given by $m_t = 175m_p$. Find the speed of protons just before the collision, if the rest mass of proton is m_p =1GeV/c^2.	
(i)	Defined $KE = \int_0^s F ds$ and explained	1
	after integration obtained $KE = \frac{m_0c^2}{\sqrt{1-v^2/c^2}} - m_0c^2$	1
	rewritten as $E = E_0 + KE$, where $E = \frac{m_0c^2}{\sqrt{1-v^2/c^2}}$ total energy, $E_0 = m_0c^2$	1
(ii)	Defined $m_p(v) + m_{\bar{p}}(v) = m_t + m_{\bar{t}}$	1
	$2\frac{m_p}{\sqrt{1-v^2/c^2}} = 2m_t$ and $m_t = 175m_p$	1
	After simplification $v = c\sqrt{1 - 1/175^2}$	1
	$v = 0.999\,984c$	1

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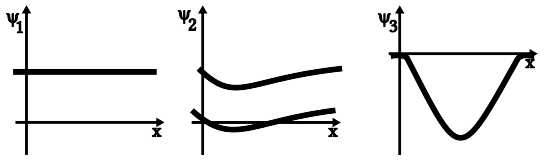
ANSWER KEYS and RUBRICS FOR Q. No. 4 Max Marks: 14

4a	Briefly discuss on ultraviolet catastrophe.	
	Pictorial graph of UV spectrum, I vs ν or I vs λ with T given	1
	Discussions on low frequency / temperature and compare with Rayleigh Jeans theory	1
4b	Using de-Broglie hypothesis, prove that the kinetic energy of a particle is $E = h^2/(2m\lambda^2)$.	2
	$\lambda = h/p$ and $KE = \frac{1}{2}mv^2$ and	1
	$KE = (mv)^2/2m = p^2/2m = h^2/(2m\lambda^2)$	1
4c	Three wavefunctions are shown in the following figure. Find and justify well behaved wavefunction(s). 	3
	ψ_1 is constant and non-zero, is not normalizable. Not a well behaved wave fn.	1
	ψ_2 not a single valued function. Not a well behaved wave fn.	1
	ψ_3 single valued, normalizable. Is a well behaved wave fn.	1
4d	(i) What do you understand by normalization? Wavefunction for a particle existing in the region $0 \le x \le L$, is defined as $\psi(x) = A\sin(\frac{n\pi x}{L})$, find A.(ii) Give your explanation: If photons are particles, why gravity should not pull them downwards on earth?	
(i)	defined $\int_{-\infty}^{\infty} \lvert\psi\rvert^2 dv = 1$	1
	$\int_0^L A^2 \sin^2(\frac{n\pi x}{L})dx = 1$	1
	After solving found $A = \sqrt{2/L}$	2
(ii)	Photons has $m_0 = 0$, or massless particle given	1
	For general discussions	1
	If large masses such as Sun attracts photon, if mentioned	1
4e	(i) Describe Compton effect. (ii) Obtain an expression for the change in wavelength of scattered light in Compton effect. (iii) Also discuss on how the results leads to the foundations of quantum mechanics.	
(i)	With neat sketch Compton effect described	2
(ii)	Obtained expression for $\lambda - \lambda'$ correctly	2
	Graphical results on λ' vs θ given.	1
(iii)	Discussion on the confirmation of particle nature of photon, leading to QM	2

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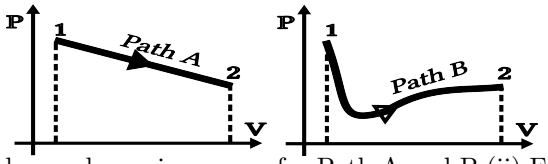
ANSWER KEYS and RUBRICS FOR Q. No. 5 Max Marks: 14

5a	State second law of thermodynamics.	
	Entropy of an isolated system can never decrease with time← or Explanations on the above with ever increasing entropy, or $\Delta S > 0$, etc.	1
	Pictorial representation or PV diagram if given	1
5b	What is a reversed heat engine?	
	Diagram shown for reveresed heat engine	1
	WHAT is reversed? (Not the reversible) explained	1
5c	How do you understand the following (i) Free energy (ii) Internal Energy and (iii) Enthalpy.	3
	From First law explained (mathematically and in words) Helmholtz and/or Gibbs free energy	1
	Internal energy $E = \sum_i E_I^i + E_k^i + E_p^i$, with explanation for each term.	1
	$H = U + pV$, or internal energy + the work under isobaric environment	1
5d	P-V diagram of two process are shown in figure.	3+2+2
		
	(i) Discuss the nature of thermodynamic process for Path A and B.(ii) Find the workdone in each case and (iii) which process consumes more energy? Why?	
(i)	first: Isothermal process, since PV is constant,	1
	second : Isobaric initially and at the end Isochoric process, since V constant initially and P constant later	1
	Temperature/entropy is constant in first process, while it second it is not.	1
(ii)	first: $W = (1/2)(P_1 + P_2)(V_2 - V_1)$; second: $W = \int_{V_1}^{V_2} PdV$	1+1
(iii)	Both path must be same. If explained given from first law/second law.	1+1
5e	Measured P−V data for an internal combustion engine is given in the following table. Estimate the work.	7

P(bar)	20.0	16.1	12.2	9.9	6.0	3.1
V (cm^3)	454	540	668	780	1175	1980

If graphical representation presented with P-V data	2
$W = (1/2)(P_1 + P_2)(V_2 - V_1)$	1
$W_1 = (1/2)(20 + 16.1)(540 - 454)$=1552 or 155.2J	1
$W_2 = 1811, W_3 = 1238, W_4 = 3140, W_5 = 3633,$	1
Total Workdone is $\sum W_i = 11400 = 1140$J	1
after multiplying with 0.1 and unit J is mentioned	1