**Indian Association for the Cultivation of Science**
**(Deemed to be University under the *de novo* Category)**

***Integrated Bachelor's-Master's Program in Science-2018***
***END-Semester Examination-2018 (Semester- I)***

***Subject: Biology (Life & Light)*** ***Subject Code(s): BIS1101***

***Full Marks: 50*** ***Time Allotted: 3 h***

## PART-A (Answer all the questions)

1. What are antenna molecules? Clorophyll is the primary pigment for light reaction, what are the accessory pigments? What is their role in photosynthesis? [1+1+1]

2. What are the difference between photosynthesis I and photosynthesis II processes? Explain the Z scheme Light reactions (photosynthesis). [2 +2]

3. Draw the Jablonski diagram for photophysical pathways. What is the difference between singlet and triplet excited states? What is the relation between fluorescence quantum yield with rate constant of unimolecular photophysical processes? [1+1+2]

4. What is the Fluorescence resonance energy transfer (FRET)? Write the rate of energy transfer and explain all the terms. Give the expression of The Förster distance ($R_0$) with explaining the terms. In which condition the distance between donor and acceptor is equal to $R_0$? [1+1+1+1]

5. Write the chemical structures of Ribose and 2-deoxyribose? How nucleotide is formed? Give chemical structure of a nucleotide. [1+1+1]

6. Why solar ultraviolet (UV) light is harmful for body? What would the product when two molecules of DNA base thymine react in presence of light? What is the photoaddition product of Cysteine (in protein) to thymine (in DNA) in presence of light? [1+1+1]

7. What is the basic mechanism of photodynamic therapy? What kind of cellular processes occur during (a) DNA replication and (b) protein conformational changes? [2+1+1]



0,1,2,3,4

**PART-B (Answer all the questions)**

8. Write a chemical equation summing up the processes occurring in the light reaction of photosynthesis. [2]

9. Explain how a pH gradient is generated across the *thylakoid* membrane in the light reaction. What is photophosphorylation, and what is its driving force? What drives water molecules to split as $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ in light reaction? [2+1+1+2]

10. What are the primary electron acceptors at the reaction centers of PS I and PS II? How are the electrons released in PS-II transferred to PS-I? [2+2]

11. Draw the structure of the photo-receptor molecule in the rod cell of the retina. What chemical change is induced in the photoreceptor upon light absorption? How does this chemical change induce the visual signal? How do the photoreceptors in the cone cells distinguish colours? [2+2+1+2]

12. Write chemical names and draw structures of two major Vitamin D molecules. How is vitamin $D_3$ produced photochemically in our skin? What is the bio-active form of vitamin $D_3$, and how is it produced? [2+2+1+1]

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Splitting

Split.

9. What is Parallax error? How it is eliminated?

10. What is dispersive power of prism? A ray of white light, incident upon a glass prism, is dispersed into its various color components. Which one of the following colors experiences the greatest amount of refraction?

(a) orange (b) violet (c) red (d) green

11. Explain Thevenin's and Norton's theorem. Are they also valid if the capacitive elements are used instead resistors?

12. The Fourier expression for a "sawtooth wave" can be represented by the following periodic function,

$$f(t) = 2\left(\frac{\sin \pi t}{1} - \frac{\sin 2\pi t}{2} + \frac{\sin 3\pi t}{3} - \frac{\sin 4\pi t}{4} + \frac{\sin 5\pi t}{5} - \ldots\right)$$

(a) What is the frequency of the sawtooth wave described by the expression above?

(b) Sketch the Fourier spectrum for this wave, including frequencies up to 5$^{th}$ harmonics.

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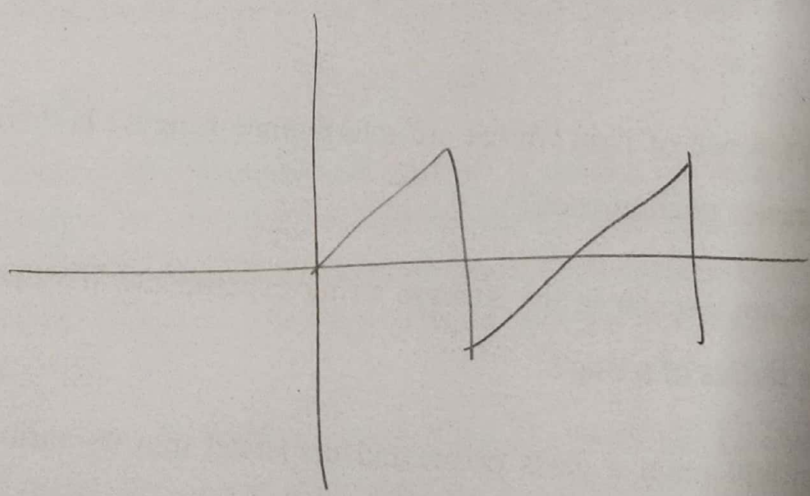

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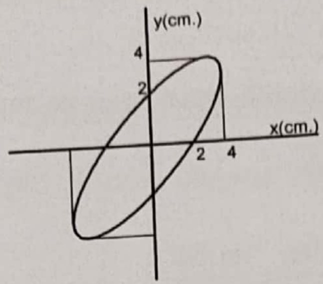
**[*There are TWELVE questions in this section. Answer any TEN. Each question carries 2 marks*]**

1. The Lissajous pattern shown in figure.1 is observed on the CRT screen. Find the phase shift between the signals applied to the X and Y inputs of the scope. Find the condition for circular Lissajous figure.




$2/4$ $\sin^{-1}$

2. Draw a series and a parallel LC circuit. Plot qualitatively the impedance as function of frequency for (L ~ 20 mH , C ~ 0.01 micro Farad). Here, which one is band stop and band pass filter?

3. Draw schematic of a series LCR circuit with an applied ac voltage $V(t) = V_0 \text{ Sin } (wt)$ and write down the differential equation for current with respect to time.

4. Write down the Newton' s law for a forced damped harmonic oscillator and map the electrical quantities appearing in a series LCR circuit with corresponding mechanical quantities.

5. What do you mean by interference of light? What are interference fringes? Is there any loss of energy in interference phenomenon?

6. Why the interference fringes are circular in the Newton's ring experiment? What are the factors which govern the radius of a ring?

7. A ray of white light is incident upon a glass prism and dispersed into its various colour components. However, for glass slab we don't see similar dispersion. Explain, why?

8. A ray of light passing through a glass prism of refracting angle 60°, undergoes a minimum deviation of 30°. Calculate the velocity of light in glass if the velocity of light in air is $3\times10^{10}$ cm $s^{-1}$.

Indian Association for the Cultivation of Science
(a deemed to be university)
Integrated BSMS Program 2018-19

Paper: Introductory Classical and Quantum Mechanics
Full Marks: 100

Paper Code: PHS-1101 [redacted]
Time Allotted: 3hrs

**Answer Question No.1 and any *eight* from the rest**

1. (a) Suppose, you are given two scalar fields $\phi$ and $\psi$ in a volume $V$, bounded by a surface $S$ with the normal vector $\mathbf{n}$. Then prove the following result,

$$\iiint_V (\phi\nabla^2\psi - \psi\nabla^2\phi)\, dV = \iint_S (\phi\nabla\psi - \psi\nabla\phi)\cdot \mathbf{n}\, dS$$

**(4 marks)**

(b) Suppose that a particle moving under a central force describes a trajectory given by $r = a(1+\cos\theta)$, where $a$ is a constant. Hence determine the force law. **(4 marks)**

(c) If the wavefunctions do not vanish at the end points, will momentum remain a hermitian operator? Explain. **(4 marks)**

(d) Given the angular momentum commutation relations, determine the commutation relations of $L_z$ with $L_x + iL_y$ and $L_x - iL_y$. **(4 marks)**

(e) Prove that all the energy eigenvalues associated with a simple harmonic oscillator are positive. **(4 marks)**

2. (a) Prove that for any scalar function $\phi$ and any vector field $\mathbf{v}$, $\nabla\times\nabla\phi = 0$ as well as $\nabla\cdot(\nabla\times\mathbf{v}) = 0$. **(5 marks)**

(b) If $\mathbf{u}$ and $\mathbf{v}$ are any two vectors, demonstrate that the following identity holds, namely $\nabla\cdot(\mathbf{u}\times\mathbf{v}) = (\nabla\times\mathbf{u})\cdot\mathbf{v} - (\nabla\times\mathbf{v})\cdot\mathbf{u}$. **(5 marks)**

3. (a) Consider a particle executing simple harmonic motion in the x-direction under the action of two separate forces, such that for the first one the displacement corresponds to $x_1 = a\sin\omega t$, while the displacement due to the other one is $x_2 = b\sin(\omega t + \delta)$. Show that the resultant displacement when the two forces are acting simultaneously is also of simple harmonic in nature. Determine the amplitude and phase of the resultant simple harmonic oscillator in terms of $a$, $b$ and $\delta$ introduced above. **(5 marks)**

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(b) Determine the moment of inertia of a thin uniform rod about an axis through its end and perpendicular to its length. Further, determine the moment of inertia of the rod about its centre and perpendicular to its length. **(5 marks)**

4. (a) For motion of a particle in a inverse cubic law force ($F \sim kr^{-3}$), determine the potential and plot it. Hence or otherwise, find out whether circular orbits exists in this force law. **(5 marks)**

(b) Let us consider a satellite moving in a circular orbit around the Earth at a height $h$ above the surface of the Earth. Hence determine its time period, i.e., how much time the satellite would take for a complete revolution around Earth? **(5 marks)**

5. Given a particle is moving in a central force field, answer the following questions,

(a) If a particle of mass $m$ moves under a central force $f(r)\hat{\mathbf{r}}$, show that the energy and angular momentum of the particle are conserved. **(5 marks)**

(b) Then starting from the conservation of energy can you derive the radial velocity of the particle, namely $\dot{r}$, as a function of $r$? **(5 marks)**

6. (a) Consider an electron, which is moving with a velocity of 100 meter-second$^{-1}$. Determine its de Broglie wavelength. Similarly if a car of mass 100 Kg is moving with a velocity of 200 meter-second$^{-1}$, what will be its de Broglie wavelength? From these two results what will be your answer regarding classical/quantum nature of these two objects. **(5 marks)**

(b) Suppose an electron is confined in a one dimensional box of length 10 nano-meter. Can you determine the minimum energy the electron can have? What happens to the minimum energy when the electron is replaced by a proton? **(5 marks)**

7. (a) Define hermitian operators. Using the definition show that $d/dx$ is not a hermitian operator but $-i(d/dx)$ is. **(5 marks)**

(b) Write down the Hamiltonian operator. Prove that the Hamiltonian operator is also hermitian. **(5 marks)**

8. (a) Given that $\hat{p} = -i\hbar(\partial/\partial x)$, show that $[\hat{x}, \hat{p}] = i\hbar$. **(5 marks)**

(b) Hence or otherwise, determine, $[\hat{x}^n, \hat{p}]$ as well as $[\hat{x}, \hat{p}^n]$. **(5 marks)**

$-i \frac{h}{2\pi} \frac{d}{dx} x^2$

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9. Consider a particle in an infinite potential well with its two end points fixed at 0 and $a$. Thus consider the following wave function,

$$\Psi(x,0) = \begin{cases} Ax & 0 \le x \le (a/2) \\ A(a-x) & (a/2) \le x \le a \end{cases}$$

and zero outside. Argue that this wave function satisfies necessary boundary condition. Hence determine the unknown constant $A$. Find out the probability that energy measurement will yield the value $E_1$. **(10 marks)**

10. Consider a particle in the $n$th excited state of an infinite potential well. Determine the average values of the operators $x$, $x^2$, $p$ and $p^2$. Hence comment on the validity of the uncertainty principle. **(10 marks)**

11. (a) Given an hermitian operator $\hat{A}$, prove that — (i) its eigenvalues are real and (ii) the eigenfunctions belonging to different eigenvalues are orthogonal. **(5 marks)**

(b) Check that eigenvalues are indeed real and eigenfunctions are orthogonal for a particle in an infinite well potential. **(5 marks)**

12. The probability density associated with a wave function $\psi(t,\mathbf{x})$ corresponds to $\rho \equiv |\psi(t,\mathbf{x})|^2$. Using Schrödinger equation prove that

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{J} = 0\,.$$

What will be the structure of the current $\mathbf{J}$, given the wave function $\psi$? What will happen if the potential becomes complex? **(10 marks)**

13. Suppose there is a rectangular potential barrier of height $V_0$ and width $a$. Show that a particle with energy $E < V_0$ can actually cross the barrier and reach the other side. Can you determine the probability of such a transmission event? **(10 marks)**

14. The canonical commutation relations between position and momenta corresponds to $[\hat{x}_i, \hat{p}_j] = i\hbar\delta_{ij}\hat{1}$, $[\hat{x}_i, \hat{x}_j] = 0 = [\hat{p}_i, \hat{p}_j]$. Also note that $\hat{\mathbf{L}} = \hat{\mathbf{r}} \times \hat{\mathbf{p}}$. Hence derive the following results,

$$\begin{aligned} [\hat{L}_z, \hat{x}] &= i\hbar\hat{y}; & [\hat{L}_z, \hat{y}] &= -i\hbar\hat{x}; & [\hat{L}_z, \hat{z}] &= 0 \\ \left[\hat{L}_z, \hat{p}_x\right] &= i\hbar\hat{p}_y; & [\hat{L}_z, \hat{p}_y] &= -i\hbar\hat{p}_x; & [\hat{L}_z, \hat{p}_z] &= 0 \end{aligned}$$

**(10 marks)**

$-\frac{i2k}{qm}$