Target IIT-JAM-2017

Test Series-3

Booklet Code: C

Electricity and Magnetism + Oscillation, Waves & Optics

Duration: 2:00 Hours | PHYSICS-PH | Date: 15-01-2017

Maximum Marks: 100

Read the following instructions carefully:

1 Attempt all the questions.

2. **Section-A** contains **30** Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which **ONLY ONE** is correct. From **Q.1 to Q.10** carries 1 Marks and **Q.11 to Q.3**0 carries 2 Marks each.

3. **Section-B** contains **10** Multiple Select Questions(MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which **ONE or MORE than ONE** is/are correct. For each correct answer you will be awarded **2 marks.**

4. Section**-C** contains **20** Numerical Answer Type (NAT) questions. From **Q.41 to Q.50** carries **1 Mark** each and **Q.51 to Q.60** carries **2 Marks** each. For each NAT type question, the value of answer in between 0 to 9.

5. In all sections, questions not attempted will result in zero mark. In Section–A (MCQ), wrong answer will result in negative marks. For all **1 mark** questions, **1/3 marks** will be deducted for each wrong answer. For all **2 marks** questions, **2/3 marks** will be deducted for each wrong answer. In Section–B (MSQ),there is no negative and no partial marking provision. There is no negative marking in Section –C (NAT) as well.

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Section-A : Multiple Choice Questions (MCQ)

Q.1 to Q.10: Carry 1 Mark each.

1. The electric field of a light wave is given by

$$\vec{E} = \hat{i}\,E_0 \cos(kz - \omega t) + \hat{j}\,E_0 \cos(kz - \omega t + \pi/4)$$

The polarization state of the wave is,

(a) Left handed circular (b) Right handed circular
(c) Left handed elliptical (d) Right handed elliptical

2. After a beam of unpolarized light has passed through two perfect loss-free sheets of polarizer, it is noticed that the light intensity has fallen to 12.5% of the initial intensity. The orientation of the second polarizer w.r.t the first polarizer, is

(a) 90º (b) 60º (c) 45º (d) 30º

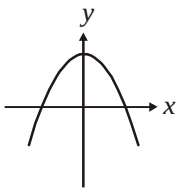
3. Two coherent sources having intensity ratio 81:1 produce interference fringes. The ratio of the intensity of the bright fringe and dark fringe, is

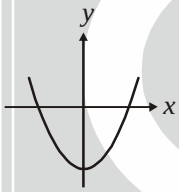
(a) 25:16 (b) 5:4 (c) 41:40 (d) none of these

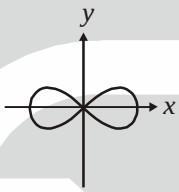
4. The displacement of a particle varies according to

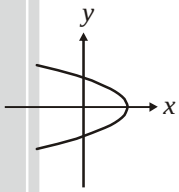
$$r(t) = 4\left[\sin \pi t\,\hat{i} + \cos 2\pi t\,\hat{j}\right]$$

which one is the possible figure represents curve of motion of the particle?

(a) 

(b) 

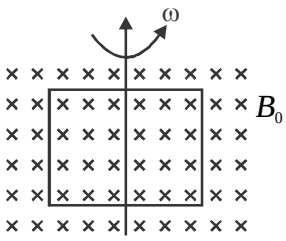
(c) 

(d) 

5. A particle of mass m is executing oscillation about the origin on the x-axis. Its potential energy $U(x) = kx^3$ where k is a positive constant. if amplitude of oscillation is a, then its frequency ω is

(a) Proportional to $\frac{1}{\sqrt{a}}$ (b) Proportional to $\sqrt{a}$
(c) Independent of a (d) Proportional to $a^{3/2}$

6. A source loop of side a and resistance R is rotating with constant angular velocity ω in a constant magnetic field (B_0) as shown in the figure. The average power (P) dissipated in the loop is proportional to



(a) ω (b) ω^2 (c) ω^4 (d) ω^6

7. A plane electromagnetic wave is propagating in non-magnetic, isotropic, dielectric medium is given by

$$\vec{E} = (A\hat{x} + \hat{z})\cos\left(10^9 t - 4x + 4\sqrt{3}\,z\right)$$

Refractive index (n) of the medium is:

(a) 4.2 (b) 2.0 (c) 2.4 (d) 1.5

8. A circular conducting loop of radius 2 cm and resistance 1Ω lies in *x-y* plane. A constant magnetic field (B) of 1T applied along *z*-direction. If radius of loop is reduced from 2 cm to 1 cm, the total charge (Q) passes through given point in the loop is (in coulombs)

(a) 0 (b) 9.4×10^{-4} (c) 9.4×10^{-2} (d) 12.6×10^{-4}

9. The charge per unit length of a circular wire of radius *a* in the *xy*-plane, with its center at the origin, is $\lambda = \lambda_0 \cos\theta$, where λ_0 is a constant and the angle θ is measured from the positive *x*-axis. The electric field at the center of the circle is

(a) $\vec{E} = -\frac{\lambda_0}{4\varepsilon_0 a}\hat{i}$ (b) $\vec{E} = \frac{\lambda_0}{4\varepsilon_0 a}\hat{i}$ (c) $\vec{E} = -\frac{\lambda_0}{4\varepsilon_0 a}\hat{j}$ (d) $\vec{E} = \frac{\lambda_0}{4\pi\varepsilon_0 a}\hat{k}$

10. Assume that a lamp radiates power P uniformly in all the directions. The electric field strength at a distance 'r' from the lamp varies as :

(a) independent of 'r' (b) $\frac{1}{r}$ (c) $\frac{1}{r^2}$ (d) $\frac{1}{r^3}$

Q.11 to Q.30: Carry 2 Marks each.

11. The distance between the successive intensity minima seen on the screen is found to be α-Suppose now the experiment is repeated with the spacing between the two slits being doubled and the whole apparatus being immersed in liquid (Refractive index 1.5). The distance between two successive intensity maxima, will be

(a) $\frac{\alpha}{2}$ (b) $\frac{\alpha}{3}$ (c) $\frac{3\alpha}{2}$ (d) $\frac{2\alpha}{3}$

12. Two thin lens of power +10 D and – 4 D are in contact and are coaxially situated. The power of the combination is,

(a) + 3 D (b) + 14 D (c) + 6 D (d) – 14 D

13. Consider a refraction at a concave spherical surface (separating glass-air medium). For the image to be real, the object distance "u" should satisfy the following condition: Where R is the radius of curvature of the spherical surface)

(a) $u > \frac{R}{2}$ (b) $u < \frac{R}{2}$ (c) $u > 2R$ (d) $u > 3R$

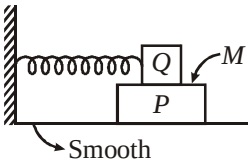
14. A telescope having larger objective diameter, will have

(a) higher resolving power (b) lower resolving power
(c) resolving power independent of diameter (d) oscillatory resolving power

15. The vibration of string of length 60 cm fixed at both ends are represented by the equation $y = 4\sin(\pi x/15)\cos 96\pi t$, all particles of string are

(a) At rest at the same time twice in every period of oscillation
(b) At rest at the same time only once in every period of oscillation
(c) Never at rest at the same time
(d) Never at rest at all

16. A block P of mass m is placed on a frictionless horizontal surface. Another block Q of same mass is kept on P and connected to the wall with the help of a spring constant k as shown in the figure. μ_s is the coefficient of the friction between P and Q. The block move together performing SHM of amplitude A. The maximum value of the friction force between P and Q



(a) kA (b) kA/2 (c) zero (d) $\mu_s mg$

17. A motor cyclist is moving towards a stationary car which is emitting sound of 165 Hz and a police car is chasing the motor cyclist blowing siren at frequency 176 Hz. If the speed of police car is 22 m/s, then the speed of motor cyclist for which the motor cyclist hears no beats is
(a) zero (b) 11 m/s (c) 22 m/s (d) 33 m/s

18. A particle is executing SHM with amplitude *A*. At displacement $x = -\frac{A}{4}$, force acting on the particle a *F*, potential energy of the particle is *v*, velocity of particle is u and K.E. is K. Assuming potential energy to be zero at mean position. At displacement $x = \frac{A}{2}$
(a) a force acting on the particle will be 2F (b) potential energy of particles will be -4*v*.
(c) velocity of particle will be $\sqrt{\frac{4}{5}}u$ (d) K.E. of particle will be 0.8K.

19. Assuming S_1 and S_2 as interfering sources, let S_1 be ahead of the phase by 90º relative to S_2. If an observation point *P* is such that $PS_1 - PS_2 = 1.5\lambda$, the phase difference between the light from S_1 and S_2 reaching *P* is
(a) 3π (b) $\frac{5\pi}{2}$ (c) $\frac{7\pi}{2}$ (d) 4π

20. In a double slit experiment, instead of taking slits of equal widths, one slits is made twice as wide as the other. Then in the interference pattern.
(a) The intensities of both the maxima and the minima increases
(b) The intensity of the maxima increases and the minima has zero intensity
(c) The intensity of the maxima decreases and that of the minima increases
(d) The intensity of the maxima decreases and the minima has zero intensity

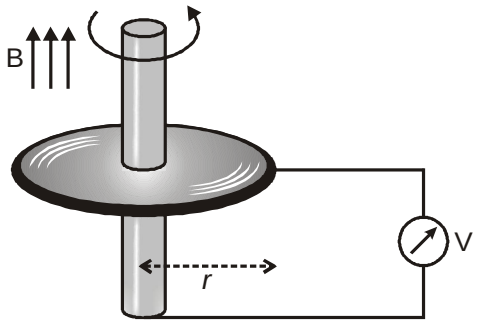
21. An electromagnetic wave is normally incident on an air-dielectric interface. The dielectric media is isotropic and non magnetic. The magnetic field of electromagnetic wave in dielectric medium is given by

$$\vec{B} = 4\times10^{-8}\left(A\hat{i} + 3\hat{j}\right)e^{i\left(3x+4y-5\times10^{8}t\right)}\ \text{wb/m}^2$$

Where A is same constant. The fraction of energy reflected from the dielectric interface is:
(a) 1 (b) 0.25 (c) 0.33 (d) 0.5

22. A sphere S of radius R has volume charge density $\rho(r) = \beta r^2$, where 'r' is distance from centre and β is a constant. The electric potential on the surface of sphere is
(a) $\frac{\beta R^4}{4\varepsilon_0}$ (b) $\frac{\beta R^3}{4\varepsilon_0}$ (c) $\frac{\beta R^4}{5\varepsilon_0}$ (d) $\frac{\beta R^3}{5\varepsilon_0}$

23. A conducting circular disc of radius r and resistivity ρ rotates with an angular velocity ω in a magnetic field B perpendicular to it. A voltmeter is connected as shown in the figure below.



Assuming its internal resistance to be infinite, the reading on the voltmeter
(a) depends on ω, B, r and ρ
(b) depends on ω, B and r, but not on ρ
(c) is zero because the flux through the loop is not changing
(d) is zero because a current flows in the direction of B

24. An alternating sinusoidal current of frequency $\omega = 1000\ s^{-1}$ flows in the winding of a straight solenoid whose cross-sectional radius is equal to R = 6.0 cm. The ratio of average values of electric and magnetic energies at surface of solenoid is

(a) 1×10^{-14} (b) 5×10^{-15} (c) 1×10^{-16} (d) 1×10^{-12}

25. The electric and magnetic fields of an electromagnetic wave in vacuum are given by $\vec{E} = \hat{i}E_0 \sin(kz - \omega t)$ and $\vec{B} = \hat{j}B_0 \sin(kz - \omega t)$, respectively. The total energy density associated with the wave is:

(a) $\frac{\epsilon_0 E_0^2}{4}$ (b) $\frac{\epsilon_0 E_0^2}{2}$ (c) $\frac{B_0^2}{\mu_0}$ (d) $\frac{B_0^2}{4\mu_0}$

26. In a region of space, a time dependent magnetic field, $B(t) = 0.4t$ Tesla, points vertically upwards. Consider a horizontal circular loop of radius 2 cm in this region. The magnitude of the electric field (in mV/m) induced in the loop is

(a) 2.00 (b) 4.00 (c) 6.25 (d) 12.50

27. A plane electromagnetic wave with

$$\vec{H} = 0.5\cos\left(4\times10^8 t - 2z\right)\hat{y}\ \text{A/m};\ \vec{E} = 80\,\pi\cos\left(4\times10^8 t - 2z\right)\hat{x}\ \text{V/m}$$

travelling in an isotropic magnetic dielectric medium. The relative permeability (μ_r) of medium is:

(a) 4 (b) 2.25 (c) 1.25 (d) 2

28. A sphere of radius R has surface charge density $\sigma = \sigma_0 \sin\theta\cos\phi$. The electric dipole moment $(\vec{p})$ about the centre of sphere is

(a) $\frac{4}{3}\pi\sigma_0 R^3\,\hat{i}$ (b) $\pi\sigma_0 R^3\,\hat{i}$ (c) $\frac{4}{3}\pi\sigma_0 R^3\,\hat{j}$ (d) $\frac{\pi\sigma_0 R^3}{3}\,\hat{j}$

29. A dielectric sphere of radius 'R' has polarization $\vec{P} = \beta\hat{r}$. The electric potential at centre of sphere is

(a) $\frac{\beta R}{\epsilon_0}$ (b) $-\frac{\beta R}{\epsilon_0}$ (c) $\frac{\beta}{3\epsilon_0}$ (d) $\frac{\beta}{\epsilon_0}$

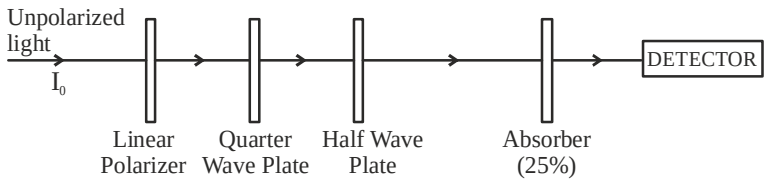
30. Suppose the electric field in some region is found to be $\bar{E} = kr^2\vec{r}$ (where k is some constant). The total charge contained in the sphere of radius R centred at origin is:

(a) $5\epsilon_0 kr^2$ (b) $4\epsilon_0 kr^2$ (c) $4\pi\epsilon_0 kR^5$ (d) $\frac{16}{5}\pi\epsilon_0 kR^5$

Section-B : Multiple Select Questions (MSQ)

Q.31 to Q.40: Carry 2 Marks each.

31. Consider the following diagram:



Which of the following is/are CORRECT ?
(a) Polarization state after QWP will be circularly polarize
(b) Polarization state after HWP will be circularly polarize
(c) Intensity of light after QWP will be $I_0/4$.
(d) Intensity of light after absorber will be $3I_0/8$

32. Fraunhoffer double slit diffraction pattern is observed in the focal plane of lens of focal length 0.5 m. The wavelength of the incident light is 500 nm. The distance between two adjacent maxima to zero order maximum, is 5 mm and the fourth order maximum is missing. Which of the following statements is/are CORRECT ?
(a) Width of each slit is 0.025 mm
(b) Centre to centre seperation between slits is 0.075 mm
(c) Opaque space distance is 0.1 mm
(d) Number of lines per cm is 2

33. The plane wave represented by an equation of the form $y = f(x - vt)$ implies the propagation along the positive x-axis without change of shape with consant velocity v, then its satisfy

(a) $\frac{dy}{dt} = -v\left(\frac{dy}{dx}\right)$ (b) $\frac{dy}{dt} = -v\frac{d^2y}{dx^2}$ (c) $\frac{d^2y}{dt^2} = v^2\left(\frac{d^2y}{dx^2}\right)$ (d) $\frac{d^2y}{dt^2} = v\left(\frac{d^2y}{dx^2}\right)$

34. A block of mass m is connected to a spring, the other end of which is fixed. There is also a viscous damping mechanism. The following observation have been made on the system:
(1) If the block is pushed horizontally with force equal to mg, the static compression of the spring is equal to h.
(2) The viscous resistive force is equal to mg if the block moves with a certain known speed u.
Which of the following is/are correct?

(a) The natural frequency of the oscillation is $\omega_0 = \sqrt{\frac{g}{h}}$

(b) If $u = 3\sqrt{gh}$, the angular frequency of the damped oscillation is $\omega = \sqrt{\frac{35g}{70h}}$

(c) The quality factor Q of this oscillator is 3.

(d) energy relaxation time of oscillation is $z = 3\sqrt{\frac{h}{g}}$

35. Second overtone frequency of a closed pipe and fourth harmonic frequency of an open pipe are same. Then choose the ***CORRECT*** options.
(a) fundamental freuqency of closed pipe is more than the fundamental frequency of open pipe
(b) first overtone frequency of closed pipe is more than the first overtone frequency of open pipe.
(c) fifteenth harmonic frequency of closed pipe is equal to twelth harmonic frequency of open pipe.
(d) tenth harmonic freuqency is closed pipe is equal to twelth harmonic frequency of open pipe.

36. An electric dipole of dipole moment $p_0\hat{i}$ is placed at origin which of the following statements is/are correct?
(a) Electric flux through *xy* plane is zero
(b) Electric flux through *yz* plane is zero
(c) Electric flux through *xz* plane is zero
(d) Electric potential at a point in space is $\dfrac{p_0 x}{4\pi \in_0 (x^2+y^2+z^2)^{3/2}}$

37. Two electromagnetic waves superpose to give resultant electric field $\vec{E} = E_0 \cos kz \sin \omega t\ \hat{i}$. Which of the following statements is correct
(a) corresponding magnetic field is $\vec{B} = \dfrac{E_0 k}{\omega} \sin kz \cos \omega t\ \hat{j}$
(b) two waves are propagating in opposite direction along *z*-axis
(c) average value of energy density is $\dfrac{1}{2}\varepsilon_0 E_0^2$
(d) average value of Poynting vector $\langle \vec{S} \rangle$ is zero.

38. An electron revolves around a long wire of uniform linear charge density. Which of the following statements is/ are correct.
(a) speed of the particle is independent of distance from wire
(b) acceleration of particle is independent of distance from wire
(c) acceleration of particle is inversely proportional to distance from wire
(d) work done on electron due to electric force is zero

39. A particle of mass *m* and charge *q* is thrown into a uniform magnetic field $B_0\hat{k}$ with velocity $v_1\hat{i} + v_2\hat{j} + v_3\hat{k}$. Which of the following statements is / are correct.
(a) radius of helix is $\dfrac{mv_3}{qB_0}$
(b) radius of helix is $\dfrac{m\sqrt{v_1^2+v_2^2}}{qB_0}$
(c) pitch of helix is $\dfrac{2\pi m v_3}{qB_0}$
(d) time of revolution is independent of v_1, v_2, v_3

40. A long cylindrical cable carries a current I distributed on its cross section in such a way that current density is proportional to distance from axis. If radius of cable R then which of the following option is / are correct.

(a) Current density is $\frac{Ir}{\pi R^3}$

(b) Magnetic field at a point $r < R$ is $\frac{\mu_0 I r^2}{2\pi R^3}$

(c) Magnetic field at a point $r > R$ is $\frac{\mu_0 I}{2\pi r}$

(d) Poynting vector at surface of cable is radially inward

Section-C : Numerical Answer Type (NAT)

Q.41 to Q.50: Carry 1 Mark each.

41. Plane transmission grating "A" has 2000 rulings in 4 cm and plane transmission grating "B" has 1000 rulings in 2 cm. The ratio of their resolvings powers, will be _____

42. A parallel beam of light of wavelength 5890 Å, is incident perpendicular on a large diffraction grating having 100 lines per mm. The highest order maxima that will be visible, is _____

43. Two radio stations broadcast their programmes at the same amplitude A, and a slightly different frequencies v_1 and v_2 respectively, where $v_2 - v_1 = 10^3$ Hz. A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity $\geq 2A^2$. The time for which the detector remains idle in each cycle of the intensity of the signal is _____ $\times 10^{-4}$ s.

44. A particle is subjected to two SHM, one along the x-axis and the other on a line making an angle 45° with the x-axis, the two motions are given by

$X = 4\sin 5\pi t$

and $S = 5\sin 5\pi t$

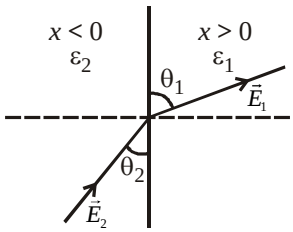
The amplitude of the resultant motion is _____

45. Three sinusoidal waves have the same frequency with amplitude A, 2A, 4A while their phase angles are 0, $\frac{\pi}{2}$, π respectively. The amplitude of the resultant wave is _____ **A.**

46. Suppose that free charges are present in a material of dielectric constant $\varepsilon = 10$ and resistivity $\rho = 10^{11}\ \Omega$-m. Using Ohm's law and the equation of continuity for charge, the time required for the charge density inside the material to decay by $1/e$ is _____ seconds

47. Magnetic field at a point is given to be $\vec{B} = ax\hat{i} + 2y\hat{j} + 3z\hat{k}$. Value of a must be _____

48. The half space regions $x > 0$ and $x < 0$ are filled with dielectric media of dielectric constants $\varepsilon_1 = 2$ and $\varepsilon_2 = 4$ respectively. There is a uniform electric field in each part. In the right half, the electric field makes an angle θ_1 to the interface. The corresponding angle in the left half is θ_2 then $\frac{\tan\theta_1}{\tan\theta_2}$ is _____



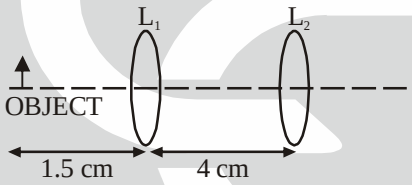
49. An electric dipole of dipole moment $p_0\hat{i}$ is placed in an external electric field $\vec{E} = A(x^3 - x^2)\hat{i}$. Force on dipole is zero at $x_1(\neq 0)$ and maximum at x_2, then value of $\frac{x_1}{x_2}$ is _____

50. A sphere of radius R has volume charge density $\rho = \rho_0\left(1 - \frac{r}{R}\right)$. Electric field is maximum at $r = \frac{R}{\beta}$, value of β is _____

Q.51 to Q.60: Carry 2 Marks each.

51. 10. The phase differce between two points, which are 1 cm apart in a wave of wavelength 1 m, is (in degrees) _____

52. Two thin convex lenses L_1 and L_2 with focal lengths 1 cm and 2 cm respectively, are separated by a distance of 4 cm along their axis. (As shown below)

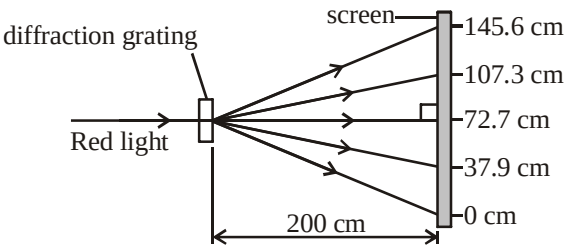


The ratio of the final image size to the object size, is _____

53. In the Newton's ring experiment, the diameter of the mth dark ring is 8 mm and $(m + 10)^{th}$ dark ring is 12 mm. If the radius of curvature of the convex surface of the lens, is 3m, then the wavelength of the light used will be _____ (in Å).

54. A source of sound is moving along a circular orbit of radius 3 m with an angular velocity of 10 rad/s. A sound detector located for away from the source is executing simple harmonic motion along the line BD (Fig.) with an amplitude BC = CD = 6 m. The frequency of oscillation of the detector is 5/π per second. The source is at the point A when the detector is at the point B. If the source emits a continuous sound wave of the frequency 340 Hz, the ratio of maximum to the minimum frequencies recorded by the detector is _____ Hz.

55. A diffraction grating with 250 lines per millimetre is placed in front of a monochromatic source of red light. A screen placed 200cm beyond the grating has red light images measured at certain positions on a scale on the screen, as shown in figure.



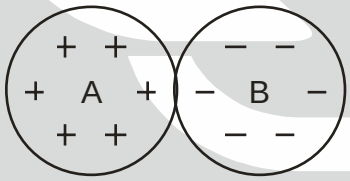
The wavelength of the red light used is _____nm.

56. A parallel plate capacitor is formed by two circular conducting plates of radius a separated by a distance d, where $d \ll a$. It is being slowly charged by a current that is nearly constant. At an instant when the current is I, the magnetic induction between the plates at a distance $a/2$ from the centre of the plate, is $\frac{\mu_0 I}{a}\beta$, value of β is .....

57. A sphere of radius R has uniform volume charge density ρ and uniform surface charge density σ. If electric potential outside the sphere is constant then value of $\rho R/\sigma$ is .....

58. Electric field associated with an electromagnetic wave in vacuum is $\vec{E} = 2\hat{i}\cos(kz - \omega t)$, at $t = 0$ a particle of charge $1\mu c$ has velocity $\sqrt{3}\times 10^8$ m/s and it is passing through origin.
Force on particle is ..... $\times 10^{-6}$N

59. Two uniformly charged insulating solid spheres A and B, both of radius a, carry total charges $+Q$ and $-Q$, respectively. The spheres are placed touching each other as shown in the figure.



If the potential at the center of the sphere A is V_A and that at the center of B is V_B, then the difference $V_A - V_B$ is $\frac{Q}{4\pi\varepsilon_0 a}\beta$, value of β is .....

60. A plane EMW with a magnetic field $\vec{B}$ of amplitude 3×10^{-6} T travelling in vacuum, falls normally on a surface and is totally reflected. Pressure exerted on the surface is (in Pascal) .....

***** END OF QUESTION PAPER *****

Space for Rough Work

IIT-JAM PHYSICA-PH

TEST SERIES - 3

(EMT, Oscillations, waves and Optics)

Date : 15-01-2017

Booklet: C

ANSWER KEY

Section-A : Multiple Choice Questions (MCQ)

1. (c)	**2.** (b)	**3.** (a)	**4.** (a)	**5.** (b)
6. (b)	**7.** (c)	**8.** (b)	**9.** (a)	**10.** (b)
11. (b)	**12.** (c)	**13.** (d)	**14.** (a)	**15.** (a)
16. (b)	**17.** (c)	**18.** (d)	**19.** (c)	**20.** (a)
21. (b)	**22.** (c)	**23.** (b)	**24.** (a)	**25.** (b)
26. (b)	**27.** (d)	**28.** (a)	**29.** (b)	**30.** (c)

Section-B : Multiple Select Questions (MSQ)

31. (a),(b),(d)	**32.** (a),(d)	**33.** (a),(c)	**34.** (a),(d)
35. (b),(c),(d)	**36.** (a),(c), (d)	**37.** (a),(b), (d)	**38.** (a),(c), (d)
39. (b),(c), (d)	**40.** (b), (c), (d)		

Section-C : Numerical Answer Type (NAT)

41. (2)	**42.** (16)	**43.** (5)	**44.** (8.30 to 8.40)
45. (3.59 to 3.62)	**46.** (8 to 10)	**47.** (–5)	**48.** (2)
49. (2)	**50.** (1.5)	**51.** (3.6)	**52.** (4)
53. (6665 to 6670)	**54.** (1.733)	**55.** (610 to 615)	**56.** (0.25)
57. (–3)	**58.** (4)	**59.** (2)	**60.** (0.70 to 0.80)