TEST SERIES CSIR-NET/JRF JUNE 2019

BOOKLET SERIES C

Paper Code 05

Test Type: TEST SERIES

[Mathematical Physics, Solid State Physics, Atomic & Molecular Physics]

PHYSICAL SCIENCES

Duration: 02:30 Hours

Date: 30-05-2019

Maximum Marks: 160

Read the following instructions carefully:

* Single Paper Test is divided into **THREE** Parts.

Part - A: This part shall carry **10** questions. Each question shall be of **2 marks.**

Part - B: This part shall contain **20** questions. Each question shall be of **2 marks**.

Part - C: This part shall contain **25** questions. Each question shall be of **4 marks**.

* Darken the appropriate bubbles with HB pencil/Ball Pen to write your answer.

* There will be negative marking @25% for each wrong answer.

* The candidates shall be allowed to carry the Question Paper Booklet after completion of the exam.

* For rough work, blank sheet is attached at the end of test booklet.

PART – A

1. 4 men and 6 women can complete a work in 8 days, while 3 men and 7 women can complete it in 10 days. In how many days will 10 women complete it?
(a) 35 (b) 40 (c) 45 (d) 50

2. If in a certain code 'AM' is coded as '28' and 'IS' is coded as '200', then in the same code for 'BY' will be
(a) 94 (b) 65 (c) 75 (d) 78

3. 8 persons A, B, C, D, E, F, G, H are to be seated in a circular table facing the centre.
B is second to the left of D.
F sits opposite to B.
A is not a neighbour of D and F.
E is second to the left of B.
C and H are neighbours of D.
C sits opposite to A.
Who sits between A and G ?
(a) E (b) B (c) F (d) C

4. The capacities of two hemispherical vessels are 6.4 litres and 21.6 litres. The area of inner curved surfaces of the vessels will be in the ratio of :
(a) $\sqrt{2}:\sqrt{3}$ (b) 2 : 3 (c) 4 : 9 (d) 16 : 81

5. In the series given below follows a certain pattern. What should come following the same pattern in place of question mark (?) ?

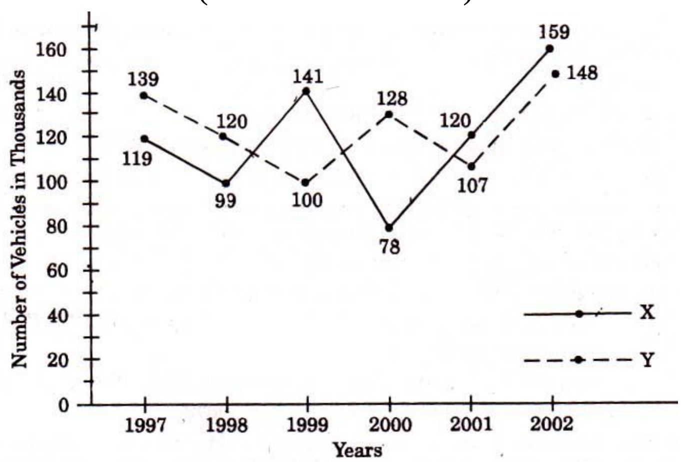
5	17	35	65	113	?

(a) 155 (b) 185 (c) 205 (d) 198

6. Nitin walks 2 km to the East, then he turns to South and walks 6 km. He again turns to East and walks 2 km. Then he turns to North and walks 12 km. How far is he from the starting point?
(a) 7 km (b) 7.5 km (c) 7.2 km (d) 7.8 km

7. A bag contains 2 red, 3 green and 2 blue balls. Two balls are drawn in random. What is the probability that none of the balls is blue ?
(a) 10/21 (b) 3/20 (c) 7/21 (d) 7/20

8. Study the following line-graph and answer the question based on it.
Number of Vehicles Manufactured by two Companies over the Years.
(Number in thousands)



What is the difference between the total productions of the two Companies in the given years ?
(a) 19000 (b) 22000 (c) 26000 (d) 28000

9. A type of solution contains water and sugar in 1 : 4 ratio and a second type of solution contains water and sugar in 7 : 13 ratio. If 10 parts of first solution is mixed with 4 parts of the second solution, then what is the percentage of water in new mixture ?

(a) $24\frac{2}{7}\%$ (b) $20\frac{1}{7}\%$ (c) 25 % (d) 20 %

10. A man on the top of a vertical observation tower observes a car moving at a uniform speed coming directly towards it. If it takes 12 minutes for the angle of depression to change from 30º to 45º, how soon after this will the car reach the observation tower ?

(a) 14 min 35 sec (b) 15 min 49 sec (c) 16 min 23 sec (d) 18 min 5 sec

PART – B

11. The value of the integral,

$$\int_{-\infty}^{\infty} e^{x} \sin\left(\frac{\pi x}{3}\right) \delta\left(4x^2 - 1\right) dx$$

is

(a) $\frac{1}{2}\sinh\left(\frac{1}{2}\right)$ (b) $\frac{1}{4}\sinh\left(\frac{1}{2}\right)$ (c) $\frac{1}{8}\sinh\left(\frac{1}{2}\right)$ (d) $\frac{1}{16}\sinh\left(\frac{1}{2}\right)$

12. The inverse Laplace transform of the function is

$$f(s) = \frac{s}{s^2 + 4s + 8}$$

(a) $e^{2t}(\cos 2t - \sin 2t)$ (b) $e^{-2t}(\cos 2t - \sin 2t)$

(c) $e^{2t}\cos 2t$ (d) $e^{-2t}\sin 2t$

13. Consider the differential equation

$$y = xy' + (y')^2$$

The general solution to this equation can be written as

(a) $y = e^x$ (b) $y = ax^2 + bx$ (c) $y = ax^2$ (d) $y = ax$

14. If $\vec{r}(t)$ denotes the position of a particle and $\vec{v}(t)$ denostes its velocity, then which of the following will be correct when the velocity is perpendicular to the position of the particle?

(a) The particles distance will be maximum
(b) The particles distance will be minimum
(c) The particles distance will be extreme
(d) None of these

15. Consider a 2×2 matrix $A = \begin{pmatrix} \frac{3}{2} & \frac{1}{2} \\ \frac{1}{2} & \frac{3}{2} \end{pmatrix}$ with eigenvector $\begin{pmatrix} 1 \\ -1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ 1 \end{pmatrix}$. The eigen values of 4^A are

(a) (6, 14) (b) (10, 10) (c) (15, 5) (d) (16, 4)

16. The Fourier sine and cosine transforms of $f(x)$ are given by

$$\tilde{f}(\omega)=\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\sin\omega x dx$$

$$\tilde{f}_c(\omega)=\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\cos\omega x dx$$

If $f(x)=e^{-ax}$ and $\tilde{f}_s(\omega)=\sqrt{\frac{2}{\pi}}\frac{\omega}{\omega^2+a^2}$, then $\tilde{f}_c(\omega)$ is equal to

(a) $\sqrt{\frac{2}{\pi}}\frac{\omega^2}{\omega^2+a^2}$ (b) $\sqrt{\frac{2}{\omega}}\frac{\omega^2}{\left(\omega^2+a^2\right)^2}$ (c) $\sqrt{\frac{2}{\pi}}\frac{a}{\left(\omega^2+a^2\right)^2}$ (d) $\sqrt{\frac{2}{\pi}}\frac{a}{\omega^2+a^2}$

17. X is a continuous random variable with probability density function given by

$$f(x)=\begin{cases} kx & (0\le x<2) \\ k & (2\le x\le 4)\end{cases}$$

The mean value of X is

(a) $\frac{16}{7}$ (b) $\frac{36}{13}$ (c) $\frac{13}{6}$ (d) $\frac{12}{5}$

18. The tight binding energy dispersion (E–k) relation for electrons in a one-dimensional array of atoms having lattice constant a and total length L is:

$$E=2E_0\left[\sin^2\left(\frac{ka}{2}\right)-\frac{1}{6}\sin^2(ka)\right]$$

Where E_0 is constant and k is the wave-vector. The effective mass (m*) of electron at $k=\frac{\pi}{2a}$ is

(a) $-\frac{\hbar^2}{E_0a^2}$ (b) $\frac{\hbar^2}{E_0a^2}$ (c) $\frac{3\hbar^2}{2E_0a^2}$ (d) $-\frac{3\hbar^2}{2E_0a^2}$

19. An intrinsic sample of silicon is doped with P and Al with doping densities of $1.5\times10^{16}/cm^3$ and $2.5\times10^{16}/cm^3$ respectively. If intrinsic carrier concentration of Si is $1.5\times10^{10}/cm^3$. The electron and hole densities per cm^3 are, respectively.

(a) $2.25\times10^4, 1\times10^{16}$ (b) $1.5\times10^4, 2.5\times10^{16}$

(c) $1\times10^{16}, 2.25\times10^4$ (d) $1.5\times10^{16}, 1\times10^4$

20. A set of primitive vectors for the unit cell of aluminium in a face-centred is given to be $\vec{a}=d(\hat{j}+\hat{k})$, $\vec{b}=d(\hat{i}+\hat{k})$ and $\vec{c}=d(\hat{i}+\hat{j})$. The density and mass number of aluminium are 2.7 g/cm^3 and 27 respectively. The value of 'd' is (approximately).

(a) 2Å (b) 4Å (c) 6Å (d) 1Å

21. The two dimensional lattice has direct primitive translation vector $\vec{a}=2\hat{i}$ Å and $\vec{b}=(\hat{i}+2\hat{j})$ Å. The area of third Brillouin Zone is

(a) $4\pi^2\ Å^{-2}$ (b) $2\pi^2\ Å^{-2}$ (c) $\pi^2\ Å^{-2}$ (d) $\frac{2}{3}\pi^2\ Å^{-2}$

22. A two-dimensional system consists of a monovalent atom in a rectangular primitive cell with $\vec{a} = 2\hat{i}\ \AA$ and $\vec{b} = 4\hat{j}\ \AA$. By assuming free electron model, the ratio of the electron energy at corner to side centre position (along k_x-direction) in I[st] BZ is:

(a) $\frac{5}{4}$ (b) $\frac{4}{5}$ (c) 2 (d) $\frac{1}{2}$

23. A GaAsP photodetector has a cross-sectional area of 2×2 mm². A light of wavelength 500 nm and intensity 0.1 mw/cm² incident on the photodetector of unity quantum efficiency. Band gap of GaAsP semiconductor is 2.20 eV. Photocurrent (I_{ph}) generated in the detector is?

(a) 3μA (b) 1.60 μA (c) 2.30 μA (d) 1.50 μA

24. Electrons moves with relativistic speeds on graphene sheet and assumed to follow the dispersion relation $\varepsilon(k) = vk$ (where v is constant) over the entire k-space, then the dependence of Fermi wave vector (K_F) on electron density (n) is

(a) $K_F \propto n^{1/2}$ (b) $K_F \propto n$ (c) $K_F \propto n^{2/3}$ (d) $K_F \propto n^{1/3}$

25. The energy of an electron in a band as a function of its wave vector **k** is given by

$E(k) = E_0 - B(\cos k_x a + \cos k_y a + \cos k_z a)$, where E_0, B and a are constants. The group velocity (v_g) of electron at $\left(\frac{\pi}{a}, 0, 0\right)$ is

(a) 0 (b) $\frac{Ba}{\hbar}$ (c) $-\frac{Ba}{\hbar}$ (d) $\frac{3Ba}{\hbar}$

26. From a two electron configuration ${}^3F_4$ state is obtained. The magnetic moment of the atom in this state is

(a) $\frac{5\sqrt{5}}{3}\mu_B$ (b) $5\sqrt{5}\,\mu_B$ (c) $\frac{5\sqrt{5}}{2}\mu_B$ (d) $\frac{\sqrt{5}}{2}\mu_B$

27. In an atom obeying L-S coupling, the components of a spectral triplet state have separations 20 cm⁻¹ and 40 cm⁻¹ between the adjacent components. The term notations for this multiplet is

(a) ${}^3D_{1,2,3}$ (b) ${}^3P_{0,1,2}$ (c) ${}^3F_{2,3,4}$ (d) ${}^3G_{3,4,5}$

28. A mixture of ordinary Hydrogen and Deuterium (whose nucleus is about two times more massive than ordinary Hydrogen) is excited and its spectrum is observed. The shift in wave length for the H_α lines of the two kinds of hydrogen is

(a) 2.4Å (b) 1.8Å (c) 3.6Å (d) 0.9Å

29. The total number of Zeeman Components abserved in an electronic transition

$${}^2D_{3/2} \rightarrow {}^2P_{1/2}$$

of an atom in a weak field is

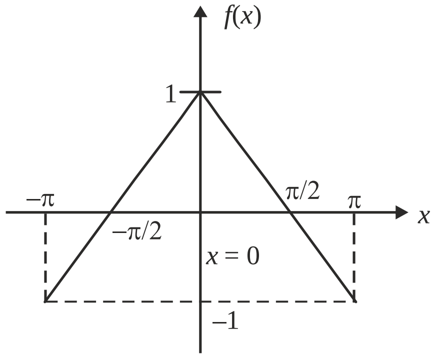
(a) 6 (b) 4 (c) 8 (d) 10

30. The spectroscopic symbol for the excited state of sodium is ${}^2P_{3/2}$. Under the action of a strong magnetic field (when L-S coupling can be neglected) the excited state energy level will split into

(a) 3 levels (b) 4 levels (c) 6 levels (d) 5 levels

PART – C

31. Consider the periodic function $f(x)$ with period 2π as shown in figure.



If the fourier series of this function is $f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos(nx) + b_n \sin(nx)$

Which of the following would be best choices of coefficient a_0, a_1, a_2, and b_2.

(a) $a_0 = 0, a_1 = \frac{8}{\pi^2}, a_2 = 0, b_1 = 0$

(b) $a_0 = 0, a_1 = \frac{8}{\pi^2}, a_2 = 0, b_1 = \frac{1}{\pi^2}$

(c) $a_0 = 0, a_1 = \frac{1}{\pi^2}, a_2 = \frac{1}{\pi^2}, b_1 = \frac{8}{\pi^2}$

(d) $a_0 = \frac{2}{\pi}, a_1 = \frac{1}{\pi}, a_2 = \frac{1}{2\pi}, b_1 = \frac{1}{3\pi}$

32. Consider the integral,

$$\oint_c \frac{dz}{z^3 \sin z}$$

over a contour of a circle of radius 3 units in the anti-clockwise direction. The value of the integral is

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

33. The value of the integral,

$$\int_0^{\pi} \sin^3\theta \, P_2(\cos\theta) \, d\theta$$ is equal to

$$\left(P_0(x) = 1, P_1(x) = x, P_2(x) = \frac{1}{2}(3x^2 - 1) \right), \int_{-1}^{1} P_n(x) P_m(x) \, dx = \frac{2\delta_{nm}}{2n+1}$$

(a) $-\frac{2}{15}$ (b) $-\frac{1}{15}$ (c) $-\frac{4}{15}$ (d) $-\frac{2}{5}$

34. The Green's function for the following equation,

$$-\frac{d^2y}{dx^2} - \frac{y}{4} = f(x)$$

with boundary conditions $y(0) = 0 = y(\pi)$ is

(a) $G(x,t)=\begin{cases}\sin\left(\frac{x}{2}\right)\cos\left(\frac{t}{2}\right), & 0\le x<t\\ \cos\left(\frac{x}{2}\right)\sin\left(\frac{t}{2}\right), & t<x\le\pi\end{cases}$
(b) $G(x,t)=\begin{cases}2\sin\left(\frac{x}{2}\right)\cos\left(\frac{t}{2}\right), & 0\le x<t\\ 2\cos\left(\frac{x}{2}\right)\sin\left(\frac{t}{2}\right), & t<x\le\pi\end{cases}$

(c) $G(x,t)=\begin{cases}-3\sin\left(\frac{x}{2}\right)\cos\left(\frac{t}{2}\right), & 0\le x<t\\ -3\cos\left(\frac{x}{2}\right)\sin\left(\frac{t}{2}\right), & t<x\le\pi\end{cases}$
(d) $G(x,t)=\begin{cases}4\sin\left(\frac{x}{2}\right)\cos\left(\frac{t}{2}\right), & 0\le x<t\\ 4\cos\left(\frac{x}{2}\right)\sin\left(\frac{t}{2}\right), & t<x\le\pi\end{cases}$

35. The error in evaluating $\int_1^3 x^3dx$ by using Simpson's 1/3 rule is equal to

(a) 0.01 (b) 0.11 (c) 0.025 (d) 0

36. Consider the differential equation,

$$\frac{dy}{dx}=x-2y$$

The value of $y(1)$ as calculated using the Euler's method of solving a differential equation with step size 0.5 and $f(0)=2$ is equal to

(a) 1 (b) 0.75 (c) 0.50 (d) 0.25

37. The Laurentz expansion of $f(z)=\frac{7z-2}{(z+1)z(z-2)}$ in the region $1<|z+1|<3$ is

(a) $\frac{3}{2}\left[1+\frac{z+1}{3}+\frac{(z+1)^2}{3^2}+\frac{(z+1)^3}{3^3}+........\infty\right]$

(b) $\left(-\frac{2}{z+1}+\frac{1}{(z+1)^2}+\frac{1}{(z+1)^3}+.........\infty\right)-\frac{3}{2}\left[1+\frac{z+1}{3}+\frac{(z+1)^2}{3^2}+\frac{(z+1)^3}{3^3}+......\infty\right]$

(c) $\left(-\frac{1}{z}-\frac{1}{(z+2)^2}-\frac{1}{(z+2)^3}-..........\infty\right)$

(d) $\left(z+\frac{1}{z+1}+\frac{1}{(z+1)^2}+\frac{1}{(z+1)^3}+........\infty\right)$

38. Consider 3×3 matrix $A=\begin{bmatrix}2&1&1\\0&1&0\\1&1&2\end{bmatrix}$, the det of matrix, $B=A^8-5A^7+7A^6-3A^5+A^4-5A^3-2A+1$ is

(a) 192 (b) 75 (c) 117 (d) Zero

39. The dispersion relation for spin waves in a magnetic solid is given by

$$\omega = \frac{4JS}{\hbar}(1-\cos\lambda a)\text{, where } J \text{ and } S \text{ are constants.}$$

The specific heat of Magnons in long wavelength and low temperature limit is proportional to

(a) T^3 (b) $T^{3/2}$ (c) $T^{1/2}$ (d) T

40. The periodic motion of electron in a simple energy band follows a dispertion relation

$$\varepsilon = \varepsilon_0(1-\cos ka)\text{, where } \varepsilon_0 \text{ is energy and } a \text{ is lattice constant}$$

If electron performs periodic motion in a constant electric field E, the Bloch frequency of the periodic band width is

(a) $\frac{eEa}{\hbar}$ (b) $\frac{2eEa}{\hbar}$ (c) $\frac{eEa}{2\hbar}$ (d) $\frac{eEa}{2}$

41. Si has a band gap of 1.1 eV, dielectric constant $\varepsilon_r = 11.7$, the effective mass of electron $m_e^* = 0.2\,m_0$. The radius of ground state orbit is (assume ground state radius of H-atom 0.53Å)

(a) 60Å (b) 30Å (c) 2.5Å (d) 6Å

42. In a Cyclotron resonance experiment for electron in a semiconductor gives effective mass found to be $m^* = 0.1\,m_0$, where m_0 is free electron mass. If resonance occurs at $\omega_c = 1.5\times10^{11}$ rad/sec frequency. The magnetic field (B) used in the resonance is

(a) 430 Gauss (b) 120 Gauss (c) 860 Gauss (d) 140 Gauss

43. From the phonon dispersion Relation, $\omega(k) = \sqrt{\frac{4c}{M}}\sin\frac{ka}{2}$

in a monoatomic linear lattice of N with extending 0 to L atoms with only nearest neighbour interaction, then the density of the vibrational states, if ω_m is the maximum frequency (where a is the lattice constant, c is the force constant)

(a) $\frac{2N}{a}\frac{1}{\sqrt{\omega_m^2-\omega^2}}$ (b) $\frac{N}{a}\frac{1}{\sqrt{\omega_m^2-\omega^2}}$ (c) $\frac{N}{2a}\frac{1}{\sqrt{\omega_m^2-\omega^2}}$ (d) $\frac{2N}{a}\frac{1}{\sqrt{\omega_m^2+\omega^2}}$

44. A hypothetical semiconductor has a conduction band that can be described by $E_c(k) = E_1 - E_2\cos ka$ and a valence band that can be described by $E_v(k) = E_3 - E_4\sin^2 ka$ where $E_i > 0 \quad (i = 1,2,3,4)$ and $-\frac{\pi}{a} \le k \le \frac{\pi}{a}$ than the band width of the conduction band and band gap of semiconductor is

(a) $E_2, E_3 + E_1 + E_2$ (b) $2E_2, E_1 - E_2 - E_3$ (c) $2E_2, E_1 - E_2$ (d) $E_3, E_2 - E_3$

45. The critical temperature (T_C) of Hg is about 4K. The maximum wavelength of photon that can break Cooper pair in superconductor is (approx.)

(a) 1000 Å (b) 600 Å (c) 300 Å (d) 100 Å

46. The spin-orbit interaction in an atom is given by $H = a\vec{\ell}\cdot\vec{s}$, where $\vec{\ell}$ and $\vec{s}$ denote the orbital and spin angular momenta, respectively, of the electron. The splitting between ${}^2D_{5/2}$ and ${}^2D_{3/2}$ is given by

(a) $\frac{5}{2}a\hbar^2$ (b) $\frac{3}{2}a\hbar^2$ (c) $5a\hbar^2$ (d) $3a\hbar^2$

47. A spectral line due to a transition from an electronic state $^1D_2$ to $^1P_1$ state splits into three Zeeman components in the presence of a weak magnetic field 0.3 T. If the wavelength corresponding to the transition is 450 nm, the separation in the Zeeman spectral lines is approximately
(a) 0.03Å (b) 0.003Å (c) 0.3Å (d) 3 Å

48. The fractional width of a spectral line of 500 nm wavelength emitted from a level of a life-time of 10^{-8} sec is
(a) 0.133Å (b) 0.0265Å (c) 0.0133Å (d) 0.266Å

49. The LS configuration of the ground state of ^{2}He, ^{3}Li, ^{4}Be and ^{5}B are, respectively
(a) $^2S_{1/2}, {}^1S_0, {}^2P_{1/2}, {}^1S_0$ (b) $^1S_0, {}^2S_{1/2}, {}^1S_0, {}^2P_{3/2}$
(c) $^1S_0, {}^1S_0, {}^2S_{1/2}, {}^2P_{3/2}$ (d) $^1S_0, {}^2S_{1/2}, {}^1S_0, {}^2P_{1/2}$

50. The transition J = 3 to J = 4 in HCl molecule is associated with radiation of 83.03 cm^{-1}. The value of rotational constant B is (use rigid-rotor approximation for diatomic molecule HCl).
(a) 20.76 cm^{-1} (b) 10.38 cm^{-1} (c) 41.52 cm^{-1} (d) 5.19 cm^{-1}

51. The diatomic molecule $^1H\,^{35}Cl$ has fundamental band in the vibrational spectra at 3.46 μ(micron). If the Hydrogen (^{1}H) is replaced by Deuterium (^{2}H), the corresponding band for the molecule $^2H\,^{35}Cl$ will be shifted by approximately
(a) 2.72 μ (b) 1.36 μ (c) 3.46 μ (d) 0.68 μ

52. An He-Ne laser is operating at 632.8 nm. The ratio of stimulated emission to spontaneous emission coefficient is
(a) 0.82×10^{-14} J-s/m^3 (b) 6.57×10^{-14} J-s/m^3
(c) $12.2\times10^{+13}$ m^3/J-sec (d) 1.52×10^{13} m^3/J-s

53. If the coefficient of stimulated emission for a particular transition is 4.2×10^{19} $m^3w^{-1}s^{-3}$ and the emitted photon is at wavelength 6000Å, then the lifetime of the excited state is approximately
(a) 80 ns (b) 310 ns (c) 230 ns (d) 155 ns

54. A gas laser cavity has been designed to operate at $\lambda = 0.6\ \mu m$ with a cavity length of 0.5m. With this set up, the frequency is found to be larger than the desired frequency by 100 Hz. The change in the effective length of the cavity required to returne the laser is
(a) $-10^{-13}\ m$ (b) $1.67\times10^{-13}\ m$ (c) $1.67\times10^{-13}\ m$ (d) $+10^{-13}\ m$

55. A muon (μ^-) from cosmic rays is trapped by a proton to form a hydrogen like atom. Given that a muon is approximately 200 times heavier than an electron. The ground state energy of such an atom will be
(a) –6.8 eV (b) –13.6 eV (c) –2453 eV (d) 613 eV

Space for rough work

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PHYSICAL SCIENCES

TEST SERIES-C

Date : 30-05-2019

ANSWER KEY

PART-A

1. (b)	2. (d)	3. (a)	4. (c)	5. (b)	6. (c)	7. (a)
8. (c)	9. (a)	10. (c)				

PART-B

11. (b)	12. (b)	13. (c)	14. (c)	15. (d)	16. (d)	17. (c)
18. (c)	19. (a)	20. (a)	21. (c)	22. (b)	23. (b)	24. (a)
25. (a)	26. (c)	27. (b)	28. (b)	29. (a)	30. (d)	

PART-C

31. (a)	32. (d)	33. (c)	34. (b)	35. (d)	36. (d)	37. (b)
38. (c)	39. (b)	40. (a)	41. (b)	42. (c)	43. (d)	44. (b)
45. (a)	46. (a)	47. (a)	48. (c)	49. (d)	50. (b)	51. (b)
52. (d)	53. (b)	54. (a)	55. (c)			