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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2022

PHSACOR08T-PHYSICS (CC8)

Time Allotted: 2 Hours — Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: $2\times10=20$

(a) Prove the equivalence of the operators, $\frac{\partial}{\partial x}=\frac{\partial}{\partial z}+\frac{\partial}{\partial \bar{z}}$ and $\frac{\partial}{\partial y}=i\left(\frac{\partial}{\partial z}-\frac{\partial}{\partial \bar{z}}\right)$, where $z=x+iy$ and $\bar{z}=x-iy$.

(b) If $u(x,\,y)=2x(1-y)$, find a function $v(x,\,y)$ such that $f(z)=u+iv$ is analytic.

(c) Evaluate $\oint_C \frac{e^z}{(z+4)^4}\,dz$ where C is the circle $|z|=3$ using Cauchy integral formula.

(d) Determine the nature of the singularities of $f(z)=\frac{z\,e^{iz}}{z^2+1}$ and evaluate the residues.

(e) Compute the integration $\int_0^{1+i}(z^2-z)\,dz$ along the line $y=x$.

(f) Show that if $f(x)$ is an odd function then its Fourier transform is always an imaginary function.

(g) Find Fourier transform of $f'(t)=\frac{df}{dt}$ in terms of $\tilde{f}(\omega)$, where $\tilde{f}(\omega)$ is the Fourier transform of $f(t)$.

(h) Find the Fourier transform of the function $f(x)=\delta(x-a)+\delta(x+a)$ where $\delta(x)$ is the Dirac-delta function.

(i) Find the form of Laplace's equation in cylindrical co-ordinate starting from

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}=0$$

(j) For **A**, a $n\times n$ diagonal matrix show that $\det(e^{\mathbf{A}}) = e^{\mathrm{Tr}\mathbf{A}}$.

(k) If two matrices A and B are such that $AB = BA$, show that $AB^{-1} = B^{-1}A$.

(l) If **A** is an antisymmetric matrix and $\mathbf{A}^2 + \mathbf{I} = \mathbf{0}$, then show that **A** is orthogonal.

(m) Show that Hermitian matrix remains Hermitian under similarity transformation.

(n) Show that all the eigenvalues of a Hermitian matrix are real.

2. (a) Show that $\oint_C \frac{dz}{z(z+1)} = \begin{cases} 0 & , \text{ for } R > 1 \\ 2\pi i & , \text{ for } R < 1 \end{cases}$ in which the contour C is the circle defined by $|z| = R$. 3

(b) Show that the Fourier transform $\tilde{f}(k)$ of the function $f(x)$ given by 3

$$f(x) = \begin{cases} 0 & , \quad -\infty < x < -a \\ 1 & , \quad -a < x < a \\ 0 & , \quad a < x < \infty \end{cases}$$

is $\tilde{f}(k) = \sqrt{\frac{2}{\pi}} \frac{\sin ka}{k}$.

(c) Find the eigenvalues and eigenvectors of the Hermitian matrix $\mathbf{H} = \begin{pmatrix} 10 & 3i \\ -3i & 2 \end{pmatrix}$. 2+2

Construct a unitary matrix **U** such that $\mathbf{U}^\dagger \mathbf{H} \mathbf{U} = \mathbf{D}$, where **D** is a real diagonal matrix.

3. (a) Solve the one-dimensional heat equation $\frac{\partial u(x,t)}{\partial t} = \frac{\partial^2 u(x,t)}{\partial t^2}$ subject to boundary conditions $u(0,t) = u(1,t) = 0$ and initial condition $u(x,0) = \sin(\pi x) + \sin(2\pi x)$ for $t > 0$. 3

(b) If inner product between two matrices is defined by $(\mathbf{A}, \mathbf{B}) = \mathbf{Tr}(\mathbf{A}^\dagger \mathbf{B})$ then show that the matrices $\mathbf{A} = \begin{pmatrix} 2 & 4 \\ -1 & 3 \end{pmatrix}$ and $\mathbf{B} = \begin{pmatrix} -3 & 1 \\ 4 & 2 \end{pmatrix}$ are orthogonal. 2

(c) Show that eigenvalues of an anti-Hermitian matrix is either zero or purely imaginary. 2

(d) Show that $\int_0^\infty \frac{e^{-x}}{\sqrt{x}}\, dx = \sqrt{\pi}$. 3

4. (a) Consider a hollow sphere of internal and external radius r_1 and r_2 maintained at temperatures T_1 and T_2 respectively. Find the temperature distribution inside the sphere. At what distance from the center the temperature will be the arithmetic mean of surface temperatures. 4+2

(b) If A and B are two matrices and both commute with their commutator, then show that $\exp(A)\exp(B) = \exp(A + B + \frac{1}{2}[A, B])$. 4

5. (a) The displacement of a damped harmonic oscillator as a function of time is given by 2+2

$$f(t)=\begin{cases}0 & ,\ \text{for } t<0\\ e^{-t/s}\sin(\omega_0 t) & ,\ \text{for } t\geq 0\end{cases}$$

Find the Fourier transform of this function and so give a physical interpretation of Parseval's theorem.

(b) Using Fourier transformation solve the following one dimensional wave equation 4

$$\frac{\partial^2 u}{\partial x^2}=\frac{1}{v^2}\frac{\partial^2 u}{\partial t^2}\ ,\quad u(x,\,0)=f(x)\quad \text{and}\quad \frac{\partial u(x,\,0)}{\partial t}=0$$

(c) If $g(k)$ is the Fourier transform of $f(x)$, then show that $g(-k)=g^*(k)$ is the sufficient and necessary condition for $f(x)$ to be real. 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2022

PHSACOR09T-PHYSICS (CC9)

Time Allotted: 2 Hours | Full Marks: 40

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Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: $2\times10 = 20$

(a) The half-life of a certain excited state is about 8 ns. If this is essentially the uncertainty Δt for photon emission, calculate the uncertainty in frequency $\Delta\nu$, assuming that $\Delta E\Delta t \approx h$. Find $\Delta\nu/\nu$ if the photons have $\lambda = 500$ nm.

(b) Assuming spherical shape of atomic nucleus, show that density of nuclear matter is constant.

(c) Calculate the de Broglie wavelength for a helium atom in a furnace at 400 K for which the kinetic energy is $3kT/2$.

Given $M_{He} = 4.002602$ u

$1\text{u} = 931$ MeV

(d) A muon is travelling through the laboratory at a speed of $3c/5$. How long does it last?

(e) Write down the important characteristics of nuclear force.

(f) Why do not we observe a Compton effect with visible light?

(g) What is a metastable state? What role do such states play in the operation of a laser?

(h) Find the total angular momentum and parity for the ground sate of ${}_{6}C^{13}$ nucleus.

(i) A proton is accelerated in a synchrotron until its kinetic energy is just equal to its rest mass (938 MeV). Find the ratio v/c for this proton.

(j) Derive Rayleigh-Jeans formula from Wien's formula in case of blackbody radiation.

(k) Calculate the binding energy and packing fraction for helium. The atomic masses of proton, neutron and helium are 1.00814 u, 1.00898 u and 4.00387 u respectively. [1u = 931 MeV]

(l) Show that it is impossible for a photon to transfer all its energy to a free electron.

(m) Why is the existence of electron within a nucleus ruled out?

(n) What are the processes by which γ-ray interacts with matter? Mention their Z-dependence.

2. (a) Deduce Planck's radiation law in the form 4+3

$$u_\lambda = \frac{8\pi ch}{\lambda^5} \cdot \frac{1}{e^{ch/\lambda kT} - 1}$$

and show that,

$$u = \int_0^\infty u_\lambda d_\lambda = \frac{8\pi^5 k^4 T^4}{15c^3 h^3}$$

u is energy density of a black body at temperature T K .

(b) When U^{235} captures a slow neutron, it fissions. If the fission products are Rb^{92} and Cs^{140}, how many neutrons are emitted? If the masses of U^{235}, Cs^{140} and Rb^{92} are 234.043915 u, 139.917110 u and 91.919140 u respectively, find the energy released in this particular fission. 3

3. (a) A 5.30 MeV α-particle happens, by chance, to be headed directly towards the nucleus of an atom of gold (Z = 79). How close does it get before it comes momentarily to rest and reverses its course? Neglect recoil of the gold nucleus. 3

(b) (i) Show that the electrostatic potential energy of a uniform sphere of charge Q and radius R is given by $U = 3Q^2/20\pi\varepsilon_0 R$ 3+2+2

(ii) Find the electrostatic potential energy for the nuclide ^{239}Pu, assumed spherical.

(iii) Compare its electrostatic potential energy per particle with its binding energy per nucleon of 7.56 MeV.

4. (a) Mention the postulates of special theory of relativity given by Einstein. 2

(b) Deduce the Lorentz transformations using simple relation between space and time. 4

(c) Find the maximum kinetic energies of photo-electrons ejected from a potassium surface, for which threshold energy is 2.1 eV, by photons of wavelengths 2000Å and 3000Å. What is the threshold frequency γ_0 and the corresponding wavelength? 2+2

5. (a) A cosmic ray photon of energy $h\nu$ is scattered through 90º by an electron initially at rest. The scattered photon has a wavelength twice that of the incident photon. Find the frequency of the incident photon. 2

(b) Establish the relation between the angle of scattered photon and recoil angle of the electron in Compton scattering. Hence find out the recoil angle of the electron in problem 5(a). 3+1

(c) Mention the basic features of nuclear shell model and discuss the significance of magic numbers with respect to stability of nuclei. 2+2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2022

PHSACOR10T-PHYSICS (CC10)

Time Allotted: 2 Hours | Full Marks: 40

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Question No. 1 is compulsory and answer any *two* from the rest

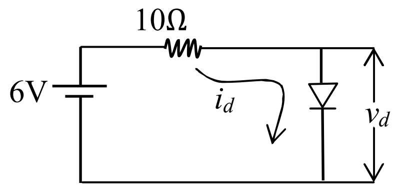
1. Answer any ***ten*** questions from the following: $2\times10=20$

(a) Both N-P-N and P-N-P transistors contain same type of material (either p-type or n-type) at collector and emitter then why we require identifying collector and emitter?

(b) In the given circuit current through diode i_d define as

$$i_d = v_d^2 + v_d \text{ when } v_d > 0$$
$$= 0 \text{ when } v_d = 0$$

here, v_d is the voltage drop across the diode. Find the value of v_d.



(c) Why is h-parameter model circuit is not valid for high frequencies?

(d) Explain why FET is called a "field effect" transistor?

(e) A multistage amplifier employs five stages each of which has a power gain 30. What is the overall gain of the amplifier in dB?

(f) What is load line? Explain its significance.

(g) Draw the ac equivalent circuit of an ideal OPAMP.

(h) An amplifier with open loop voltage gain $A_v = 1000 \pm 100$ is available. It is necessary to have an amplifier where voltage gain varies by not more than $\pm 1\%$. Find the reverse transmission factor β of the feedback network to be used.

(i) What is Schmitt trigger? Name an application of it.

(j) State the Barkhausen criterion for sustaining oscillation in a feedback amplifier and represent it graphically.

(k) Why must a solar cell be operated at the 4th quadrant of its I-V characteristics?

(l) Explain how triangular waveforms can be produced using OP-AMPs.

(m) A Zener diode regulates at 50 V over a range of diode current 5 mA to 40 mA. The supply voltage is 200 V. Find the value of resistance R to allow voltage regulation from a load current 0 A to a Maximum value of load current I_{max}. Find also I_{max}.

(n) Thermal noise in a CE mode circuit is much higher than that in a CB mode circuit. Explain.

2. (a) Explain why the depletion region in FET is wider near the drain and narrower near source? 3

(b) Explain why the gain of a R-C coupled amplifier falls at low and high frequencies? 4

(c) Determine the output voltage of an OPAMP for input voltages v_{i1} = 150 μV, v_{i2} = 140 μV. The amplifier has a differential gain A_d = 4000 and CMRR = 100. 3

3. (a) Draw the circuit diagram of a non-inverting summing amplifier and find its voltage gain. 3

(b) A PNP transistor is used in self biasing arrangement. The circuit components are V_{CC} = 10 V, R_C = 5.2 kΩ, R_1 = 27 kΩ, R_2 = 2.7 kΩ, R_E = 0.27 kΩ, V_{BE} = 0.7 V and β = 49. Find the stability factor and quiescent point. (The variables have their usual meaning) 4

(c) Calculate the ripple percentage of a capacitor filter for a peak rectified voltage of 30 V, the value of capacitor C = 50 μF and a load current of 50 mA. 3

4. (a) Derive the expressions for non-ideal inverting voltage gain and non-inverting voltage gain of an operational amplifier. Hence find the ideal voltage gains also. $1\frac{1}{2}+1\frac{1}{2}+1$

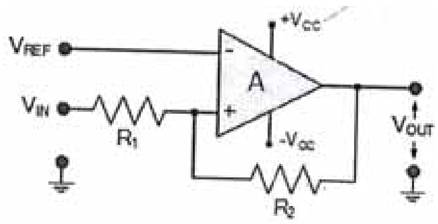
(b) Determine the feedback factor for the RC-phase-shift oscillator using BJT. 3

(c) What is negative feedback in amplifier? Find the effect of negative feedback on distortion. 1+2

5. (a) In a Hartley oscillator the self inductances are L_1 = 100 mH, L_2 = 1 mH and mutual inductance between the coils is 20 mH, Find the frequency of oscillation of the oscillator if the value of capacitance = 20 μF. 3

(b) Find the forward resistance of a Si PN junction diode if the forward current through the diode is 5 mA at Temperature T = 300 K (η for Si = 2). 3

(c) An operational amplifier is to be used with positive feedback to produce a non-inverting comparator circuit. If resistor, R_1 = 10 kΩ and resistor, R_2 = 90 kΩ, what will be the values of the upper and lower switching points of the reference voltage and the width of the hysteresis if the op-amp is connected to a dual ±10 V power supply. 4



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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2021

PHSACOR08T-PHYSICS (CC8)

MATHEMATICAL PHYSICS-III

Time Allotted: 2 Hours | Full Marks: 40

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Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) If $i=\sqrt{-1}$, show that $i^{-2i}=e^{\pi}$.

(b) Show that $f(z)=|z|^2$ satisfies Cauchy-Riemann conditions only at $z=0$.

(c) Show that there are exactly *n* distinct *n*-th roots of z.

(d) Find the residues at the poles of the function $f(z)=\dfrac{z^2+4}{z^3+2z^2+2z}$.

(e) Evaluate $\oint_C (z^4+2z^3+3z^2+4z+5)dz$, where C is a unit circle around $z=0$.

(f) Give reasons whether the Fourier transformation of the following function exists.

$$f(x)=\begin{cases} 1, & \text{if } x \text{ is a rational number} \\ -1, & \text{if } x \text{ is a irrational number} \end{cases}$$

(g) If $F(k)$ is the Fourier transform of $f(x)$ and $G(k)$ is the Fourier transform of $g(x)=f(x+a)$, then show that $G(k)=e^{-iak}F(k)$.

(h) Find the Fourier transform of exponential decay function $e^{-\frac{t}{\tau}}$.

(i) Evaluate the Fourier transformation of $f(x)=(x^2-x+1)\delta(x-1)$. Where $\delta(x)$ is the Dirac-delta distribution.

(j) Show that the scalar potential associated with a vector field which is irrotational and also solenoidal, obeys Laplace's equation.

(k) If ϕ be a function of r only, then show that $\nabla^2\phi = \dfrac{d^2\phi}{dr^2} + \dfrac{2}{r}\dfrac{d\phi}{dr}$.

(l) Show that under similarity transformation the trace of a matrix remains invariant.

(m) If $\boldsymbol{A}$ is non-singular, then show that the eigenvalues of $\boldsymbol{A}^{-1}$ are the reciprocals of those of $\boldsymbol{A}$ and every eigen vectors of $\boldsymbol{A}$ is also an eigen vectors of $\boldsymbol{A}^{-1}$.

(n) Let $\boldsymbol{P}$ be a hermitian matrix with property $\boldsymbol{P}^2 = \boldsymbol{P}$. Show that for any vector $\mathbf{x}$, the vectors $\boldsymbol{P}\mathbf{x}$ and $(1-\boldsymbol{P})\mathbf{x}$ are orthogonal.

2. (a) Find the roots of the equation $z^4 = -256$ and plot the roots in the complex plane. 2

(b) Evaluate $I = \int_0^{2\pi} \dfrac{\cos 2\theta}{a^2 + b^2 - 2ab\cos\theta} d\theta,\ b > a > 0$. 4

(c) If the inner product between two matrices $\boldsymbol{A}$ and $\boldsymbol{B}$ is defined by $(\boldsymbol{A}, \boldsymbol{B}) = \text{Trace}(\boldsymbol{A}^\dagger \boldsymbol{B})$, show that $\boldsymbol{\sigma}_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$ and $\boldsymbol{\sigma}_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$ are orthogonal to each other. Determine the eigenvalues of the matrices $\boldsymbol{\sigma}_1$ and $\boldsymbol{\sigma}_2$. 2+2

3. (a) Find the Laurent series of $f(z) = \dfrac{1}{z(z-2)^3}$ about $z = 0$. 2

(b) For source free region, the electrostatic potential $V(r)$ can be obtained from the solution of Laplace equation, which reads $\nabla^2 V = 0$. A unit disk $(r \le 1)$ has no source of charge on it. The potential on the rim $(r = 1)$ is given by $2\sin 4\theta$, where θ is the polar angle. Obtain an expression for potential inside the disk. 4

(c) Verify Caley-Hamiltonian theorem for the matrix $\boldsymbol{A} = \begin{pmatrix} 4 & 2 \\ 1 & 3 \end{pmatrix}$, and hence find $\boldsymbol{A}^{-1}$. 4

4. (a) Find the Fourier transformation of $f(t) = e^{-|t|}$, and hence using inversion, deduce that $\int_0^\infty \dfrac{dx}{1+x^2} = \dfrac{\pi}{2}$. 3

(b) The Gaussian distribution centred on $t = 0$ with root mean square deviation $\Delta t = \tau$ is given by $f(t) = \dfrac{1}{\tau\sqrt{2\pi}} \exp\left(-\dfrac{t^2}{2\tau^2}\right)$, $t \in (-\infty, \infty)$. If $\tilde{f}(\omega\}$ is the Fourier transformation of $f(t)$ with the Kernel $\dfrac{1}{\sqrt{2\pi}} e^{-i\omega t}$, show that $\Delta\omega\Delta t = 1$. 3

(c) If $z = x + iy$, show that the complex valued function $f(z) = |x| - i|y|$ is analytic, only in the second and fourth quadrants. 4

5. (a) For a spherically symmetric function $f(\mathbf{r}) = f(r)$ in three dimensions find the Fourier transform of $f(\mathbf{r})$ as a one-dimensional integral. 4

(b) A complex function $g(w)$ is define as 4

$$g(w) = \oint_C \frac{z^3 + 2z}{(z-w)^3}\, dz\,.$$

show that $g(w) = 6\pi i w$, when w is inside the contour C.

(c) Show that if $\boldsymbol{A}$ and $\boldsymbol{B}$ are two similar matrices related through the non-singular matrix $\boldsymbol{S}$ as $\boldsymbol{B} = \boldsymbol{S}^{-1}\boldsymbol{A}\boldsymbol{S}$, then $\boldsymbol{A}$ and $\boldsymbol{B}$ have same set of eigenvalues. 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2021

PHSACOR09T-PHYSICS (CC9)

Time Allotted: 2 Hours | Full Marks: 40

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Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) Discuss Heisenberg's uncertainty principle as a consequence of wave-particle duality.

(b) A hydrogen atom is 5.3×10^{-11} m in radius. Use the uncertainty principle to estimate the minimum energy an electron can have in this atom.

(c) Compare the wavelengths of an electron (m_e) and a muon (m_μ) each with kinetic energy 15 keV. Given, $m_\mu = 207 m_e$

(d) 'Although the efficiency of a four level laser is less than that of a three level laser, still the four level laser is better than the three level laser.' Why?

(e) Compute the coherence length of yellow light with 5893Å in 10^{-12} second pulse duration. Find also the bandwidth.

(f) Write down the important characteristics of nuclear force.

(g) Assuming spherical shape of atomic nucleus, show that density of nuclear matter is constant.

(h) When light of a given wavelength is incident on a metallic surface, the stopping potential for the photoelectrons is 3.2 V. If a second light source whose wavelength is double that of the first is used, the stopping potential drops to 0.8 V. Find the cut off frequency of the metal. (Given, Speed of light in vacuum $c = 3\times 10^{8}$ m/s and charge of an electron $e = 1.6\times 10^{-16}$ C).

(i) A muon is travelling through the laboratory at a speed of $(3/5)c$. How long does it last?

(j) A 45 kW antenna emits radio waves at a frequency of 4 MHz. How many photons are emitted per second? (Given, Planck constant $h = 6.63\times 10^{-34}$ Js)

(k) The Davisson-Germer experiment that first demonstrate the wave nature of matter used non relativistic electrons accelerated to 54 V. Determine the energy of the electrons in joules. Also calculate the speed of the electrons moving in this experiment.

(l) Ra-226 decays by α-particle emission with $T_{1/2} = 1590$ years and produces radon. Calculate the volume of radon at STP evolved from 1g of radium in 50 years.

(m) Write down some points of resemblance between the nucleus of an atom and a liquid drop.

(n) What is space-time interval? What is the value of space-time interval when two events can be connected with a light signal only?

2. (a) Explain the difference between group velocity and phase (wave) velocity. Which of these is associated with the particle velocity? The velocity of ocean waves is $u = \sqrt{\frac{g\lambda}{2\pi}}$, where g is the acceleration due to gravity and λ is the wavelength. Find the group velocity of ocean waves. 2+1+2

(b) An electron has a de Broglie wavelength of 2×10^{-12} m. Find its kinetic energy, group and phase velocities (given, rest mass energy of electron = 511 keV, Planck constant $h = 4.136\times10^{-15}$ eV/s, velocity of light in air $c = 3\times10^{8}$ m/s). 2+2+1

3. (a) What is 4-momentum? Write down the conservation law of 4-momentum. 3

(b) Draw the β-decay energy spectrum and describe the necessity of existence of a new particle to explain the discrepancies in the spectrum. 4

(c) A particle of rest mass M_1 decays into a particle of rest mass m_2 and a photon. What are the 4-momenta of the decaying particle and produced particle in their respective rest frames? In the rest frame of the produced particle what is the energy E_γ of the photon in terms of M_1, m_2 and the speed of light in vacuum c? 3

4. (a) Using semi-empirical mass formula show that α-decay can occur only for nuclei with mass number, $A > 160$. [Given that $a_1 = 0.016919\text{u}$, $a_2 = 0.019114\text{u}$, $a_3 = 0.0007626\text{u}$, $a_4 = 0.02544\text{u}$, $a_5 = 0.036\text{u}$, $E_B({}^4_2\text{He}) = 28.3\,\text{MeV}$] 4

(b) Show that for a normal optical source with temperature about 10^3K and wavelength 6000Å, the emission is predominantly due to spontaneous transitions. 3

(c) Event A happens at point $(x_A = 5, y_A = 3, z_A = 0)$ and at time t_A given by $ct_A = 15$; event B occurs at (10, 8, 0) and $ct_B = 5$. Both in system S. 3

(i) What is the invariant interval between A and B?

(ii) Is there an inertial system in which they occur simultaneously? If so, find its velocity relative to S.

(iii) Is there an inertial system in which they occur at the same point? If so, find its velocity relative to S.

5. (a) Find the total angular momentum and parity for the ground state of ${}_{16}S^{33}$ and ${}_{6}C^{13}$ nuclei. 2+2

(b) Derive Rayleigh-Jeans' formula from Wien's formula in case of blackbody radiation. 2

(c) A blackbody of surface area 1cm^2 is placed inside an encloser. The encloser has a constant temperature 27ºC and the blackbody is maintained at 327ºC by heating it electrically. What electric power is needed to maintain the temperature? 2

[Given $\sigma = 6.0\times10^{-8}\,\text{Wm}^{-2}\text{K}^{-4}$]

(d) Discuss Wilson-Sommerfeld quantization rule. 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2021

PHSACOR10T-PHYSICS (CC10)

Time Allotted: 2 Hours Full Marks: 40

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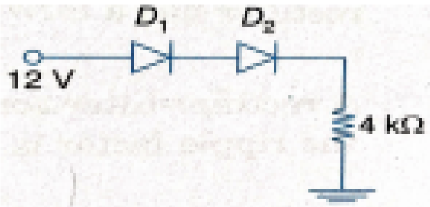
Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: $2\times10 = 20$

(a) The forbidden energy gap in a direct band gap semiconductor is 1.43 eV. Determine the wavelength of radiation emitted when a conduction band electron makes a direct recombination with a valance band hole.

(b) A current of 2.75 mA flows through the circuit given below:



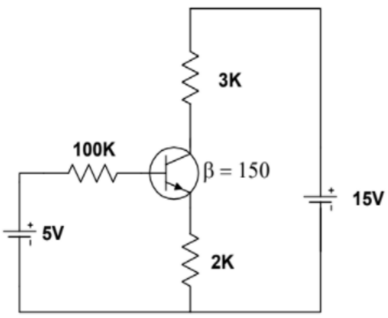
If the power dissipation of D_1 is 0.825 mW then find the voltage drop and power dissipation of D_2.

(c) Why do Si or Ge diode not emit light but GaAs diodes do?

(d) Establish the relation $I_D = \left(\frac{g_m^2 V_P^2}{4I_{DSS}}\right)$ for a FET. Where I_D is drain current, V_P is pinch-off voltage, and g_m is trans-conductance of the FET, I_{DSS} is shorted-gate drain current.

(e) Write down the advantages and disadvantages of Bridge rectifier over centre-tap rectifier.

(f) Silicon transistor with β = 150, V_{BE} = 0.7 V, I_{CO} = 30 nA is shown in the figure below. Find the values of I_C, I_E, I_B, V_{CE}.



(g) On which factors does biasing of a transistor depend?

(h) What are the leakage currents of a transistor and how they are related?

(i) Write an n channel FET has the ratio of drain current and I_{DSS} is 1:4 and $V_{GS} = -3$ Volt. Find the pinch-off voltage (V_p).

(j) Draw input-output characteristics of an OPAMP. Explain why it saturates after a certain voltage?

(k) A 4-bit R-2R D/A converter have its output voltage 5 V. Find its resolution percentage.

(l) Find the maximum frequency of operation of an OPAMP if the peak input voltage is 1.5 V and slew rate 0.89 V/μs.

(m) Oscillators are not given any ac input then where from ac comes at the output? Explain how it is achieved?

(n) What is positive feedback in an amplifier? Write two advantages of positive feedback.

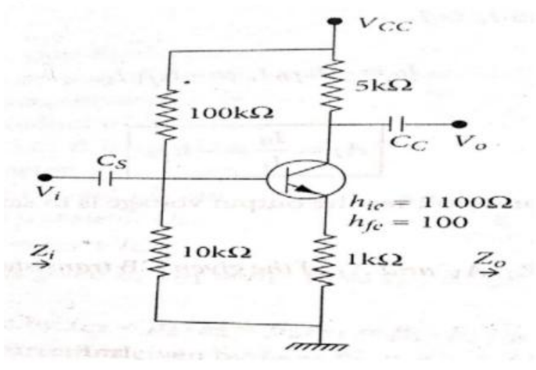
2. (a) The effective barrier voltage of a abrupt p-n junction is given by $V_T = \dfrac{eN_d}{2\varepsilon} W^2$ where N_d is the donor concentration and W the junction width. Find the transition capacitance of the junction if junction area is A. 3

(b) Draw the bridge rectifier with c-filter circuit and output voltage waveform. Explain it. 2+2

(c) How negative feedback improves bandwidth of an R-C coupled amplifier? 3

3. (a) Explain with circuit diagram the self or emitter bias of transistor amplifier. Determine the stability factor for this type of transistor biasing. 2+2

(b) Given a CE amplifier. Find Current gain, Voltage gain, Input impedance and Output impedance. 4



(c) Draw the frequency response of a practical OPAMP integrator and explain it. 2

4. (a) Why an offset voltage appears at the output of an OPAMP? How it can be eliminated? 4

(b) Derive an expression to show the effect of negative feedback on voltage gain in an amplifier. 3

(c) An amplifier with negative feedback has a voltage gain of 50. It is found that without feedback, an input signal of 60 mV is required to produce a given output; whereas with feedback, the input signal must be 0.3 V for the same output. Calculate the open-loop voltage gain (A) and feedback factor (β). 1+2

5. (a) Briefly describe the working principle of Schmidt trigger circuit using OP-AMP. Calculate the hysteresis voltage and draw the transfer characteristics for increasing and decreasing of output voltage. 1+2+2

(b) What do you mean by 3dB frequencies of an R-C coupled amplifier and why they are so called? Show that Gain Bandwidth product of the amplifier is constant. 2+3

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West Bengal State University Barasat, N 24 Pgs
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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2020

PHSACOR08T-PHYSICS (CC8)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) If $z=x+iy$, show that $|\sin z|^2=\sin^2 x+\sinh^2 y$.

(b) Evaluate $\oint f(z)dz$ for $f(z)=1/z$ along the circle of radius R centred at origin.

(c) Show that $f(z)=\sin z/z$ has a removable singularity at $z=0$.

(d) Find the branch points of $f(z)=\sqrt{(z^2+1)}$.

(e) $f(z)=u(x,y)+iv(x,y)$ is analytic where $u=x^2-y^2$. Find v.

(f) Prove that if $f(x)$ is periodic with period a then Fourier transform $\tilde{f}(k)=0$ unless $ka=2\pi n$ for n being an integer.

(g) If Fourier transform of $f(x)$ is $g(s)$, then show that Fourier transform of $f(x)\cos ax$ is $\frac{1}{2}[g(a+s)+g(a-s)]$.

(h) Find Fourier transform of a Dirac delta function $f(x)=\delta(x-b)$, b being some constant.

(i) What kind of boundary condition do you need for unique solution of Laplace equation in a bound smooth domain?

(j) Show that real and imaginary parts of an analytic complex function individually satisfy Laplace's equation in two dimensions.

(k) For a 2 × 2 square matrix A find its eigenvalues in terms of t and d, given $\mathrm{Tr}(A)=t$ and $\det(A)=d$.

(l) Prove that the product of two Hermitian matrices is Hermitian if and only if they commute.

(m) Find eigenvalues of matrix $\boldsymbol{R}=\begin{pmatrix}\cos\theta & \sin\theta\\ -\sin\theta & \cos\theta\end{pmatrix}$.

(n) Pauli spin matrix σ_x is conventionally written as, $\sigma_x=\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}$. Find $\sin\alpha\sigma_x$, α being a constant.

2. (a) State with justification, whether or not the function $f(z)=Re(z)=x$ is analytic. Find the Laurent Series of $f(z)=\dfrac{1}{z(z-2)^3}$ about the singularity $z=2$ and find the residue of $f(z)$ at $z=2$. 1+2+1

(b) Solve using Fourier Transform $\frac{d^2\phi}{dx^2} - m^2\phi = f(x)$, in terms of an integral, m being some constant. 2

(c) Verify Caley-Hamilton theorem for the matrix $\boldsymbol{A} = \begin{pmatrix} 5 & 4 \\ 1 & 2 \end{pmatrix}$, and hence find $\boldsymbol{A}^{-1}$. 2+2

3. (a) Expand $f(z) = \frac{1}{z(z-1)}$ in a Laurent series valid for $1 < |z-2| < 2$. 2

(b) In physical optics, Fraunhofer diffraction pattern is given by Fourier transform of the aperture function. Suppose the aperture function (for a single slit), 2+2

$$f(x) = \begin{cases} 1, & |x| < a, \\ 0, & |x| > a, \end{cases}$$

Calculate $F(t)$, the amplitude of the diffraction pattern. Use Parseval relation to calculate

$$\int_{-\infty}^{\infty} \frac{\sin^2 t}{t^2}\, dt\,.$$

(c) An uncharged conducting sphere of radius R is placed in a uniform electrostatic field $\vec{E} = E_0\hat{k}$. Find the potential outside the sphere using solution of Laplace's equation in spherical polar coordinates. 4

4. (a) Evaluate the following integral, 3

$$I = \oint_C \frac{z+1}{z^4 + 2iz^3}\, dz\,,$$

where C is the circle $|z| = 1$.

(b) What is meant by the Fourier transform of a function $f(x)$? Show that under complex conjugation Fourier transform of a real function $f(x)$ satisfies $\tilde{f}(-k) = [\tilde{f}(k)]^*$. 1+2

(c) Solve one dimensional heat equation, 4

$$\frac{\partial u(x,\, t)}{\partial t} = \frac{\partial^2 u(x,\, t)}{\partial x^2}\,,$$

for $t > 0$ and $u(x, 0) = \delta(x)$.

5. (a) Evaluate the integral 3

$$I = \int_0^{2\pi} \frac{\mathrm{d}\theta}{5 + 4\cos\theta}$$

(b) Find the eigenvalues of $\boldsymbol{H} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 2 \end{pmatrix}$. 3+4

Also show that its diagonalizing matrix (which makes it diagonal by similarity transformation) can be chosen to be orthogonal.

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2020

PHSACOR09T-PHYSICS (CC9)

Time Allotted: 2 Hours Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No.1 is compulsory and answer any *two* from the rest.

1. Answer any ***ten*** questions from the following: 2×10=20

(a) Determine the velocity at which a particle has to move so that the relativistic mass of the particle is twice its rest mass.

(b) Show that $x^2 + y^2 + z^2 - c^2t^2$ is invariant under Lorentz transformation. Symbols are of usual significance.

(c) A civil engineer measures a street to be $L = 100$ m long in Earth frame (assumed to be an inertial frame). Use the Lorentz transformation to obtain an expression for its length measured from a spaceship S', moving at a speed 0.20c in a direction parallel to the street.

(d) Write down the Rayleigh-Jeans formula for classical blackbody radiation, explaining each term. Demonstrate "ultraviolet catastrophe" from the formula.

(e) Write down the expression of the change in wavelength of the scattered light in case of Compton scattering in terms of the mass of the scatterer and fundamental constants. Find the value of the maximum change.

(f) Using the principle of uncertainty find out the minimum energy of a particle of mass *m* confined in a small cube of length *a*.

(g) Using De Broglie formulation, show that the group velocity of a wave packet corresponding to a particle is equal to the velocity of the particle.

(h) If a certain metal with a work function of $W = 2.5$ eV is illuminated by a monochromatic light of wavelength 3500 Å. What is the maximum kinetic energy of the electrons ejected in the photoelectric effect?

(Given, Planck constant $h = 6.63\times10^{-34}$ Js, speed of light in vacuum $c = 3\times10^{8}$ m/s, charge of an electron $e = 1.6\times10^{-19}$ C).

(i) An excited atom radiates energy of a characteristic frequency and comes down to the ground state. If the average time gap between the excitation of the atom and the time it radiates is 1×10^{-8} s then estimate the inherent uncertainty in the frequency of the emitted radiation.

(j) Define four velocity and express its relation with three velocity.

(k) Is the reaction $p \rightarrow n + e^{+} + \bar{\nu}_e$ possible? Give reasons.

(l) Why are the α-particles, rather than protons and neutrons, emitted from radioactive nuclei?

(m) Sketch schematically the N-Z plot where N is the neutron number and Z is the atomic number. Briefly explain the significance of the plot.

(n) Find out the relation between the mean life time and half life time of a radioactive decay.

2. (a) Show that it is impossible for a photon to transfer all its energy to a free electron. 2

(b) Show that the de Broglie wavelength of a particle of rest mass m_0 and kinetic energy T is given by the relativistic formula $\lambda = \dfrac{hc}{\sqrt{T^2 + 2m_0c^2T}}$. 3

(c) A charged π-meson (rest mass = $273m_e$) at rest decays into a muon (rest mass = $207m_e$) and a neutrino (zero rest mass), where m_e denotes the rest mass of electron. What is the energy of the emitted neutrino? 3

(d) A system has only two possible non-degenerate energy levels E_1 and E_2. The system is in equilibrium at a temperature T and $p(E)$ is the probability that the system is at an energy E. Show that $p(E_2) = \dfrac{1}{1 + \exp\left(\dfrac{\Delta E}{k_B T}\right)}$, where $\Delta E = E_2 - E_1$. 2

3. (a) Energy required to dislodge a bound electron from sodium is 2.3 eV. Calculate the threshold wavelength of the light for the photoelectric effect to occur. How long the light is to be shined on the surface of the metal to observe the photoelectrons? 2+1

(b) If the position of a quantum particle is located using a gamma ray microscope then deduce the relation between the uncertainties in position and momentum of the particle. 4

(c) What is the probabilistic interpretation of wave function associated with a particle? If the wave function of a particle is given by $\psi(x) = A\exp(ikx)$, show that its momentum is exactly known but its position is completely uncertain. 1+2

4. (a) An incandescent lamp is operating at a temperature of 1000 K at an operating frequency of 5.2×10^{14} Hz. Calculate the ratio of stimulated emission rate to spontaneous emission rate. Value of $h = 6.63\times10^{-34}$ Js and $k_B = 1.38\times10^{-23}$ JK^{-1}. 2

(b) Calculate the mass of 1 Curie of ^{234}U. Half life of ^{234}U is 245,000 years. 2

(c) Why is the existence of electron within a nucleus ruled out? 2

(d) Explain how the neutrino hypothesis solves the apparent breakdown of conservation of energy and momentum in beta decay. 2

(e) 'Although the efficiency of a four level laser is less than that of a three level laser, still a four level laser is better than a three level laser.' — Why? 2

5. (a) How long does it take for 60% of a sample of radon to decay? Given that the half life of radon is 3.8 days. 3

(b) Draw schematically the nuclear binding energy curve. Hence explain nuclear fission and fusion. 1+4

(c) What is the need of moderators in a nuclear reactor? 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 4th Semester Examination, 2020

PHSACOR10T-PHYSICS (CC10)

Time Allotted: 2 Hours — Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) How the slew rate of an OPAMP is related to the maximum operating frequency of an OPAMP?

(b) Distinguish between Zener breakdown and avalanche breakdown.

(c) Draw the circuit diagram of an emitter follower and state one of its use.

(d) Draw the energy band diagrams for intrinsic and *p*-type semiconductors.

(e) What is the Barkhausen criterion for a feedback amplifier to function as an oscillator?

(f) A differential amplifier has difference mode gain $A_d = 5000$ and CMRR = 1000. Find the output voltage for inputs $v_1 = 200\ \mu\text{V}$ and $v_2 = 190\ \mu\text{V}$.

(g) What are the fundamental differences between class A and class C amplifiers?

(h) Establish $\mu = r_p \times g_m$ for a JFET.

(i) Find the bandwidth of an inverting OPAMP with $R_1 = 1\ \text{k}\Omega$, $R_2 = 15\ \text{k}\Omega$. Assume that the unity gain bandwidth of the OPAMP is 3.

(j) Draw a circuit diagram of a D/A converter using R-2R.

(k) Establish the relation $I_C = (1+\beta)I_{CBO} + \beta I_B$ for a BJT.

(l) Write down the approximate drops of voltages across an LED and a Si-diode respectively when they are forward biased at room temperature.

(m) A capacitor of $0.1\mu\text{F}$ is charged to 10 V and then discharged through a resistance $1\ \text{M}\Omega$. Calculate time required by the capacitor to reach 5 V.

(n) Two capacitors $1\ \mu\text{F}$ and $9\ \mu\text{F}$ are connected in series with a 10 V AC source. Calculate the voltage drops across the respective capacitors.

2. (a) Write down the relation among barrier potential, doping concentrations and intrinsic carrier concentration for a *p-n* junction diode. Explain the statement: "The barrier potential across a *p-n* junction diode cannot be measured directly by connecting a voltmeter across the *p-n* junction." 1+2

(b) What do you mean by load line and the Q-point of a semiconductor diode circuit? Explain with suitable diagram. 2+1

(c) Draw a circuit diagram of a full wave bridge rectifier using semiconductor diodes. Why one should prefer a bridge rectifier over a full wave rectifier using centre tap transformer? 2+2

3. (a) A phase shift oscillator uses OPAMP as amplifying element. Find the capacitance of the capacitor used in the RC network employed in the oscillator, if the frequency of oscillation is 10 kHz and $R = 100$ kΩ. 3

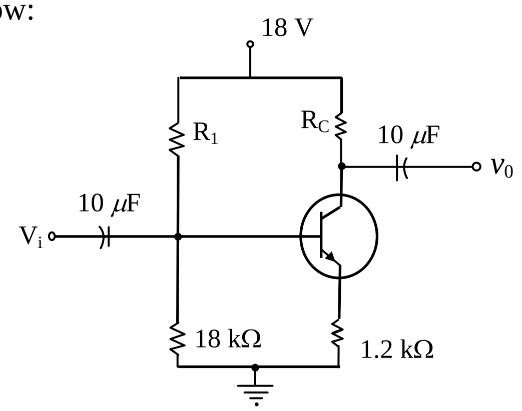
(b) Design a non-inverting amplifier of gain 5 using an ideal OPAMP. Draw the necessary circuit diagram. 2+1

(c) Draw the circuit diagram of a Wien-bridge oscillator with output frequency 500 Hz, choosing suitable circuit elements and identify the feedback mechanisms in this case. 2+2

4. (a) Draw the output characteristics of an *n-p-n* transistor in CE and CC modes respectively, labelling different regions of operations. 3+3

(b) What is JFET? An *n*-channel Si (having dielectric constant 12) JFET with a channel width 0.06 cm is doped with a concentration $N_d = 10^{21}\,\text{m}^{-3}$. Find the pinch off voltage. 1+3

5. (a) Given $I_{CQ} = 2\,\text{mA}$ and $V_{CEQ} = 10\ \text{V}$, determine R_1 and R_C for the *n-p-n* transistor circuit given below: 2+2



(b) Draw a labelled circuit diagram of a two stage R-C coupled amplifier. Find the mid frequency gain of the amplifier with the help of an ac equivalent circuit. Explain why gain falls at high frequencies. 1+3+2

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