IIT-JAM-2016

Test Series-7

FULL LENGTH TEST SERIES-3

Duration: 03:00 Hours **PHYSICS-PH** **Date: 27-01-2016**

Maximum Marks: 100

Read the following instructions carefully:

1 Attempt all 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 provisions. There is no negative marking in Section –C (NAT) as well.

Name of Student .....

College Name .....

Batch : ☐ Weekend ☐ Regular ☐ Test Series ☐ Correspondence

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Section-A : Multiple Choice Questions (MCQ)

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

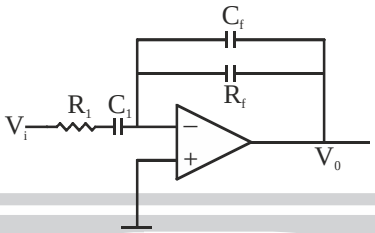
1. If a particle executes SHM with frequency v, its kinetic energy varies with a frequency

(a) $\sqrt{v}$ (b) $2v$ (c) v^2 (d) $\frac{v}{2}$

2. In case of forced vibration if f_0 be the undamped natural frequency and f_1 and f_2 be the half-power frequencies, then

(a) $f_0 = \frac{1}{2}(f_1 + f_2)$ (b) $f_0 = \frac{1}{\sqrt{2}}(f_1 + f_2)$ (c) $f_0 = \frac{f_1 f_2}{f_1 + f_2}$ (d) $f_0 = \sqrt{f_1 f_2}$

3. For the given circuit diagram shown below



The type of filter is

(a) Band pass filter (b) Band reject filter

(c) All pass filter (d) Low pass filter

4. For an R_C phase shift oscillator to products an additional phase shift of 180° by using its feedback network the minimum number of R_C stages required is

(a) 2 (b) 3 (c) 4 (d) 5

5. Which of the following field is **NOT** conservative in nature?

(a) $x\,\hat{x} + y\,\hat{y} + z\,\hat{z}$ (b) $\left(2x^3y^4 + x\right)\hat{x} + \left(2x^4y^3 + y\right)\hat{y}$

(c) $yz\,\hat{x} + xz\,\hat{y} + xy\,\hat{z}$ (d) $\left(x^2 - yx\right)\hat{x} + \left(y^2 - xy\right)\hat{y}$

6. $f(x)$ is a periodic function of x with a period of 2π. In the interval $-\pi < x < \pi$, $f(x)$ is given by

$$f(x) = \begin{cases} 0 & \text{for } -\pi < x < 0 \\ \sin x & \text{for } 0 < x < \pi \end{cases}$$

In the expansion of f(x) as a Fourier series of sine and cosine functions, the coefficients of cos (2x) is:

(a) $\frac{2}{3\pi}$ (b) $\frac{1}{\pi}$ (c) 0 (d) $-\frac{2}{3\pi}$

7. Consider the Bohr model of the hydrogen atom. If α is the fine structure constant, then the velocity of the electron in $n = 2$ orbit is

(a) $\frac{\alpha c}{2}$ (b) αc (c) $2\alpha c$ (d) $\frac{\alpha c}{4}$

8. Consider a particle of mass m which is occupying any one of the energy eigenstates of a one-dinesional box of length L. The force exerted by the particle on the boundary walls is proportional to

(a) L (b) $\frac{1}{L}$ (c) $\frac{1}{L^2}$ (d) $\frac{1}{L^3}$

9. If g_0 is the statistical weight of the ground state, the entropy at absolute zero in a canonical ensemble can be expressed as

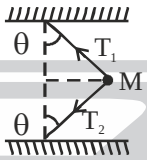
(a) $S = k\ \ell n\ g_0$ (b) $S = -k\ \ell n\ g_0$ (c) $S = \frac{1}{k}\ \ell n\ g_0$ (d) None of these

10. A charge distribution has the charge density given by $\rho = Q\{\delta(x - x_0) - \delta(x + x_0)\}$. For this charge distribution the electric field at $(2x_0, 0, 0)$

(a) $\frac{2Q\hat{x}}{9\pi \in_0 x_0^2}$ (b) $\frac{Q\hat{x}}{4\pi \in_0 x_0^3}$ (c) $\frac{Q\hat{x}}{4\pi \in_0 x_0^2}$ (d) $\frac{Q\hat{x}}{16\pi \in_0 x_0^2}$

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

11. A particle of mass *M* is attached to the mid-ponit of a string of length *'L'* stretched vertically shown in the figure below. The ends of the string are fixed to rigid supports. The time period of small horizontal oscillation of the mass is (neglecting the weight of the string)



(a) $\pi\sqrt{\frac{2ML}{T_1 + T_2}}$ (b) $2\pi\sqrt{\frac{ML}{T_1}}$ (c) $\pi\sqrt{\frac{ML}{T_1 + T_2}}$ (d) $\pi\sqrt{\frac{ML}{T_2}}$

12. A diffraction grating used at normal incidence gives a line 5400Å in certain order superposed on another line 4050Å of the next higher order. If the angle of diffraction be 30º. The number of lines/cm on the grating is

(a) 3000 (b) 3086 (c) 3056 (d) 4000

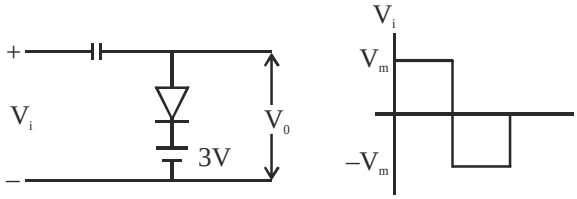
13. In a Lloyd's mirror experiment, the reflectivity of the mirror is $\frac{3}{4}$. The ratio of the intensities of the interference maxima and minima is

(a) 194 : 1 (b) $\sqrt{3} : 2$ (c) 184 : 3 (d) 100 : 15

14. For an HCP structure its packing efficiency is given by

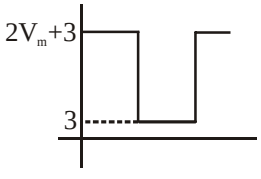
(a) 60.4% (b) 70.4% (c) 74% (d) 90.2%

15. For the given Pn junction diode circuit shown below

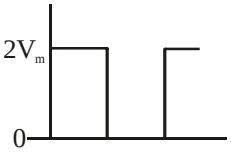


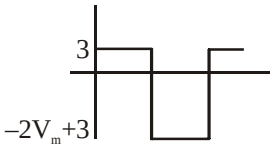
The correct output waveform is

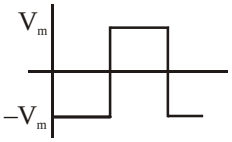
(a)



(b)



(c) 

(d) 

16. Consider the following matrix $A=\begin{bmatrix}1 & 1\\ 2 & 1\end{bmatrix}$. Then $A^6-2A^5-A^4+A^3-A^2-2A+I$ can be written as

(a) A^2+A+I (b) A^2-A+I (c) A^2-2A+I (d) A^2-2A-I

17. If $\vec{F}=x\hat{i}-y\hat{j}+\left(z^2-1\right)\hat{k}$, then the value of $\oint \vec{F}\cdot\hat{n}dS$, where S in the closed surface bounded by the planes $z = 0$, $z = b$ and the cylinder $x^2+y^2=a^2$ is

(a) πab (b) $2\pi ab$ (c) πa^2b^2 (d) $2\pi a^2b^2$

18. Let A be a 3×3 matrix such that $\det(A)=-2$, then $\det\left(-2A^{-1}\right)$ is equal to

(a) 1 (b) 4 (c) -4 (d) -1

19. Consider a particle of mass m moving in 1-D potential $V(x)=V_0+\beta x^2$, then the minimum energy of the particle will be

(a) $V_0+\sqrt{\frac{\beta\hbar^2}{2m}}$ (b) $V_0+\sqrt{\frac{2\beta\hbar^2}{m}}$ (c) $V_0+\sqrt{\frac{\beta\hbar^2}{4m}}$ (d) $V_0+\sqrt{\frac{3\beta\hbar^2}{4m}}$

20. There are only three anti-symmetric bound states for a particle of mass 'm' and energy 'E', in a 1-D finite potential well of the form given below:

$$V(x)=\begin{cases}0 & \text{for } |x|<\frac{3a}{4}\\ \frac{3}{2}V_0 & \text{for } |x|\geq\frac{3a}{4}\end{cases}$$

The range of the V_0 is

(a) $\frac{64\pi^2\hbar^2}{27ma^2}<V_0<\frac{16\pi^2\hbar^2}{3ma^2}$ (b) $\frac{100\pi^2\hbar^2}{27ma^2}<V_0<\frac{196\pi^2\hbar^2}{27ma^2}$

(c) $\frac{32\pi^2\hbar^2}{9ma^2}<V_0<\frac{8\pi^2\hbar^2}{3ma^2}$ (d) $\frac{4\pi^2\hbar^2}{3ma^2}<V_0<\frac{100\pi^2\hbar^2}{27ma^2}$

21. Consider the following successive radioactive transformation $P\rightarrow Q\rightarrow R$, with λ_P and λ_Q as the decay constants of the sample P and Q. Here R is a stable sample. Assume that at $t = 0$, $N_P=N_0$, $N_Q=0$, $N_R=0$, where N_P, N_Q and N_R are the number of atoms in the samples P, Q and R respectively. The number of atoms in the sample Q at a later time t, will be

(a) $\frac{\lambda_P N_0}{\lambda_Q-\lambda_P}\left[e^{-\lambda_P t}-e^{-\lambda_Q t}\right]$ (b) $\frac{\lambda_P N_0}{\lambda_P-\lambda_Q}\left[e^{-\lambda_P t}-e^{-\lambda_Q t}\right]$

(c) $\frac{N_0}{\lambda_P-\lambda_Q}\left[e^{-\lambda_P t}-e^{-\lambda_Q t}\right]$ (c) $\frac{\lambda_P N_0}{2\left(\lambda_P-\lambda_Q\right)}\left[e^{-\lambda_P t}-e^{-\lambda_Q t}\right]$

22. The r.m.s. speed of molecules in a sample of helium is 5/7th of that of the molecules of hydrogen. If the temperature of hydrogen sample is 0°C, the temperature of helium sample is – (nearest integer)
(a) 100°C (b) 278°C (c) 0°C (d) 6°C

23. A heat pump working on the carnot's cycle maintains the inside temperature of a house at 22°C by supplying 450 kJ/s. If the outside temperature is 0°C, then heat taken in kJ/s, from the outside air is approximately-
(a) 487 (b) 470 (c) 467 (d) 417

24. If an EM wave is represented by $\vec{E}(\vec{r},t)=\vec{E}_0\, e^{j(\vec{k}\cdot\vec{r}-\omega t)}$ and $\vec{B}(\vec{r},t)=\vec{B}_0\, e^{j(\vec{k}\cdot\vec{r}-\omega t)}$ then

(a) $\vec{k}\cdot\left(\vec{E}_0\times\vec{B}_0\right)=0$ (b) $\frac{d\omega}{dk}=0$ (c) $\vec{k}\times\left(\vec{E}_0\times\vec{B}_0\right)=0$ (d) none of these

25. The motion of a particle of mass m is described in a non-inertial frame of reference that is rotating with a uniform angular velocity ω. If *r* denotes the position of the particle in the non-inertial frame

(a) The centrifugal force on the particle is $-m\omega^2\dot{r}$

(b) The centrifugal force on the particle is $-m\vec{\omega}\times\left(\vec{\omega}\times\vec{r}\right)$

(c) The Coriolis force on the particle is $-m\left(\omega\times\frac{dr}{dt}\right)$

(d) The Coriolis force on the particle $-2m\omega^2 r$

26. A particle of mass M moving in a straight line with speed υ collides with a stationary particle of the same mass. In the center of mass coordinate system, the first particle is deflected by 90°. The speed of the second particle, after collision, in the laboratory system will be:
(a) $v/\sqrt{2}$ (b) $\sqrt{2}v$ (c) v (d) $v/2$

27. Two uniform thin rods of equal length L, and masses M_1 and M_2 are joined together along the length. The moment of inertia of the combined rod of length 2L about an axis passing through the mid-point perpendicular to the length of the rod is,

(a) $(M_1+M_2)\frac{L^2}{12}$ (b) $(M_1+M_2)\frac{L^2}{6}$ (c) $(M_1+M_2)\frac{L^2}{3}$ (d) $(M_1+M_2)\frac{L^2}{2}$

28. A circular loop of radius 'r' is lying in the *xy*-plane with its centre at the origin. If there exists a time varying magnetic field $\vec{B}(t)=B_0e^{-\alpha t}\hat{z}\,(B_0>0,\alpha>0)$, then the induced emf in the loop is

(a) $-\pi r^2\alpha B_0e^{-\alpha t}$ (b) $-\pi r^2B_0e^{-\alpha t}$ (c) $\pi r^2B_0e^{-\alpha t}$ (d) $\pi r^2\alpha B_0e^{-\alpha t}$

29. A particle is moving in a plane. Its velocity $\vec{v}$ is

(a) $r\dot{\theta}\hat{r}$ (b) $\dot{r}\hat{r}+r\dot{\theta}\hat{\theta}$ (c) $\dot{r}\hat{r}$ (d) $r\dot{\theta}\hat{\theta}$

30. A rocket starts vertically upward with a speed v_0. The velocity of the rocket at a height h from the earth surface is (Given, R is the radius of the earth and g is the acceleration due to gravity on the earth's surface).

(a) $\sqrt{v_0^2-\frac{gh}{1+2h/R}}$ (b) $\sqrt{v_0^2-\frac{2gh}{1+h/R}}$ (c) $\sqrt{v_0^2-\frac{gh}{1+h/R}}$ (d) $\sqrt{v_0^2-\frac{gh}{1-h/R}}$

Section-B : Multiple Select Questions (MSQ)

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

31. Consider a grating of width 5 cm with slits of width a = 0.001 mm separated by a distance of 0.002 mm. The incident light has wavelength $\lambda = 550\ nm$. Choose the following correct statements.

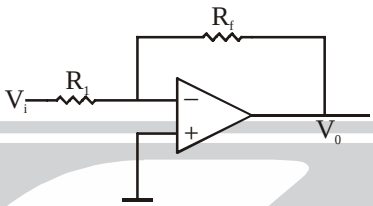
(a) the maximum number of observable orders is 5

(b) angular width of principal maximum is $2.2\times10^{-5}\ rad$

(c) third order interference maxima will be missing.

(d) angular width of principal maximum is

32. For the given OP-AMP circuit shown below as



The correct statements are

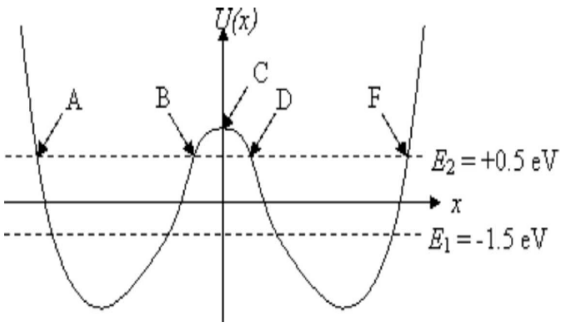
(a) It is current controlled current source

(b) It is a voltage controlled voltage source

(c) It has shunt series connections

(d) It has series shunt connection

33. An electron is moving in the potential *U(x)* shown below. The energies, E_1 = -1.5 *eV* and E_2 = +0.5 *eV*, of the two lowest energy states are indicated by the dashed lines. $\psi_1(x)$ and $\psi_2(x)$ are the wave functions of the ground state and first excited state respectively. Which one of the following statements is **CORRECT**?



(a) $\psi_1(A) = \psi_1(F)$

(b) $\psi_2(A) = -\psi_2(F)$

(c) Both $\psi_1(x)$ and $\psi_2(x)$ are proportional to sin(*kx*) in the regions $A < x < B$ and $D < x < F$ (though *k* might be different for $\psi_1(x)$ and $\psi_2(x)$)

(d) $\frac{d\psi_1}{dx} = 0$ at $x = C$

34. A particle moves counterclockwise along the curve $3x^2 + y^2 = 3$ from the point (1,0) to a point $P(\theta)$ [where θ is angular coordinate of point P w.r.t the origin], under the action of the force

$$\vec{F}(x, y) = \frac{x}{y}\hat{i} + \frac{y}{x}\hat{j}$$

The value of θ of the possible location of the particle such that the work done by the force field $\vec{F}$ is unity, are

(a) 28.6^0 (b) 38.2^0 (c) 49.5^0 (d) 60^0

35. Suppose a plane EM-wave with electric field

$$\vec{E} = \hat{x}10\cos(kz - \omega t)V \cdot m^{-1}$$

is incident from air on a dielectric occupying the region $z \geq 1$. Assuming that the permitativity of the medium is $4 \in_0$ and permeability μ_0.

(a) the magnitude of reflection coefficient is $\frac{1}{3}$ (b) the amplitude of transmission coefficient is $\frac{2}{3}$

(c) electric field of reflected wave is $\vec{E}_r = -\hat{x}\frac{10}{3}\cos(kz + \omega t)V \cdot m^{-1}$

(d) electric field of transmitted wave is $\vec{E}_t = \hat{x}\frac{20}{3}\cos(kz - \omega t)V \cdot m^{-1}$

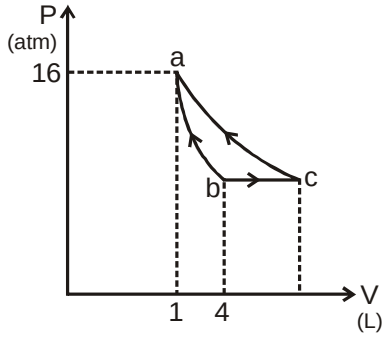
36. In a hypothetical thermodynamic process, internal energy of an ideal gas varies with volume as $U = \alpha V^{\beta}$, where α and β are constants. If the internal energy of the gas increases by ΔU and W is the work done, then

(a) $P = (\gamma - 1)\,\alpha\, V^{\beta - 1}$ (b) $W = \frac{\gamma}{\beta}\Delta U$

(c) $P = \gamma\,\alpha\, V^{\beta}$ (d) $W = \frac{(\gamma - 1)}{\beta}\Delta U$

(P is pressure and γ is adiabatic exponent)

37. Figure shows three processes for an ideal gas. The temperature at '*a*' is 600 K, pressure 16 atm., and volume 1L. The volume at '*b*' is 4L. Out of two processes *ab* and *ac* one is adiabatic and other is isothermal. The ratio of speed, heat of the gas is 1.5. Choose the correct statements:



(a) Process *ab* is adiabatic

(b) Pressure at '*b*' and '*c*' is 4 atm.
(c) Temperature at '*b*' and '*c*' is 300 K and 600 K
(d) Work done in process *bc* is 8 atm

38. Choose the correct statement
(a) the laws of conservation of angular momentum is a consequence of isotropy of space.
(b) homogeneity of time leads to the conservation of total mechanical energy
(c) laws of conservation of linear momentum is a consequence of homogeneity of space
(d) the generalized momentum conjugate to a cyclic coordinate is a constant of motion.

39. Consider the following vector field:

$$\vec{A} = -\frac{y}{x^2+y^2}\hat{i} + \frac{x}{x^2+y^2}\hat{j}$$

Which of the following statements is/are **CORRECT**?

(a) The vector field is conservative in nature.

(b) The vector field is not conservative in nature.

(c) Work done by the vector field on a particle moving along the circle $x^2 + y^2 = 1$ (in the x-y plane, described in counter clockwise direction) is zero.

(d) Work done by the vector field on a particle moving along the circle $x^2 + y^2 = 1$ (in the x-y plane, described in counter clockwise direction) is 2π units.

40. An electret sphere of radius 'a' centred at the origin carries a frozen-in polarization $\vec{P} = k\vec{r}$, where *k* is consant and *r* is the distance from the centre.
(a) polarization volume charge density is –3*k*.

(b) electric field at a point ($r < a$) is given by $\vec{E} = -\frac{kr}{\epsilon_0}\hat{r}$

(c) electric field at a point ($r > a$) is given by $\vec{E} = 0$

(d) $\vec{D}$ is zero everywhere.

Section-C : Numerical Answer Type (NAT)

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

41. The refractive index of water is 1.33. The angle of polarisation of light reflect from the surface of a pond is ..... degree.

42. For the given logic circuit shown below

The minimum numbers of two input NOR GATE required to implement the circuit is .....

43. A one-dimensional harmonic oscillator is in the superposition of number states $|n\rangle$, given by

$$|\psi\rangle = \frac{\sqrt{3}}{2}|1\rangle + \frac{1}{2}|3\rangle$$

The average energy of the oscillator in the given state is ..... $\hbar\omega$

44. If 1, ω, ω^2 are the cube roots of unity, then $\left(1-\omega+\omega^2\right)^5+\left(1+\omega-\omega^2\right)^5$ will be .....

45. The amount of heat needed to raise the temperature of 2 mol of an ideal monoatomic gas from 273K to 373K when no work is done is ..... R.

46. 10 gm of steam (Latent heat 2.238×10^6 J/kg) at 100°C and 1 atm. pressure condenses at the same temperature and pressure. Loss of entropy of steam is ..... J/K.

47. The electric field at any point (x, y, z) in free space is $\vec{E} = x\hat{i} + y\hat{j} + z\hat{k}\ Nm^{-1}$. The charge density $\rho(x, y, z)$ is .....$\times 10^{-12}$ C.m^{-3}.

48. The gravitational potentials of two homogeneous spherical shells (radius r_1 and r_2) of the same surface density of internal points are in the ratio 3 : 4. The value of r_1/r_2 will be .....

49. A particle describes a circular orbit given by $r = 2a\cos\theta$ under the influence of an attractive centra force directed towards a point on the circle. The force varies as $f(r) \propto r^n$. The value of n is .....

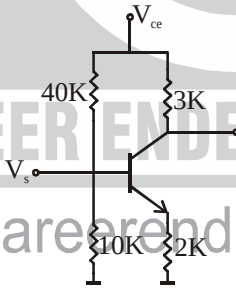
50. The current passing through a choke coil of 1 H is decreasing at the rate of 2A/s. Then, the emf developed in the coil is V

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

51. Suppose a source of sound (200 Hz) is in between the stationary listener and reflector. Now source is moving towards reflector with velocity (30 km/hr). The number of beats heard by the stationary listner (Assume the velocity of sound = 340 m/sec) ..... (Answer should be an integer)

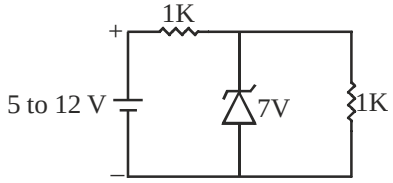
52. In Newton's ring experiment, the diameter of m^{th} dark ring is 8 mm and the diameter of $(m + 5)^{th}$ dark ring is 12 mm. If the radius of curvature of the lower surface of the lens is 10 m. The wavelength of light is .....nm.

53. For the given transistor circuit shown below h_{fe} = 100, h_{re} = 1K



the input resistance of transistor is .....KΩ.

54. For the given diode circuit shown below. Did the maximum load current I_1 .....mA



55. Consider the following differential equation:

$$3x\frac{dy}{dx} - y = \ln x + 1 \quad (x > 0)$$

subjected to the conditions $y(x=1) = -2$. The value of y at $x = 8$ will be .....

56. A spaceship S_1 leaves the earth surface along the positive *x*-direction. Another spaceship S_2 also leaves the earth along a direction that makes an angle 60^0 with *x*-axis. The speeds of S_1 and S_2 are measured as 0.6c and 0.9c respecively by an observer on the earth. The speed of S_2 as measured by an observer in S_1, is

(in the units of ***c***) .....

57. When 1 gm of water is converted into steam, the change in specific volume is 1676 cm^3. Water would boil at 150°C if the pressure be ..... atm. (Given latent heat of vaporisation of steam = 540 cal/gm, J = 4.2×10^7 Erg/cal and 1 atmosphere, pressure = 10^6 dyne/cm^2). (Upto 1^{s}t decimal place).

58. A horizontal pipe of 20 cm dia has a constriction of 4 cm dia. The velocity of water in the pipe is 2 m/s. and the pressure is 10^7 N/m^2. The pressure in the construction is .....$\times 10^5$ Nm^{-2}.

59. Two particles of identical mass move in circular orbits under a central potential $V(r) = \frac{1}{2}kr^2$. Let ℓ_1 and ℓ_2 be the angular momenta and r_1, r_2 be the radii of the orbits respectively. If $\ell_1 / \ell_2 = 2$, the value of r_1 / r_2 is .....

60. An EM wave is incident normally from air on air-glass interface. Taking refractive index of the glass as 1.5, the percentage of total incident energy that is transmitted into glass is .....%

Space for Rough Work

IIT-JAM PHYSICS-PH

Date : 27-01-2016

TEST SERIES - 7
(Full Length Test - 3)

ANSWER KEY

Section-A : Multiple Choice Questions (MCQ)

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

Section-B : Multiple Select Questions (MSQ)

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

Section-C : Numerical Answer Type (NAT)

41. (53.1)	**42.** (4)	**43.** (2)	**44.** (32)
45. (300)	**46.** (60)	**47.** (26.5)	**48.** (0.75)
49. (–5)	**50.** (2)	**51.** (10)	**52.** (400)
53. (203)	**54.** (7)	**55.** (2.06 to 2.09)	**56.** (0.86 to 0.90)
57. (2.8)	**58.** (87.52)	**59.** (1.41)	**60.** (96)