DPP - Daily Practice Problems

Date : ______ **Start Time :** ______ **End Time :** ______

PHYSICS

CP24

SYLLABUS : Atoms

Max. Marks : 74 **Time : 60 min.**

GENERAL INSTRUCTIONS

- The Daily Practice Problem Sheet contains 20 Questions divided into 5 sections.
  Section I has **5** MCQs with ONLY 1 Correct Option, **3** marks for each correct answer and **–1** for each incorrect answer.
  Section II has **4** MCQs with ONE or MORE THAN ONE Correct options.
  For each question, marks will be awarded in one of the following categories:
  Full marks: **+4** If only the bubble(s) corresponding to all the correct option(s) is (are) darkened.
  Partial marks: **+1** For darkening a bubble corresponding to each correct option provided NO INCORRECT option is darkened.
  Zero marks: If none of the bubbles is darkened.
  Negative marks: **–2** In all other cases.
  Section III has **4** Single Digit Integer Answer Type Questions, **3** marks for each Correct Answer and 0 marks in all other cases.
  Section IV has Comprehension/Matching-cum-Comprehension Type Questions having **5** MCQs with ONLY ONE correct option, **3** marks for each Correct Answer and 0 marks in all other cases.
  Section V has **2** Matching Type Questions, **2** mark for the correct matching of each row and 0 marks in all other cases.
- You have to evaluate your Response Grids yourself with the help of Solutions.

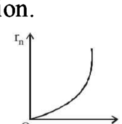
Section I - Straight Objective Type

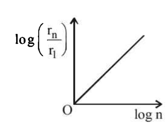
This section contains 5 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d), out of which **ONLY ONE** is correct.

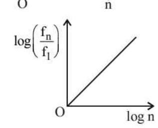
1. Suppose potential energy between electron and proton at separation r is given by $U = K \ln(r)$, where K is a constant. For such a hypothetical hydrogen atom, the ratio of energy difference between energy levels ($n = 1$ and $n = 2$) and ($n = 2$ and $n = 4$) is

(a) 1 (b) 2 (c) 3 (d) 4

2. If in hydrogen atom, radius of n^{th} Bohr orbit is r_n, frequency of revolution of electron in n^{th} orbit is f_n, choose the correct option.

(a) 

(b) 

(c) 

(d) Both (a) and (b)

RESPONSE GRID 1. ⓐⓑⓒⓓ 2. ⓐⓑⓒⓓ

Space for Rough Work

3. A sample of hydrogen gas is excited by means of a monochromatic radiation. In the subsequent emission spectrum, 10 different wavelengths are obtained, all of which have energies greater than or equal to the energy of the absorbed radiation. It follows that the initial quantum number of the state (before absorbing radiation) was

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

4. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r. If we calculate its rotational energy by applying Bohr's rule of angular momentum quantization, its energy will be given by : (n is an integer)

(a) $\frac{(m_1+m_2)^2 n^2 h^2}{2m_1^2 m_2^2 r^2}$ (b) $\frac{n^2 h^2}{2(m_1+m_2)r^2}$

(c) $\frac{2n^2\hbar^2}{(m_1+m_2)r^2}$ (d) $\frac{(m_1+m_2)n^2\hbar^2}{2m_1 m_2 r^2}$

5. An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of electron in the initial state is eight times that in the final state. Then which of the following statement is true ?

(a) $n_1 = 3n_2$ (b) $n_1 = 4n_2$
(c) $n_1 = 2n_2$ (d) $n_1 = 5n_2$

Section II - Multiple Correct Answer Type

This section contains 4 multiple correct answer(s) type questions. Each question has 4 choices (a), (b), (c) and (d), out of which **ONE OR MORE** is/are correct.

6. Suppose the potential energy between electron and proton at a distance r is given by $-\frac{Ke^2}{3r^3}$. Application of Bohr's theory to hydrogen atom in this case shows that –

(a) energy in the nth orbit is proportional to n^6
(b) energy is proportional to m^{-3} (m : mass of electron)
(c) energy the nth orbit is proportional to n^{-2}
(d) energy is proportional to m^3 (m = mass of electron)

7. Let A_n be the area enclosed by the nth orbit in a hydrogen atom. The graph of ln (A_n/A_1) against ln (n) –

(a) will pass through origin
(b) will a straight line with slope-4
(c) will be a monotonically increasing nonlinear curve
(d) will be a circle

8. Highly excited states for hydrogen–like atoms (also called Rydberg states) with nuclear charge Ze are defined by their principal quantum number n, where n>>1. Which of the following statement(s) is(are) true?

(a) Relative change in the radii of two consecutive orbitals does not depend on Z
(b) Relative change in the radii of two consecutive orbitals varies as 1/n
(c) Relative change in the energy of two consecutive orbitals varies as $1/n^3$
(d) Relative change in the angular momenta of two consecutive orbitals varies as 1/n

9. The radius of the orbit of an electron in a Hydrogen-like atom is 4.5 a_0, where a_0 is the Bohr radius. Its orbital angular momentum is $\frac{3h}{2\pi}$. It is given that h is Planck constant and R is Rydberg constant. The possible wavelength(s), when the atom de-excites, is (are)

(a) $\frac{9}{32R}$ (b) $\frac{9}{16R}$ (c) $\frac{9}{5R}$ (d) $\frac{4}{3R}$

Section III - Integer Type

This section contains 4 questions. The answer to each of the questions is a single digit integer ranging from 0 to 9.

10. A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. The excited atom can make a transition to the first excited state by successively emitting two photons of energy 10.2 and 17.0 eV respectively. Alternately, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV and 5.95 eV respectively. Determine the value of n. (Ionization energy of H-atom = 13.6 eV)

11. Let neutron be a point mass and hydrogen atom a solid sphere. A neutron makes a head on collision with a hydrogen atom in ground state kept at rest. The coefficient of restitution for collision is e = 1/2. The minimum kinetic energy of colliding neutron (in eV) so that hydrogen atom is excited to higher energy level such that magnitude of electrostatic potential energy in the excited state is one-eighth of K.E. of electron in ground state is 4x. Find the value of x. (mass of neutron = mass of hydrogen).

12. A hydrogen-like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transitions between a group of levels. These levels have energies between -0.85 eV and -0.544 eV (including both these values). Find the atomic number of the atom. (Take hc = 1240 eV-nm, ground state energy of hydrogen atom = –13.6 eV)

RESPONSE GRID	
	3. ⓐⓑⓒⓓ 4. ⓐⓑⓒⓓ 5. ⓐⓑⓒⓓ 6. ⓐⓑⓒⓓ 7. ⓐⓑⓒⓓ
	8. ⓐⓑⓒⓓ 9. ⓐⓑⓒⓓ 10. ⓪①②③④⑤⑥⑦⑧⑨
	11. ⓪①②③④⑤⑥⑦⑧⑨ 12. ⓪①②③④⑤⑥⑦⑧⑨

Space for Rough Work

13. Electrons in hydrogen like atom ($Z = 3$) make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volts. Calculate the work function of the metal (ine V).

(Rydberg constant = $1.094 \times 10^7 m^{-1}$)

Section IV - Comprehension/Matching Cum-Comprehension Type

Directions (Qs. 14 and 15) : Based upon the given paragraph, 2 multiple choice questions have to be answered. Each question has 4 choices (a), (b), (c) and (d), out of which **ONLY ONE** is correct.

PARAGRAPH

A small particle of mass m moves in such a way that the potential energy of particle is given as $U = -\frac{1}{2}m\alpha^2 r^2$ where α is constant and r is the distance of particle from centre. If Bohr's model of quantization of angular momentum and circular orbit is valid for the particle, answer the following questions (h = Planck's constant)

14. Kinetic energy of particle in n^{th} orbit is

(a) $\frac{nh\alpha}{4\pi}$ (b) $\frac{n^2h\alpha}{4\pi^2}$

(c) $\frac{nh\alpha}{2\pi}$ (d) $\sqrt{\frac{n^2h^2\alpha}{\pi}}$.

15. Total energy of particle in its orbits is

(a) $-\frac{nh\alpha}{4\pi}$ (b) $\frac{nh\alpha}{2\pi}$ (c) zero (d) $-\frac{nh\alpha}{2\pi}$

Directions (Qs. 16-18) : This passage contains a table having 3 columns and 4 rows. Based on the table, there are three questions. Each question has four options (a), (b), (c) and (d) **ONLY ONE** of these four options is correct.

According to Bohr's model, electron revolves in circular orbits around the nucleus under the influence of coulombic force of attraction in defined stationary orbits, for which angular momentum, $mvr = \frac{nh}{2\pi}$. Column I, II & III give different relation between Z = atomic number, n = orbit number, and different physical quantities like angluar velocity, energy, current, ionization energy. (Here A_0, B_0, C_0 and D_0 are constants)

	Column I		Column II		Column III
I.	Ionisation energy of an electron in n^{th} Bohr's orbit	(i)	Inversely proportional to n	(P)	$A_0 \frac{Z^2}{n^3}$ (Sec^{-1})
II.	Current developed due to motion of an electron in n^{th} orbit	(ii)	Inversely proportional to n^3	(Q)	$B_0 \frac{Z}{n}$
III.	Velocity of an electron in n^{th} Bohr's orbit	(iii)	Directly proportional to Z^2	(R)	$C_0 \frac{Z^2}{n^3}$
IV.	Angular speed of an electron in n^{th} Bohr's orbit	(iv)	Directly proportional to Z	(S)	$D_0 \frac{Z^2}{n^2}$

RESPONSE GRID	13. ⓪①②③④⑤⑥⑦⑧⑨ 14. ⓐⓑⓒⓓ 15. ⓐⓑⓒⓓ

Space for Rough Work

16. If the value of current developed due to motion of an electron in 3^{rd} Bohr's orbit (for Z = 3) is $\frac{1}{3} \times$ constant then correct match satisfying the above condition will be:

(a) II (iii) R (b) IV (iii) P (c) II (ii) P (d) I (iv) S

17. Which of the following shows the correct matching?

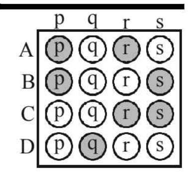
(a) II (ii) Q (b) III (i) Q (c) IV (ii) Q (d) I (i) R

18. Which of the following does not show the correct matching?

(a) IV (ii) P (b) II (iii) R (c) II (ii) R (d) I (iv) Q

Section V - Matrix-Match Type

This section contains 2 questions. It contains statements given in two columns, which have to be matched. Statements in column I are labelled as A, B, C and D whereas statements in column II are labelled as p, q, r and s. The answers to these questions have to be appropriately bubbled as illustrated in the following example. If the correct matches are A-p, A-r, B-p, B-s, C-r, C-s and D-q, then the correctly bubbled matrix will look like the following:



19. Match the different kinds of radiations emitted by a hydrogen atom given in Column I with the corresponding electron transitions given in Column II.

	Column-I		**Column-II**
(A)	Ultraviolet light	(p)	$n = 6 \to n = 3$
(B)	Visible light	(q)	$n = 3 \to n = 1$
(C)	Infrared radiation	(r)	$n = 4 \to n = 2$
(D)	Microwaves	(s)	$n = 7 \to n = 6$

20. Using Bohr's model, match the following (where the letters *n* and *Z* have usual meaning).

	Column I		**Column II**
(A)	Due to revolving electron, the magnetic field produced at its centre is proportional to	(p)	n^{-5}
(B)	Magnetic moment of revolving electron is proportional to	(q)	n
(C)	De-Broglie wavelength of revolving electron is proportional to	(r)	Z^3
(D)	Areal velocity of revolving electron about nucleus is proportional to	(s)	independent of Z

RESPONSE GRID

16. ⓐⓑⓒⓓ 17. ⓐⓑⓒⓓ 18. ⓐⓑⓒⓓ

19. A - ⓟⓠⓡⓢ; B - ⓟⓠⓡⓢ; C - ⓟⓠⓡⓢ; D - ⓟⓠⓡⓢ

20. A - ⓟⓠⓡⓢ; B - ⓟⓠⓡⓢ; C - ⓟⓠⓡⓢ; D - ⓟⓠⓡⓢ

DAILY PRACTICE PROBLEM DPP CP24 - PHYSICS

Total Questions	20	Total Marks	74
Attempted		Correct	
Incorrect		Net Score	
Cut-off Score	24	Qualifying Score	35

$$\text{Net Score} = \sum_{i=1}^{V} \left[\left(\text{correct}_i \times MM_i \right) - \left(In_i - NM_i \right) \right]$$

Space for Rough Work

DAILY PRACTICE PROBLEMS

PHYSICS SOLUTIONS

DPP/CP24

1. **(a)** $-\frac{dU}{dr} = F$ (conservative force field)

$\Rightarrow \quad F = \frac{-K}{r}$ provides the centrifugal force for circular motion of electron.

$$\frac{mv^2}{r} = \frac{K}{r} \Rightarrow r = \frac{nh}{2\pi\sqrt{mK}}$$

K.E. of electron = $\frac{1}{2}mv^2 = \frac{1}{2}K$

P.E. of electron = K ln r

E (n) = Total energy = K.E. + P.E.

$$= \frac{1}{2}K + K\ln r = \frac{K}{2}\left[1 + \log\frac{n^2h^2}{4\pi^3 mk}\right]$$

Required ratio = $\frac{E(2) - E(1)}{E(4) - E(2)} = 1$

2. **(d)** Radius of n^{th} orbit $r_n \propto n^2$, graph between r_n and n is a parabola. Also, $\frac{r_n}{r_1} = \left(\frac{n}{1}\right)^2 \Rightarrow \log_e\left(\frac{r_n}{r_1}\right) = 2\log_e(n)$

Comparing this equation with $y = mx + c$,

Graph between $\log_e\left(\frac{r_n}{r_1}\right)$ and $\log_e(n)$ will be a straight line, passing from origin.

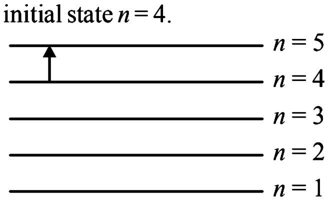
Similarly it can be proved that graph between $\log_e\left(\frac{f_n}{f_1}\right)$ and $\log_e n$ is a straight line. But with negative slops.

3. **(b)** 10 emission lines

$\Rightarrow$ final state n = 5

If the initial state were not n = 4, in the emission spectrum some lines with energies less than that of absorbed radiation would have been observed.

$\therefore$ initial state $n = 4$.



4. **(d)** The energy of the system of two atoms of diatomic molecule $E = \frac{1}{2}I\omega^2$

where I = moment of inertia

$$\omega = \text{Angular velocity} = \frac{L}{I},$$

L = Angular momentum

$$I = \frac{1}{2}(m_1r_1^2 + m^2r_2^2)$$

Thus, $E = \frac{1}{2}(m_1r_1^2 + m_2r_2^2)\omega^2 \quad \ldots(i)$

$$E = \frac{1}{2}(m_1r_1^2 + m_2r_2^2)\frac{L^2}{I^2}$$

$L = n\frac{nh}{2n}$ (According Bohr's Hypothesis)

$$E = \frac{1}{2}(m_1r_1^2 + m_2r_2^2)\frac{L^2}{(m_1r_1^2 + m_2r_2^2)^2}$$

$$E = \frac{1}{2}\frac{L^2}{(m_1r_1^2 + m_2r_2^2)} = \frac{n^2h^2}{8\pi^2(m_1r_1^2 + m_2r_2^2)}$$

$$E = \frac{(m_1 + m_2)n^2h^2}{8\pi^2r^2m_1m_2} \quad \left[\because r_1 = \frac{m_2r}{m_1 + m_2};\ r_2 = \frac{m_2r}{m_1 + m_2}\right]$$

5. **(c)** In the nth orbit, let r_n be the radius and v_n be the speed of electron.

Time period, $T_n = \frac{2\pi r_n}{v_n} \propto \frac{r_n}{v_n}$

Now $r_n \propto n^2$; $v_n \propto \frac{1}{n}$ $\therefore$ $\frac{r_n}{v_n} \propto n^3$ or $T_n \propto n^3$

Here $8 = \left(\frac{n_1}{n_2}\right)^3$ or $\frac{n_1}{n_2} = 2$ i.e., $n_1 = 2n_2$

6. **(a, b)** $|F| = \frac{dU}{dr} = \frac{Ke^2}{r^4}$ .... (1)

$\frac{Ke^2}{r^4} = \frac{mv^2}{r}$ .... (2)

and $mvr = \frac{nh}{2\pi}$ .... (3)

By (2) and (3),

$r = \frac{Ke^2 4\pi^2}{h^2}\frac{m}{n^2} = K_1\frac{m}{n^2}$ .... (4)

Total energy = $\frac{1}{2}$ (potential energy)

$$= \frac{Ke^2}{6r^3} = \frac{-Ke^2}{6\left(\frac{K_1m}{n^2}\right)^3} = \frac{-Ke^2n^6}{6K_1^3m^3}$$

Total energy $\propto n^6$

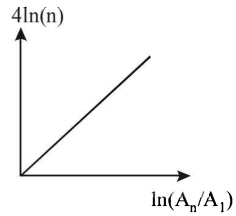
Totan energy $\propto m^{-3}$

7. **(a,b,d).**

$\because r_n = n^2 r_1$

$\ln\left(\frac{A_n}{A_1}\right) = \ln\left(\frac{\pi r_n^2}{\pi r_1^2}\right)$

$= \ln n^4 = 4\ln(n)$



8. **(a, b, d)**

We know that $r = r_0\frac{n^2}{z}$, $E_n = -\frac{13.6Z^2}{n^2}$, $L_n = \frac{nh}{2\pi}$

Relative change in the radii of two consecutive orbitals

$\frac{r_n - r_{n-1}}{r_n} = 1 - \frac{r_{n-1}}{r_n} = 1 - \frac{(n-1)^2}{n^2}$ does not depend on Z

$= \frac{2n-1}{n^2} \approx \frac{2}{n}$ $(\because n >> 1)$

Relative change in the energy of two consecutive orbitals

$\frac{E_n - E_{n-1}}{E_n} = 1 - \frac{E_{n-1}}{E_n} = 1 - \frac{n^2}{(n-1)^2} = \frac{-2n+1}{(n-1)^2} \approx \frac{-2}{n}$

$\frac{L_n - L_{n-1}}{L_n} = 1 - \frac{L_{n-1}}{L_n} = 1 - \frac{(n-1)}{n} = \frac{1}{n}$

9. **(a, c)** Angular momentum $= \frac{nh}{2\pi} = \frac{3h}{2\pi}$. Therefore $n = 3$.

Also $r_n = \frac{a_o n^2}{z} = 4.5 a_o$

$\therefore \frac{n^2}{z} = 4.5 \quad \Rightarrow \frac{9}{z} = 4.5 \Rightarrow z = 2$

we know that

$\frac{1}{\lambda} = R z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = \frac{1}{\lambda} = 4R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For $n_2 = 3, n_1 = 1$ we get $\lambda = \frac{9}{8 \times 4R} = \frac{9}{32R}$

For $n_2 = 3, n_1 = 2$ we get $\lambda = \frac{36}{5 \times 4R} = \frac{9}{5R}$

For $n_2 = 2, n_1 = 1$ we get $\lambda = \frac{4}{3 \times 4R} = \frac{1}{3R}$

(a), (c) are correct options

10. **6**

For hydrogen like atoms

$E_n = -\frac{13.6}{n^2}Z^2$ eV/atom

Given $E_n - E_2 = 10.2 + 17 = 27.2$eV ..(i)

$E_n - E_3 = 4.24 + 5.95 = 10.2$ eV

$\therefore E_3 - E_2 = 17$

But $E_3 - E_2 = -\frac{13.6}{9}Z^2 - \left(-\frac{13.6}{4}Z^2\right)$

$= -13.6Z^2\left[\frac{1}{9} - \frac{1}{4}\right]$

$= -13.6Z^2\left[\frac{4-9}{36}\right] = \frac{13.6 \times 5}{36}Z^2$

$\therefore \frac{13.6 \times 5}{36}Z^2 = 17 \Rightarrow Z = 3$

$E_n - E_2 = -\frac{13.6}{n_2} \times 3^2 - \left[-\frac{13.6}{2^2} \times 3^2\right]$

$= -13.6\left[\frac{9}{n^2} - \frac{9}{4}\right] = -13.6 \times 9\left[\frac{4-n^2}{4n^2}\right]$ ...(ii)

From eq. (i) and (ii)

$-13.6 \times 9\left[\frac{4-n^2}{4n^2}\right] = 27.2$

$\Rightarrow -122.4\,(4 - n^2) = 108.8n^2 \Rightarrow n^2 = \frac{489.6}{13.6} = 36 \Rightarrow n = \mathbf{6}$

11. **8**

Let e^- in hydrogen atom is excited to n[th] level.

$\therefore \quad E_{KE(n-1)} = 8\,|E_{P.E.(n)}|$

$\therefore \quad 13.6eV = 8\,|\,2 \times \frac{13.6}{n^2}eV\,| \quad \Rightarrow n = 4$

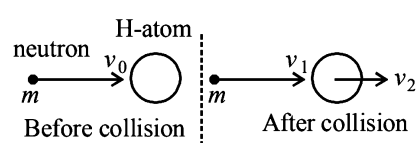
$\therefore \quad \Delta E = 13.6\left(1 - \frac{1}{16}\right) = \frac{15}{16} \times 13.6eV = 12.75eV$

Using conservation of linear momentum

$mv = mv_1 + mv_2$ ...(1)

$(v_2 - v_1) = \frac{1}{2}v$ ...(2)

$\therefore v_1 = \frac{v}{4}, v_2 = \frac{3v}{4}$ ....(3)



By energy conservation

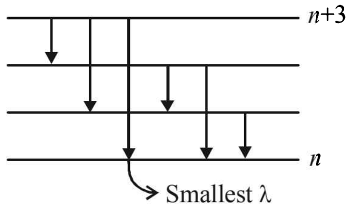
$\therefore \frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 + \Delta E$

$\Rightarrow \frac{1}{2}mv^2\left(1 - \frac{1}{16} - \frac{9}{16}\right) = \Delta E$

$\Rightarrow \frac{1}{2}mv^2 = \frac{16}{6}\Delta E = \frac{8}{3} \times 12.75eV = 32$ eV

12. **3**

If x is the difference in quantum number of the states than ${}^{x+1}C_2 = 6 \Rightarrow x = 3$



Now, we have $\frac{-Z^2(13.6\text{eV})}{n^2} = -0.85\text{eV}$ ...(i)

and $\frac{-Z^2(13.6\text{eV})}{(n+3)^2} = -0.544 \text{ eV}$ ...(ii)

Solving (i) and (ii), we get $Z = $ **3.**

13. 2

For hydrogen like atom energy of the nth orbit is

$$E_n = -\frac{13.6}{n^2}Z^2 \text{ eV/atom}$$

For transition from $n = 5$ to $n = 4$,

$$h\nu = 13.6 \times 9\left[\frac{1}{16} - \frac{1}{25}\right] = \frac{13.6 \times 9 \times 9}{16 \times 25} = 2.754 \text{ eV}$$

For transition from $n = 4$ to $n = 3$,

$$h\nu' = 13.6 \times 9\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{13.6 \times 9 \times 7}{9 \times 16} = 5.95\text{eV}$$

For transition $n = 4$ to $n = 3$, the frequency is high and hence wavelength is short.

For photoelectric effect, $h\nu' - W = eV_0$, where W = work function

$5.95 \times 1.6 \times 10^{-19} - W = 1.6 \times 10^{-19} \times 3.95$

$\Rightarrow W = 2 \times 1.6 \times 10^{-19} = 2$ eV

14. (a) 15. (c)

$$F = -\frac{dU}{dr} = \frac{mv_n^2}{r_n} \quad m\alpha^2 r_n = \frac{mv_n^2}{r_n} \quad \text{... (i)}$$

and $mv_n r_n = \frac{nh}{2\pi}$ ... (ii)

Solving equations (i) and (ii)

$$r_n = \left(\frac{nh}{2\pi m\alpha}\right)^{1/2}$$

and KE $= \frac{1}{2}mv_n^2 = \frac{nh\alpha}{4\pi}$

Total energy, E = U + KE $= -\frac{1}{2}m\alpha^2 r_n^2 + \frac{1}{2}mv_n^2 = 0.$

16. (a) Current developed due to motion of an electron in n^th^ Bohr's orbit = $I_0\frac{Z^2}{n^3}$ (unit ampere) here in column III option (r) $C_0\frac{Z^2}{n^3}$, for z = 3 and n = 3, $I = C_0 \times \frac{3^2}{3^3} = \frac{C_0}{3}$

17. (b) $\omega_n = \omega_0\frac{z^2}{n^3}$ sec^{-1}, $I_n = I_0\frac{Z^2}{n^3}$ A,

$V_n = V_0\frac{Z}{n}$ m/s, $E_n = E_0\frac{Z^2}{n^2}$ J

18. (d) Ionization energy, $E_n = E_0\frac{Z^2}{n^2}$

19. (A) → q; (B) → r; (C) → p; (D) → s

20. (A) → p, r; (B) → q, s; (C) → q; (D) → q, s

(A) $B = \frac{\mu_0 i}{2\pi r}$ where $i_{eq} = \frac{q}{T} = \frac{e}{2\pi r/v}$

$$\Rightarrow B = \frac{\mu_0 e}{4\pi^2}\frac{v}{r^2} \propto \frac{v}{r^2} \propto \frac{(Z/n)}{(n^2/Z^2)} \propto \frac{Z^3}{n^5}$$

(B) Magnetic moment,

$$M = iA = \left(\frac{q}{T}\right)(\pi r^2) = \frac{e}{2\pi r/v}\pi r^2 \propto rv \propto \left(\frac{n^2}{Z}\right)\left(\frac{Z}{n}\right)$$

(C) $\lambda = \frac{h}{mv} \propto \frac{1}{Z/n} \propto \frac{n}{Z}$

(D) Areal velocity $= \frac{L}{2m} = \frac{nh/2\pi}{2\pi} \propto n$