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Solution-Mathematical Methods

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Section B

Q26. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R):

Assertion (A): A given vector $\vec{F}$ is irrotational i.e., $\vec{\nabla}\times\vec{F}=0$

Reason (R): The vector $\vec{F}$ is conservative.

In the light of the above statements, choose the most appropriate answer from the options given below.

1. Both (A) and (R) are correct and (R) is the correct explanation of (A)
2. Both (A) and (R) are correct but (R) is not the correct explanation of (A)
3. (A) is correct but (R) is not correct
4. (A) is not correct but (R) is correct

Ans.: (1)

Q27. Given below are two statements: If z_1 and z_2 are complex numbers

Statement - I: $\arg\left(\frac{z_1}{z_2}\right)=\arg(z_1)-\arg(z_2)$

Statement - II: $|z_1+z_2|^2=|z_1|^2+|z_2|^2-2\,\mathrm{Re}(z_1\bar{z}_2)$

In the light of the above statements, choose the correct answer from the options given below.

1. Both Statement - I and Statement - II are true
2. Both Statement - I and Statement - II are false
3. Statement - I is correct but Statement - II is false
4. Statement - I is incorrect but Statement - II is true

Ans.: (3)

Q28. Match List - I with List II:

	List - I		List - II
(A)	$\sin z$ for $\lvert z\rvert<\infty$	(I)	$(-1)^{n-1}z^{2n-2}/(2n-2)!$
(B)	$\cos z$ for $\lvert z\rvert<\infty$	(II)	$(-1)^{n-1}z^{n}/n$
(C)	$\tan^{-1}z$ for $\lvert z\rvert<1$	(III)	$(-1)^{n-1}z^{2n-1}/(2n-1)!$
(D)	$\ln(1+z)$ for $\lvert z\rvert<1$	(IV)	$(-1)^{n-1}z^{2n-1}/(2n-1)$

Choose the correct answer from the options given below:

1. (A)-(II); (B)-(III); (C)-(IV); (D)-(I)
2. (A)-(I); (B)-(II); (C)-(IV); (D)-(III)
3. (A)-(III); (B)-(I); (C)-(IV); (D)-(II)
4. (A)-(III); (B)-(I); (C)-(II); (D)-(IV)

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Ans.: (3)

Solution.:

(A) $\sin z$ for $|z|<\infty$ (III) $(-1)^{n-1} z^{2n-1}/(2n-1)! = z-\frac{z^3}{3!}+\frac{z^5}{5!}-...$

(B) $\cos z$ for $|z|<\infty$ (I) $(-1)^{n-1} z^{2n-2}/(2n-2)! = 1-\frac{z^2}{2!}+\frac{z^4}{4!}-...$

(C) $\tan^{-1} z$ for $|z|<1$ (IV) $(-1)^{n-1} z^{2n-1}/(2n-1) = z-\frac{z^3}{3}+\frac{z^5}{5}-...$

(C) $\ln(1+z)$ for $|z|<1$ (II) $(-1)^{n-1} z^n/n = z-\frac{z^2}{2}+\frac{z^3}{3}-...$

Q29. If $A=\begin{bmatrix}2 & 3 & 1\\ 0 & -1 & 5\end{bmatrix}$ and $B=\begin{bmatrix}1 & 2 & -1\\ 0 & -1 & 3\end{bmatrix}$, what is the value of $(2A-3B)$?

1. $\begin{bmatrix}1 & 1 & 0\\ 0 & 1 & 5\end{bmatrix}$ 2. $\begin{bmatrix}1 & 0 & 5\\ 0 & 1 & 1\end{bmatrix}$ 3. $\begin{bmatrix}0 & 1 & 1\\ 1 & 0 & 5\end{bmatrix}$ 4. $\begin{bmatrix}5 & 0 & 1\\ 1 & 1 & 0\end{bmatrix}$

Ans.: (2)

Solution.: $(2A-3B)=2A+(-3B)=\begin{bmatrix}4 & 6 & 2\\ 0 & -2 & 10\end{bmatrix}+\begin{bmatrix}-3 & -6 & 3\\ 0 & 3 & -9\end{bmatrix}=\begin{bmatrix}1 & 0 & 5\\ 0 & 1 & 1\end{bmatrix}$

Q30. The line integral per unit area along the boundary of small area around a point in vector field $\vec{A}$ is called

1. grad $\vec{A}$ 2. div $\vec{A}$ 3. curl $\vec{A}$ 4. line integral $\vec{A}$

Ans.: (3)

Q31. If $A=\begin{bmatrix}1 & 0\\ 2 & -1\end{bmatrix}$, $B=\begin{bmatrix}3 & 7\\ 4 & 8\end{bmatrix}$ and $C=\begin{bmatrix}-1 & 1\\ 0 & 0\end{bmatrix}$. The value of $A+(B+C)$ is

1. $\begin{bmatrix}3 & 7\\ 6 & 8\end{bmatrix}$ 2. $\begin{bmatrix}6 & 7\\ 3 & 8\end{bmatrix}$ 3. $\begin{bmatrix}8 & 3\\ 7 & 6\end{bmatrix}$ 4. $\begin{bmatrix}3 & 8\\ 6 & 7\end{bmatrix}$

Ans.: (4)

Solution.:

$$A+(B+C)=\begin{bmatrix}1 & 0\\ 2 & -1\end{bmatrix}+\left(\begin{bmatrix}3 & 7\\ 4 & 8\end{bmatrix}+\begin{bmatrix}-1 & 1\\ 0 & 0\end{bmatrix}\right)=\begin{bmatrix}1 & 0\\ 2 & -1\end{bmatrix}+\begin{bmatrix}2 & 8\\ 4 & 8\end{bmatrix}=\begin{bmatrix}3 & 8\\ 6 & 7\end{bmatrix}$$

Q32. What is the value of div $\vec{r}$, if $\vec{r}$ is the position vector of a particle? $(\vec{r}=x\hat{i}+y\hat{j}+z\hat{k})$

(1) 1 (2) 2 (3) 3 (4) Zero

Ans.: (3)

Solution.: $\because \vec{r}=x\hat{i}+y\hat{j}+z\hat{k}$

$$\text{div}\,\vec{r}=\vec{\nabla}.\vec{r}=\left(\hat{x}\frac{\partial}{\partial x}+\hat{y}\frac{\partial}{\partial y}+\hat{z}\frac{\partial}{\partial z}\right).\left(x\hat{i}+y\hat{j}+z\hat{k}\right)=\frac{\partial x}{\partial x}+\frac{\partial y}{\partial y}+\frac{\partial z}{\partial z}=1+1+1=3$$

Q33. If $\vec{r}$ is the position vector of any point on a surface S that encloses the volume V, then find $\iint_S \vec{r}\cdot d\vec{S}$.

(1) 1V (2) 2V (3) 3V (4) 4V

Ans.: (3)

Solution.: $\because \vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$;

$$\vec{\nabla}.\vec{r} = \left(\hat{x}\frac{\partial}{\partial x} + \hat{y}\frac{\partial}{\partial y} + \hat{z}\frac{\partial}{\partial z}\right).\left(x\hat{i} + y\hat{j} + z\hat{k}\right) = \frac{\partial x}{\partial x} + \frac{\partial y}{\partial y} + \frac{\partial z}{\partial z} = 1+1+1 = 3$$

Thus $\iint_S \vec{r}\cdot d\vec{S} = \int_V \left(\vec{\nabla}.\vec{r}\right)d\tau = \int_V 3d\tau = 3V$

Q35. Choose the correct sequence of the four statements given below, so that the phrase makes a complete sense:

A. Then the sets of equations connecting both are known as transformation of co-ordinates.

B. We can associate a unique set of co-ordinates.

C. Given a point P in rectangular co-ordinates.

D. Called the curvilinear co-ordinates of P.

Choose the correct answer from the options given below.

1. (A), (B), (C), (D) 2. (B), (C), (D), (A)

3. (C), (B), (D), (A) 4. (B), (A), (D), (C)

Ans.: (3)

Q57. Given $\vec{A}\times\vec{B} = \vec{C}$, where $\vec{A} = x\hat{i} + y\hat{j} + 3\hat{k}$, $\vec{B} = y\hat{i} + x\hat{j} + 2\hat{k}, \vec{C} = -5\hat{i} + 5\hat{k}$. Find the value of x and y

(1) $x = 2, y = 3$ (2) $x = 3, y = 2$ (3) $x = 1, y = 3$ (4) $x = 2, y = 1$

Ans.: (2)

Solution.:

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ x & y & 3 \\ y & x & 2 \end{vmatrix} = \hat{x}(2y-3x) - \hat{y}(2x-3y) + \hat{z}\left(x^2 - y^2\right)$$

$\because \vec{A}\times\vec{B} = \vec{C} = -5\hat{i} + 5\hat{k} \Rightarrow 2y - 3x = -5$, $-(2x-3y) = 0$ and $\left(x^2 - y^2\right) = 5$

$$\Rightarrow 2x = 3y \Rightarrow y = \frac{2}{3}x$$

and $2\frac{2}{3}x - 3x = -5 \Rightarrow -\frac{5}{3}x = -5 \Rightarrow x = 3,\ y = \frac{2}{3}x = 2$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

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Solution- Mechanics and General Properties of Matter

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Section B

Q36. The general form of a central force is represented by $\vec{F}=\frac{C}{r^n}\hat{r}$ (C = constant) known as Inverse Power law.

A. The force represented by above equation will be attractive if $C<0$.

B. The force represented by above equation will repulsive if $C<0$.

C. The force represented by above equation will be repulsive if $C>0$.

D. The force represented by above equation will be attractive if $C>0$.

Choose the correct answer from the options given below.

(1) A and B only (2) B and C only (3) A and C only (4) A and D only

Ans.: (3)

Solution.: $\because \vec{F}=\frac{c}{r^n}\hat{r} \Rightarrow V=-\int_{\infty}^{r}\vec{F}\cdot dr=-c\int_{\infty}^{r}\frac{dr}{r^n}=-\frac{cr^{-n+1}}{-n+1}\Big|_{\infty}^{r} \Rightarrow V(r)=\frac{c}{(n-1)r^{n-1}}$

(i) Negative potential represents attractive interaction, so force will be attractive if c is negative.

(ii) Positive potential represents repulsive interaction, so force will be repulsive if c is positive.

Q37. There are three planets in circular orbits around a star at a distance a, $9a$ and $16a$ respectively. At time $t=t_0$, the star and the planets are in a straight line. The period of revolution of the closest planet is T. How long after t_0, will they again be in the same line?

(1). 216 T (2). 512 T (3). 1728 T (4). 3456 T

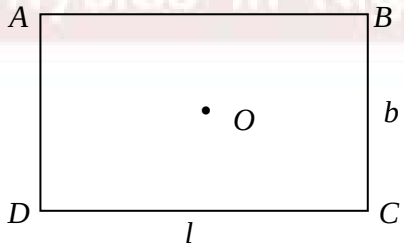
Ans.: (3)

Solution.:

$T_1=ka^{3/2}=T$, $T_2=k(9a)^{3/2}=27T$, $T_3=k(16a)^{3/2}=64T$

Stars will again be in the same line after time $=1\times27\times64T=1728T$

Q38. What will be the expression for moment of inertia of a rectangular lamina (ABCD having length l and breadth b) about an axis passing through one of its corners and perpendicular to its plane?



1. $I=\frac{M}{12}(l^2+b^2)$

2. $I=M\left(\frac{l^2}{12}+\frac{b^2}{6}\right)$

3. $I=M\left(\frac{l^2}{6}+\frac{b^2}{12}\right)$

4. $I=\frac{M}{3}(l^2+b^2)$

Ans.: (4)

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Q39. Match List-I with List-II:

	List-I		List-II
(A)	Green's theorem	(I)	Moment of inertia
(B)	Kepler's laws	(II)	Vectors
(C)	Theorem of parallel and perpendicular axes	(III)	Inertia
(D)	Newton's law	(IV)	Motion of planets

Choose the correct answer from the options given below:

(1). (A)-(I); (B)-(III); (C)-(II); (D)-(IV)

(2). (A)-(III); (B)-(II); (C)-(IV); (D)-(I)

(3). (A)-(II); (B)-(IV); (C)-(I); (D)-(III)

(4). (A)-(IV); (B)-(III); (C)-(I); (D)-(II)

Ans.: (3)

Solution:

(A) Green's theorem is related to vectors

(B) Kepler's laws for planetary motion

(c) Theorem of parallel and perpendicular axes of moment of inertia

(d) Newton's first law is also known as law of inertia

Q40. Gravitational force between two masses m_1 and m_2 separated by a distance r is

(A) central force (B) non-central force (C) attractive force

(D) repulsive force (E) directly proportional to the distance between m_1 and m_2

Choose the correct answer from the options given below.

(1) A only (2) B only (3) A and C only (4) D and E only

Ans.: (3)

Solution.: $\vec{F}_G(r) = \frac{Gm_1m_2}{r^2}\hat{r}$. This force is central and attractive in nature.

Q41. A bullet of mass 10g moving horizontally with a speed of 500 m/s passes through a block of wood of mass 1 kg, initially at rest on a frictionless surface. The bullet comes out of the block with a speed of 200 m/s. What is the final speed of the block?

(1) 0 (2) 1 m/s (3) 2 m/s (4) 3 m/s

Ans.: (4)

Solution.:

$mu + MU = mu + Mv$

$\left(10\times10^{-3}\right)\times500 + 1\times0 = \left(10\times10^{-3}\right)\times200 \Rightarrow 5 = 2 + V \Rightarrow V = 3\,m/s$

Q42. What will be the spring constant of a spring? When it is stretched 10 cm, it has potential energy of 5600 J.

(1) 1.12 N/m (2) 11.2 N/m (3) 1.12×10^{6} N/m (4) Zero

Ans.: (3)

Solution.:

$$\because V=\frac{1}{2}kx^2 \Rightarrow k=\frac{2V}{x^2}=\frac{2\times5600}{\left(10\times10^{-2}\right)^2}=1.12\times10^{6}\ N/m$$

Q43. The work done in a gravitational field between two points does not depend upon the path between these points. The field

1. can be conservative or non-conservative
2. is conservative
3. is non-conservative
4. Nature of field cannot be determined

Ans.: (2)

Solution.: Work done by a conservative force between two points is path independent.

Q44. Two bodies of different masses are moving with the same kinetic energy. Which one has a greater momentum?

(1) Body of greater mass will have the greater momentum

(2) Body of lighter mass will have the greater momentum

(3) Both bodies will have same momentum

(4) Depending on initial conditions any body can have greater momentum

Ans.: (1)

Solution.: $k_1=k_2,\ \frac{p_1^2}{2m_1}=\frac{p_2^2}{2m_2}\Rightarrow\frac{p_1}{p_2}=\sqrt{\frac{m_1}{m_2}}$

If $m_1>m_2$ then, $p_1>p_2$.

Q45. If the earth suddenly contracts to half its radius, what would be the length of the day?

(1) Remain the same (2) 6 hours (3) 12 hours (4) 18 hours

Ans.: (2)

Solution.: $I_2\omega_2=I_1\omega_1\Rightarrow\frac{2}{5}MR_2^2\frac{2\pi}{T_2}=\frac{2}{5}MR_1^2\frac{2\pi}{T}$

$$T_2=\frac{R_2^2}{R_1^2}T_1=\frac{\left(R_1/2\right)^2}{R_1^2}\times24\,hrs\Rightarrow T_2=6\,hrs$$

Q46. The angular speed of a motor wheel is increased from 1200 r.p.m. to 3120 r.p.m. in 16s. What is its angular acceleration?

(1) $\pi\ \text{rad/s}^2$ (2) $2\pi\ \text{rad/s}^2$ (3) $3\pi\ \text{rad/s}^2$ (4) $4\pi\ \text{rad/s}^2$

Ans.: (4)

Solution.:

$$\omega=\omega_0+\alpha t;\ \alpha=\frac{\omega-\omega_0}{t}=\frac{2\pi\left(3120-1200\right)/60}{16}=\frac{2\times1920}{16\times60}\pi\Rightarrow\alpha=4\pi\ rad/s^2$$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

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Solution- Oscillations, Waves and Optics

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Section B

Q47. Given below are two statements:

Statement - I: In case of bi-prism, the coherent sources are produced by the phenomenon of refraction.

Statement-II: In case of Llyod mirror, coherent sources are produced by the phenomenon of reflection.

In the light of above statements, choose the correct answer from the options given below.

(1) Both Statement-I and Statement-II are true

(2) Both Statement-I and Statement-II are false

(3) Statement-I is correct but Statement-II is false

(4) Statement-I is incorrect but Statement-II is true

Ans.: (1)

Solution.:

[I] In Fresnel's biprism, both the coherent sources are virtual images of the source. They are formed by the refraction of light by bi-prism.

[II] In Llyod's mirror experiment, one coherent source is real while second coherent source is the virtual image of the source, that is formed by the reflection of light from mirror.

Q48. If two simple harmonic motions having angular frequency 440 rad/s and 396 rad/s are superimposed, what will be the number of beats produced?

(1) 5 beats/s (2) 6 beats/s (3) 7 beats/s (4) 8 beats/s

Ans.: (3)

Solution.:

$$\omega_1 - \omega_2 = 440 - 396$$

$$2\pi\left(n_1 - n_2\right) = 44 \Rightarrow n_1 - n_2 = \frac{44}{2\pi} = \frac{44\times 7}{2\times 22} = 7 \text{ beats/s}$$

Q49. Which will be the separation between the coherent sources formed by a bi-prism whose inclined faces makes an angle of 2° with its base, the slit source being 0.10 m away from the bi-prism (Given $\mu = 1.5$)?

(1) 1.5 mm (2) 2.5 mm (3) 3.5 mm (4) 4.5 mm

Ans.: (3)

Solution.: $d = 2a\left(\mu - 1\right)\alpha = 2\times 0.10\times\left(1.5-1\right)\times\frac{2^\circ}{180^\circ}\times 3.14\, m$

$$\Rightarrow d = 3.48\times 10^{-3}\, m = 3.48\, mm$$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Q50. A grating has 15 cm of the surface ruled with 6000 lines per cm. What is the Dispersive power of grating at the angle of $\theta = 60°$ in the first order?

(1) 8000 rad/m (2) 20000 rad/m (3) 8000 rad/cm (4) 2000 rad/cm

Ans.: drop

Solution.:

$$(e+d)\sin\theta = n\lambda \Rightarrow (e+d)\cos\theta\frac{d\theta}{d\lambda} = n$$

$$DP = \frac{d\theta}{d\lambda} = \frac{n}{(e+d)\cos\theta}$$

Q51. The Lissajous figure of two rectangular SHMs of equal frequency and phase difference of $\pi/2$ is

(1) Straight line (2) Circle (3) Ellipse (4) Parabola

Ans.: (3)

Solution.:

$$x = a\sin(\omega t),\ y = b\sin\left(\omega t + \frac{\pi}{2}\right) = b\cos\omega t \Rightarrow \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

This equation represents rectangular ellipse.

Q52. What is the phase change for a light of wavelength 5000 Å, passing through a glass plate, if the refractive index of the glass plate is changed from $\mu_0 = 1.5418$ to $\mu = 1.5508$.

(1) 3.14 radian (2) 6.28 radian (3) 36.17 radian (4) 3.617 radian

Ans.: Drop

Solution.:

This question is incomplete. Thickness of the glass plate should be provided.

$$\delta = \frac{2\pi}{\lambda}(\mu_1 - \mu_2)t$$

Q53. Angular width of central maxima of a diffraction pattern of a single slit does not depend upon

(1) wavelength of light (2) frequency of light

(3) distance between slit and source (4) width of the slit

Ans.: (3)

Solution.: $e\sin\theta_1 = 1\times\lambda \Rightarrow \theta_1 = \sin^{-1}\frac{\lambda}{e}$

Angular width of the central maxima $\omega_0 = 2\theta_1 = 2\sin^{-1}\frac{\lambda}{e}$

Q54. The Lissajous figure may be a straight line if the phase difference is

(1) 0 or π (2) $\pi/4$ (3) $\pi/2$ (4) $\pi/3$

Ans.: (1)

Solution.: (i) $x = a\sin\omega t$, $y = b\sin\omega t \Rightarrow y = \frac{b}{a}x$

(ii) $x = a\sin\omega t$, $y = b\sin(\omega t + \pi) = -b\sin\omega t \Rightarrow y = -\frac{b}{a}x$

Q55. If I_0 is the intensity of the principal maxima in a single slit diffraction pattern, then what will be its intensity when the slit width is doubled?

(1) $I_0/2$ (2) I_0 (3) $2I_0$ (4) $4I_0$

Ans.: (4)

Solution.: $I_{prin} \propto (\text{width})^2 \Rightarrow \frac{I_0^1}{I_0} = \frac{(2a)^2}{(a)^2} \Rightarrow I_0^1 = 4I_0$

Q56. The kinetic energy of a particle executing simple harmonic motion is

(A) maximum at equilibrium position (B) constant

(C) minimum at extremes positions (D) zero (E) negative

Choose the correct answer from the options given below.

(1) A and C only (2) B only (3) C and D only (4) E only

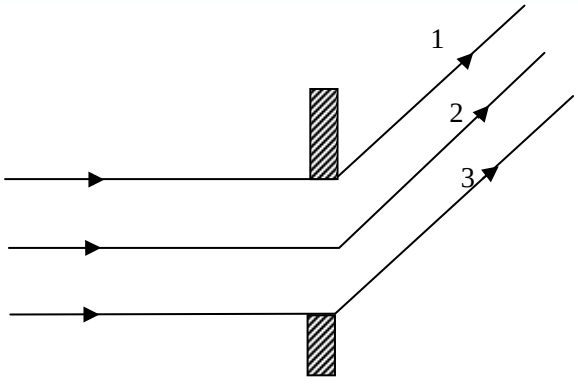
Ans.: (1)

Solution.: $k = \frac{1}{2}m\omega^2(a^2 - x^2)$.

(i) At equilibrium position, $x = 0$, $k = \frac{1}{2}m\omega^2a^2 =$ maximum

(ii) At extreme positions, $x = \pm a$, $k = 0 =$ Minimum

Q58. Figure shows Fraunhofer's diffraction due to a single slit. If first minima is obtained in the direction shown, then the path difference between ray 1 and ray 3 is



(1) $\lambda/3$ (2) $\lambda/2$ (3) λ (4) zero

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Ans.: (3)

Solution.:

For first minima, the path difference between ray-1 and ray-3 should be λ. There will always be two corresponding points one in the upper half and second in the lower half, of the slit, which act as point sources and light emerging from these points will interfere destructively in the given direction consequently, the diffraction minima is formed in this particular direction.

Q86. Given below are two statements:

Statements - I: Compton effect can be explained on the basis of wave nature of light.

Statements - II: Diffraction pattern of light can be explained on the basis of particle nature of light.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both Statement - I and Statement - II are true

(2) Both Statement - I and Statement - II are false

(3) Statement - I is correct but Statement - II is false

(4) Statement - I is incorrect but Statement - II is true

Ans.: (2)

Solution.:

[I] Compton effect can be explained on the basis of particle nature of radiation.

[II] Diffraction of light can be explained on the basis of wave nature of light.

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Solution- Electricity and Magnetism

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Section B

Q34. A infinite long wire is stretched horizontally 4 m above the surface of the earth, It has a charge of 1.0 micro-coulomb (μC) per cm of its length. The value of electric field at a point on earth vertically below the wire is

1. 4.5 N/C 2. 45.0 N/C 3. 4.5×10^5 N/C 4. 2.5×10^3 N/C

Ans.: (3)

Solution.: $E=\dfrac{\lambda}{2\pi\varepsilon_0 r}=\dfrac{1}{4\pi\varepsilon_0}\dfrac{2\lambda}{r}=\left(9\times10^9\right)2\dfrac{1\times10^{-6}/10^{-2}C/m}{4m}=4.5\times10^5 N/C$

Q59. In the given question, choose the correct sequence of four statements given below:

(A) It was found that the charge determined in each case

(B) Which reveals that charge is quantised

(C) When the experiment was repeated for a number of times

(D) Was an integral multiple of elementary charge

Choose the correct answer from the options given below.

(1) (A), (B), (D), (C) (2) (C), (A), (D), (B)

(3) (D), (B), (A), (C) (4) (C), (A), (B), (D)

Ans.: (2)

Q60. Given below are two statements:

Statement - I: Important characteristic of electromagnetic wave is that it can transport energy from one point to another point.

Statement - II: The direction of electromagnetic wave at a given point is the direction in which energy is being transmitted.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both Statement - I and Statement - II are true

(2) Both Statement - I and Statement - II are false

(3) Statement - I is correct but Statement - II is false

(4) Statement - I is incorrect but Statement - II is true

Ans.: (1)

Q61. The relative magnitude of $\vec{H}$ in a plane wave is $1Am^{-1}$. What will be the magnitude of $\vec{E}$ for a plane wave in free space?

(1) 3760 V/m (2) 3.760 V/m (3) 37.60 V/m (4) 376.0 V/m

Ans.: (4)

Solution.: $\because \dfrac{\vec{E}}{\vec{H}}=\sqrt{\dfrac{\mu_0}{\varepsilon_0}}=377\Omega \Rightarrow \vec{E}=377\Omega\times\vec{H}=377\ V/m \qquad \because \vec{H}=1Am^{-1}$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Q62. If magnetic monopole existed, then which of the following Maxwell's equations will be modified?

(1) div $\vec{D}=\rho$ (2) div $\vec{B}=0$ (3) curl $\vec{E}=-\frac{\partial\vec{B}}{\partial t}$ (4) curl $\vec{H}=\vec{J}+\frac{\partial\vec{D}}{\partial t}$

Ans.: (2)

Q63. When a charge particle moves in a uniform magnetic field, its kinetic energy

(1) goes on increasing

(2) goes on decreasing

(3) remains unchanged

(4) may increase or decrease depending upon the sign of charge

Ans.: (3)

Q64. The relative permittivity of distilled water is 81. What is the velocity of light in the distilled water?

(1) 1.1×10^{7} m/s (2) 2.2×10^{7} m/s (3) 3.3×10^{7} m/s (4) 3×10^{8} m/s

Ans.: (3)

Solution.: $\because v=\frac{c}{n}=\frac{c}{\sqrt{\varepsilon_r}}=\frac{3\times10^{9}}{\sqrt{81}}m/\sec=3.3\times10^{7}m/\sec$

Q65. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R):

Assertion (A): All points inside a charged hollow spherical conducting sphere are at equal potential.

Reason (R): The electric field inside a charged hollow spherical conducting sphere is non-zero.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A)

(2) Both (A) and (R) are true but (R) is not the correct explanation of (A)

(3) (A) is true but (R) is false

(4) (A) is false but (R) is true

Ans.: (3)

Q66. The time period of oscillation of the charge in a circuit containing inductance (L) and capacitance (C) only is

(1) $\frac{1}{2\pi\sqrt{LC}}$ (2) $\frac{2\pi}{\sqrt{LC}}$ (3) $\frac{\sqrt{LC}}{2\pi}$ (4) $2\pi\sqrt{LC}$

Ans.: (4)

Q67. The self-inductance of a solenoid is

(1) directly proportional to the current in the solenoid

(2) inversely proportional to the length of the solenoid

(3) directly proportional to the cross-sectional area of the solenoid

(4) inversely proportional to the cross-sectional area of the solenoid

Ans.: (3)

Q68. A solenoid of length 30 cm is wound uniformly with 3000 turns of wire. The wire carries a current of 10 A. What is the value of $\vec{B}$ on the axis within the solenoid? [$\mu_0 = 4\pi \times 10^{-7} T\, m/A$]

(1) 0.126 T (2) 1.26 T (3) 12.6 T (4) 0 T

Ans.: (1)

Solution.: $B = \mu_0 nI = \mu_0 \dfrac{N}{l} I = 4\pi \times 10^{-7} T\, m/A \dfrac{3000}{30 \times 10^{-2} m} \times 10A = 4\pi \times 10^{-2} T$

$\Rightarrow B = 4 \times 3.14 \times 10^{-2} T = 12.56 \times 10^{-2} T = 0.126T$

Q69. What will be potential and field due to a dipole of dipole moment 4.5×10^{-10} Cm at a distance from 1m from the center of the dipole along its axis?

(1) 4.05 V and 8.1 V/m

(2) 4.05 V and 10.1 V/m

(3) 6.05 V and 8.1 V/m

(4) 6.05 V and 10.1 V/m

Ans.: (1)

Solution.: $V = \dfrac{1}{4\pi\varepsilon_0} \dfrac{p\cos\theta}{r^2}$, $\vec{E} = \dfrac{p}{4\pi\varepsilon_0 r^3}\left(2\cos\theta\hat{r} + \sin\theta\hat{\theta}\right)$

Along dipole axis $\theta = 0^0$: $V = 9 \times 10^9 \dfrac{4.5 \times 10^{-10}}{1^2} = 4.05V$;

$\left|\vec{E}\right| = 9 \times 10^9 \dfrac{4.5 \times 10^{-10}}{1^3}(2) = 8.1\, V/m$

Q70. A parallel plate capacitor consists of two square metal plates 5.0 cm of side and separated by 1 cm. A sulphur slab of thickness 5 mm is placed on the lower plate. What will be the capacitance of the capacitor? (Dielectric constant of sulphur = 4)

(1) $2.5 \times 10^{-12} F$ (2) $3.5 \times 10^{-12} F$ (3) $4.5 \times 10^{-12} F$ (4) $5.5 \times 10^{-12} F$

Ans.: (2)

Solution.:

$C_1 = \dfrac{\varepsilon_0 \varepsilon_r A}{d_1} = \dfrac{8.86 \times 10^{-12}(4) \times 25 \times 10^{-4}}{5 \times 10^{-3}} = 17.72 \times 10^{-12} F$

$C_2 = \dfrac{\varepsilon_0 A}{d_1} = \dfrac{8.86 \times 10^{-12} \times 25 \times 10^{-4}}{1 \times 10^{-2} - 5 \times 10^{-3}} = \dfrac{221.5 \times 10^{-16}}{0.5 \times 10^{-2}} = 4.43 \times 10^{-12} F$

Thus $C = \dfrac{C_1 C_2}{C_1 + C_2} = \dfrac{17.72 \times 4.43}{17.72 + 4.43} \times 10^{-12} F = \dfrac{68.5}{22.15} \times 10^{-12} F = 3.1 \times 10^{-12} F$

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Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

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Section B

Q71. The change in entropy (ΔS) for a reversible adiabatic process is

(1) $\Delta S > 0$ (2) $\Delta S = 0$ (3) $\Delta S < 0$ (4) $\Delta S > 0$ and $\Delta S < 0$

Ans.: (2)

Q72. The r.m.s. speed of hydrogen atom at room temperature (300 K) is 2000 m/s. What is the r.m.s. speed of hydrogen atom on the surface of sun where temperature is $T = 2\times10^6$ K?

(1) 164 m/s (2) 1640 m/s (3) 164000 m/s (4) 16400 m/s

Ans.: (3)

Solution.: $v_{rms} = \sqrt{\frac{3k_BT}{m}} \Rightarrow \frac{v_{rms,2}}{v_{rms,1}} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{2\times10^6 K}{300K}} = \sqrt{\frac{20000}{3}} = 81.6$

$\Rightarrow v_{rms,2} = 81.6\times v_{rms,1} = 81.6\times 2000 m/\sec = 163299\, m/\sec$

Q73. In Fermi-Dirac statistics, the particles are

(1) indistinguishable and obey Pauli exclusion principle with half integer spin angular momentum

(2) indistinguishable with integral spin angular momentum

(3) distinguishable with integral spin angular momentum

(4) indistinguishable and do not obey Pauli exclusion principle

Ans.: (1)

Q74. Which is the relation between Boyle temperature (T_B) and critical temperature (T_C) of a gas?

(1) $T_B = \frac{27}{8}T_C$ (2) $2T_B = \frac{8}{27}T_C$ (3) $T_B = \frac{3}{7}T_C$ (4) $3T_B = 2T_C$

Ans.: (1)

Q75. What is the change in entropy when 10 g of ice at 0°C is converted into water at the same temperature? The latent heat of ice is 80 cal/g.

(1) 0 cal/K (2) 2.93 cal/K (3) 29.3 cal/K (4) 293 cal/K

Ans.: (2)

Solution.: $\Delta S = \frac{\Delta Q}{T} = \frac{mL}{T} = \frac{10g\times 80 cal/g}{273K} = 2.93 cal/K$

Q76. Five Carnot engines operate between reservoir temperatures of

(A) 100 K and 500 K (B) 200 K and 500 K

(C) 400 K and 500 K (D) 200 K and 800 K

(E) 200 K and 400 K

Arrange the engines according to their decreasing efficiencies.

Choose the correct answer from the options given below.

(1) B, C, D, A, E (2) A, D, B, E, C

(3) A, B, C, D, E (4) A, E, B, C, D

Ans.: (2)

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Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Q77. C_1 and C_2 represent the specific heat of a liquid and its saturated vapour where as L is latent heat of vaporization. (T is the temperature) the correct option is

(1) $C_2 - C_1 = \frac{dL}{dT} - \frac{L}{T}$ (2) $C_1 - C_2 = \frac{dL}{dT} + \frac{L}{T}$

(3) $C_1 + C_2 = \frac{dL}{dT} - \frac{L}{T}$ (4) $C_1 + C_2 = \frac{dL}{dT} + \frac{L}{T}$

Ans.: (1)

Q78. The Bose-Einstein distribution is applied on

(1) identical, distinguishable particles

(2) identical, indistinguishable particles that do not obey exclusion principle

(3) identical, indistinguishable particles which obey exclusion principle

(4) distinguishable particles which obey exclusion principle

Ans.: (2)

Q81. A white dwarf star has volume V and contains N electrons so that the density of electron is $n = \frac{N}{V}$. Taking the temperature of the star to be 0 K, what will be the expression for average energy per electron in the star?

(1) $\frac{3\hbar^2}{m}\left(3\pi^2 n\right)^{3/2}$ (2) $\frac{3\hbar^2}{10m}\left(3\pi^2 n\right)^{2/3}$ (3) $\frac{\hbar^2}{m}\left(3\pi^2 n\right)^{2/3}$ (4) $\frac{3\hbar^2}{10m}\left(3\pi^2 n\right)^{1/3}$

Ans.: (2)

Q99. The phase space is a

(1) two-dimensional space (2) one-dimensional space

(3) three-dimensional space (4) six-dimensional space

Ans.: (4)

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Section B

Q79. Given below are two statements:

Statement - I: Law of conservation of momentum is invariant to Galilean transformation.

Statement - II: Law of conservation of energy is invariant to Galilean transformation.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both Statement - I and Statement - II are true

(2) Both Statement - I and Statement - II are false

(3) Statement - I is correct but Statement - II is false

(4) Statement - I is incorrect but Statement - II is true

Ans.: (1)

Solution.: In Galilean transformations both law of conservation of linear momentum and law of conservation of energy are invariant.

Q80. What is the kinetic energy of an electron in the lowest energy level of a hydrogen atom?

(1) 27.2 eV (2) 13.6 eV (3) 1.36 eV (4) 2.72 eV

Ans.: (2)

Solution.: $k = |E| = |-13.6| = 13.6 eV$

Q82. The de Broglie wavelength of an electron having kinetic energy of 100 eV is

(1) 200 pm (2) 120 pm (3) 50 pm (4) 300 pm

Ans.: (2)

Solution.: $\lambda_D = \sqrt{\frac{150}{V}}\text{Å} = \sqrt{\frac{150}{100}}\text{Å} = 1.22\text{Å} = 122\ pm$

Q83. A metal has work function $w_0 = 3.3\times10^{-19}\ J$. What should be the minimum frequency of the incident radiation that can remove an electron from the metal surface? [Given $h = 6.6\times10^{-34}$ J-s]

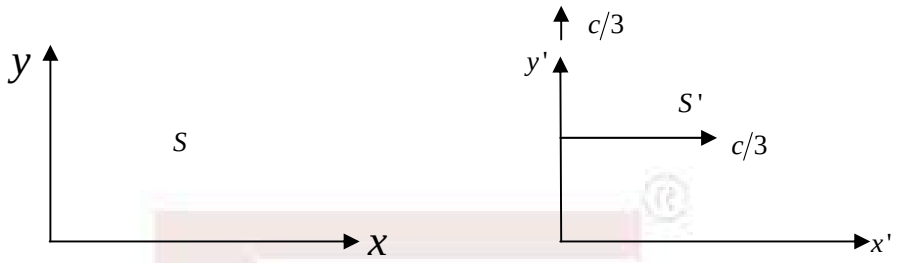
(1) 5×10^{10} Hz (2) 5×10^{12} Hz (3) 5×10^{14} Hz (4) 5×10^{15} Hz

Ans.: (3)

Solution.: $W_0 = h\nu_0,\ \nu_0 = \frac{W_0}{h} = \frac{3.3\times10^{-19}}{6.6\times10^{-34}} = \frac{1}{2}\times10^{15} = 5\times10^{14}\ Hz$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

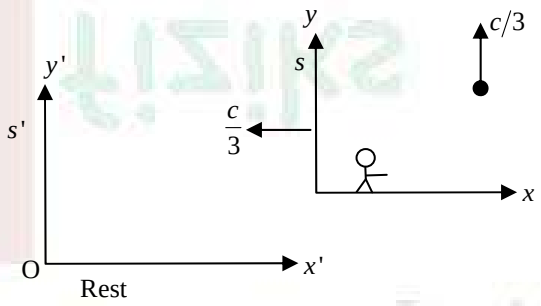
Q84. Consider an inertial frame S' moving at a speed $\frac{c}{3}$ away from another inertial frame S along the common x-axis, where c is the speed of light. As observed from S', a particle is moving with speed $\frac{c}{3}$ in the y' direction as shown in the figure. The speed of the particle as seen from S will be



(1) $\frac{\sqrt{15}}{9}c$ (2) $\frac{\sqrt{17}}{9}c$ (3) $\frac{\sqrt{21}}{9}c$ (4) $\frac{\sqrt{18}}{9}c$

Ans.: (2)

Solution.:



Here we have made S' a rest frame: $\vec{u}' = 0\hat{i} + \frac{c}{3}\hat{j} + 0\hat{k}$

$$u_x = \frac{u_x' - v}{1 - \frac{u_x' v}{c^2}} = \frac{0 - \left(-\frac{c}{3}\right)}{1 - 0} = \frac{c}{3},\ u_y = \frac{u_y' \sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{u_x' v}{c^2}} = \frac{c}{3}\sqrt{1 - \frac{1}{9}} = \frac{2\sqrt{2}c}{9},\ u_z = \frac{u_z' \sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{u_x' v}{c^2}} = 0$$

$$u = \sqrt{\frac{c^2}{9} + \frac{8c^2}{81}} = \frac{c}{9}\sqrt{1 + \frac{8}{9}} = \frac{\sqrt{17}c}{9}$$

Q87. What is the relation between half-life (T) and decay constant (λ) of a radioactive element?

(1) $T = 0.693\lambda$ (2) $T = \frac{\lambda}{0.693}$ (3) $T = \frac{0.693}{\lambda}$ (4) $T = \frac{0.693}{\lambda^2}$

Ans.: (3)

Solution.: Half life time $T = \frac{ln\ 2}{\lambda} = \frac{0.693}{\lambda}$

Q88. Consider Rydberg (hydrogen-like) atoms in a highly excited state with n around 400. The wavelength of radiation coming out of these atoms for transitions to the adjacent levels in the range.

(1) Gamma rays (λ ~pm) (2) Ultra violet rays (λ ~nm)

(3) infrared rays ($\lambda \sim \mu m$) (4) radio frequency (λ ~m)

Ans.: (4)

Solution.: $E_{n+1} - E_n = \left[-\frac{Rhc}{(n+1)^2} + \frac{Rhc}{(n)^2} \right] Z^2 \Rightarrow \frac{hc}{\lambda} = Rhc \left[\frac{1}{n^2} - \frac{1}{(n+1)^2} \right] Z^2$

$$\Rightarrow \frac{1}{\lambda} = R \frac{(n+1)^2 - n^2}{n^2 (n+1)^2} Z^2 = R \frac{2n}{n^4} Z^2 = \frac{2RZ^2}{n^3}$$

$$\lambda = \frac{n^3}{2RZ^2} = \frac{n^3}{2 \times 1.09 \times 10^7 Z^2} = \frac{10^{-7}}{2.18} \frac{n^3}{Z^2} = \frac{64}{2.18} \times 10^{-1} = \frac{6.4}{2.18} m \quad ; \text{Let } Z = 1$$

$\Rightarrow \lambda = 2.94\, m$ [Radio frequency]

Q89. What is the mean life time $(\bar{T})$ of a radioactive substance of which the decay constant (λ) is 4.28×10^{-4} per year?

(1) 584 years (2) 1168 years (3) 1619 years (4) 2336 years

Ans.: (4)

Solution.: $\tau = \frac{1}{\lambda} = \frac{1}{4.28 \times 10^{-4}}$ years $\Rightarrow \tau = 2336$ years

Q90. The dispersion relation for electromagnetic waves travelling in a plasma is given by $\omega^2 = c^2 k^2 - \omega_\rho^2$, where c and ω_ρ are constants. In this plasma, group velocity will be

(1) proportional to but not equal to phase velocity

(2) equal to the phase velocity

(3) inversely proportional to the phase velocity

(4) constant

Ans.: (3)

Solution.: $\omega^2 = c^2 k^2 - \omega_P^2 \Rightarrow 2\omega \frac{d\omega}{dk} = 2kc^2 \Rightarrow \frac{\omega}{k} \frac{d\omega}{dk} = c^2 \Rightarrow \boxed{v_p . v_g = c^2}$

Q94. What happens if the electron spin is 3/2 instead of ½?

(1) The Bohr levels will change (2) The size of atoms will change

(3) Energy will change (4) Atoms will not be stable

Ans.: (3)

Solution.:

If electron spin is 3/2 then occupancy of different levels will increase and at the same time, new levels will come into the picture.

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
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Section B

Q85. What will be drift velocity v_d of the free electron in a copper wire whose cross-sectional area is $A = 1.00\, mm^2$ when the wire carries a current of 1.0 A. Assume that each copper atom contributes 1 electron to the electron gas. [Given density of copper $= 8.94\times10^3\, kg/m^3$, atomic mass of copper $= 63.5u$, $1u = 1.66\times10^{-27}$ kg)

(1) 7.4×10^{-5} m/s (2) 7.4×10^{-2} m/s (3) 7.4×10^{-7} m/s (4) 7.4 m/s

Ans.: (1)

Solution.: Drift current $I_d = neAv_d \Rightarrow v_d = \dfrac{I_d}{neA}$

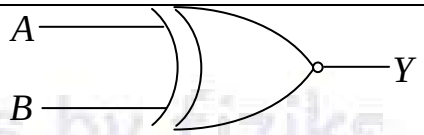
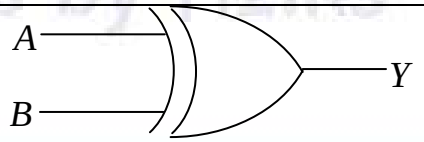
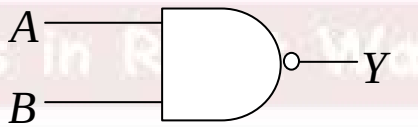
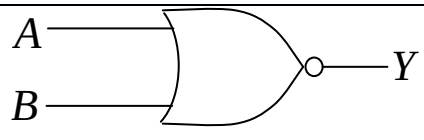
$I_d = 1A, e = 1.6\times10^{-19}C, A = 1.00\ mm^2$,

$$n = \frac{density}{atomic\,mass} = \frac{= 8.94\times10^3\, kg/m^3}{63.5\times1.66\times10^{-27}\, kg} = 85\times10^{27}\, m^{-3}$$

Thus

$$v_d = \frac{I_d}{neA} = \frac{1A}{\left(85\times10^{27}\, m^{-3}\right)\left(1.6\times10^{-19}C\right)\left(10^{-6}m^2\right)} = \frac{1}{136\times10^2}\, m/\sec = 7.4\times10^{-5}\, m/\sec$$

Q91. Match List - I with List - II:

	List - I		List - II
(A)	NAND Gate	(I)	
(B)	NOR Gate	(II)	
(C)	X-NOR Gate	(III)	
(D)	XOR Gate	(IV)	

Choose the correct option from those given below.

1. (A)-(III); (B)-(IV); (C)-(II); (D)-(I)
2. (A)-(II); (B)-(I); (C)-(IV); (D)-(III)
3. (A)-(III); (B)-(IV); (C)-(I); (D)-(II)
4. (A)-(IV); (B)-(III); (C)-(I); (D)-(II)

Ans.: (3)

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
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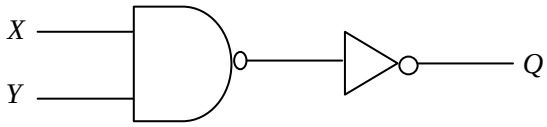
Q92. The following logic circuit represents



1. NAND gate with output $Q = \bar{X} + \bar{Y}$
2. NOR gate with output $Q = \overline{X + Y}$
3. AND gate with output $Q = X \cdot Y$
4. NOR gate with output $Q = \bar{X} + \bar{Y}$

Ans.: (3)

Q93. Find the shortest wavelength present in the radiation from an X-ray machine whose accelerating potential is 50000 V.

(1) 0.0248 Å (2) 0.248 Å (3) 2.48 Å (4) 24.80 Å

Ans.: (2)

Solution.: $\lambda = \dfrac{hc}{eV} = \dfrac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(1.6\times10^{-19}\right)\left(50000\right)} m = 2.49\times10^{-11} m = 0.249$ Å

Q95. Operational amplifiers can be used as

(A) Summing circuit (B) Voltage regulator (C) Integrator

(D) Differentiator (E) Clipping Circuit

Choose the correct answer from the options given below.

(1) A and C only (2) C and D only (3) A, C and D only (4) A and E only

Ans.: (3)

Q96. Given below are two statements:

Statement - I: We can join two P-N junctions back-to-back to form a transistor

Statement - II: In a transistor the emitter base junction is forward biased while base collector junction is reverse biased

In the light of the above statements, choose the correct answer from the options given below.

(1) Both Statement - I and Statement - II are true

(2) Both Statement - I and Statement - II are false

(3) Statement - I is correct but Statement - II is false

(4) Statement - I is incorrect but Statement - II is true

Ans.: (4)

Q97. Electrons are accelerated by 344 volts and reflected from the crystal. The first reflection maximum occurs when glancing angle is 30°. What will be the value of interplaner spacing of the crystal? [Given $h = 6.62\times10^{-34}\,Js$, $m_e = 9.1\times10^{-31}\,\text{kg}$]

(1) $0.06\times10^{-10}\,\text{m}$ (2) $0.66\times10^{-10}\,\text{m}$ (3) $1.66\times10^{-10}\,\text{m}$ (4) $2.66\times10^{-10}\,\text{m}$

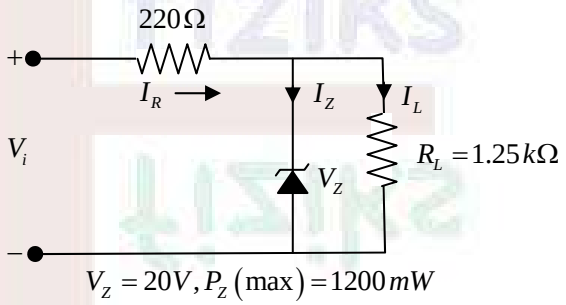
Ans.: (2)

Solution.: $2d\sin\theta = n\lambda$ where $\theta = 30^0, n = 1$ and $\lambda = \dfrac{h}{p} = \dfrac{h}{\sqrt{2m_eE}} = \dfrac{h}{\sqrt{2m_e(eV)}}$.

$$\Rightarrow \lambda = \frac{6.62\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times344}} = \frac{6.62\times10^{-34}}{\sqrt{10017.28\times10^{-50}}} \approx \frac{6.62\times10^{-34}\times10^{25}}{100} \approx 0.66\times10^{-10}\,m$$

Thus $d = \dfrac{n\lambda}{2\sin\theta} = \dfrac{1\times0.66\times10^{-10}\,m}{2\sin30^0} \approx 0.66\times10^{-10}\,m$

Q98. What will be the range of input voltage V_i in which the Zener diode shown in the figure below, conducts?



(1) 20.52 V to 30.72 V (2) 23.52 V to 36.72 V
(3) 26.52 V to 40.72 V (4) 30.52 V to 42.72 V

Ans.: (2)

Solution.: $P_{ZM} = V_Z I_{ZM} \Rightarrow 1200mW = 20V\times I_{ZM} \Rightarrow I_{ZM} = 60\,mA$

$$V_{i_{\min}} = \frac{(R_L + R)V_Z}{R_L} = \frac{(1250\ \Omega + 220\Omega)}{1250\ \Omega}\times20V = 23.52V$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{20V}{1.25k\Omega} = 16\ mA$$

$$I_{R_{\max}} = I_{ZM} + I_L = 60mA + 16mA = 76mA$$

$$V_{i_{\max}} = I_{R_{\max}}R + V_Z = (76\ mA)\,(0.22\ k\Omega) + 20V = 16.72\ V + 20V = 36.72\ V$$

Q100. Find the output voltage of a non-inverting OP-AMP having $R_1 = 100\,k\Omega$, $R_f = 500\,k\Omega$, when the input signal is of 2.0 V.

(1) 6 V (2) 8 V (3) 12 V (4) 16 V

Ans.: (3)

Solution.: $v_o = \left(1 + \dfrac{R_f}{R_1}\right)v_{in} = \left(1 + \dfrac{500\,k\Omega}{100\,k\Omega}\right)2\,volt = 12\,volt$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com