



PHYSICS

BOOKS - HC VERMA

BOHR'S MODEL AND PHYSICS OF THE ATOM

Examples

1. Calculate the energy of a He^+ ion in its first excited state solution



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2. Calculate the wavelength of radiation emitted when He^+ makes a transition from the state $n = 3$ to the state $n = 2$



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3. The excitation energy of a hydrogen-like ion in its first excited state is 40.8eV . Find the energy needed to remove the electron from the ion the ground state is



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Worked Out Examples

1. Find the radius of Li^{++} ions in its ground state assuming Bohr's model to be valid



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2. A particular hydrogen like radiation of frequency $2.467 \times 10^{15} \text{ Hz}$ when it makes transition from $n = 2 \rightarrow n = 1$, What will be the frequency of the radiation emitted in a transition from $n = 3 \rightarrow n = 1$?



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3. Calculate the two highest wavelength of the radiation emitted when hydrogen atoms make transition from higher state to $n = 2$



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4. What is the wavelength of the radiation emitted to the electron in a hydrogen atom jumps from $n = 1 \rightarrow n = 2$?



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5. (a) Find the wavelength of the radiation required to excite the electron in Li^{++} from the first to the third Bohr orbit (b) How many spectral lines are observed in the emission spectrum of the above excited system?

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6. Find the wavelength present in the radiation emitted when hydrogen atoms excited to $n = 3$ states return to their ground state

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7. How many different wavelength may be observed in the spectrum from a hydrogen sample if the atoms excited to states with principal quantum number n ?

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8. Monochromatic radiation of wavelength λ is incident on a hydrogen sample in ground state hydrogen atoms absorb a fraction of light and subsequently emit radiation of six different wavelength. Find the value of λ

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9. The energy needed to detach the electron of a hydrogen like ion in ground state is a system 4 rydberg (a) what is the wavelength of the radiation emitted when the electron jumps from the first excited state to the ground state? (b) What is the radius of the orbit for this atom?



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10. A hydrogen sample is prepared in a particular excited state A photon of energy $2.55eV$ is absorbed into the sample to take some of the

electron to a further excited state B find the quantum numbers of the state A and B



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11. (a) Find the maximum wavelength λ_{90} of light which can ionize a hydrogen atom in its ground (b) light of wavelength λ_0 is inclined on a hydrogen atom which is in its first excited state find the kinetic energy of the electron coming out



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12. Derive an expression for the magnetic field at the site of the nucleus in a hydrogen atom due to the circular motion of the electron. Assume that the atom is in its ground state and the answer in terms of fundamental constants



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13. A lithium atom has three electrons. Assume the following simple picture of the atom: Two electrons move close to the nucleus making up a spherical cloud in a circular orbit. Bohr's model can be used for the motion of this third electron but $n = 1$ state are

not andiable is it calculate the ionzation energy of lithium in ground state using the above picture



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14. A particle known as mu mean has a charge equal to that of no electron and mass 208times the mass of the electron B moves in a circular orbit around a nucleus of charge $+3e$ Take the mass of the nucles to be infinite Assuming that the bohr's model is applicable to this system (a)drive an eqression for the radius of the nth Bohr orbit (b) find the value of a for which the readius of the orbit it approninately the same as that at the first bohr for a hydrogen atom (c)

find the wavelength of the radiation emitted when the u - mean jump from the orbit to the first orbit



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15. Find the wavelength in a hydrogen spectirm between the range $500nm \rightarrow 700nm$



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16. A beam of ultraviolet radius hacking wavelength between $100nm$ and $200nm$ is inclined on a sample of atomic hydrogen gos Assuming that the atoms are in ground state which wavelength will have low

intensity in the transnilled been? If the energy of a photon is equal to the ground state it has large probability of being observed by on atom in the ground state



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17. A neutron moving with a speed ' v ' makes a head on collision with a stationary hydrogen atom is ground state. The minimum kinetic energy of the neutron for which inelastic colision will take place is :-



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18. Light corresponding in the transition $n = 4 \rightarrow n = 2$ in hydrogen atoms falls on cesium metal (work function = 1.9eV) Find the maximum kinetic energy of the photoelectrons emitted



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19. A small particle of mass m moves in such a way that the potential energy $U = \frac{1}{2}m^2\omega^2r^2$ when ω is a constant and r is the distance of the particle from the origin. Assuming Bohr's model of quantization of angular momentum and circular orbits, show that the radius of the n th allowed orbit is proportional to n^2 .



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Short Answer

1. How many wavelength are emitted by atomic hydrogen in visible range ($380nm - 780nm$) ? In the range $50nm \rightarrow 100nm$?



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2. The excited energy of a He^+ ion is the same as the ground state energy of hydrogen is it always true that one of the energies of any hydrogen like ion will

be the same as the ground state energy of a hydrogen atom?



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3. Which wavelength will be emitting by a sample of atomic hydrogen gas (in ground state) if electron of energy 12.5eV collide with the atoms of the gas?



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4. What wavelength radiation is passed through a sample of hydrogen gas at room temperature, absorption lines are observed in Lyman series only Explain



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5. Balmer series was observed and analysed before the other series. Can you suggest a reason for such an order?



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6. What will be the energy corresponding to the first excited state of a hydrogen atom if the potential energy of the atom is taken to be $10eV$ when the electron is widely separated from the proton? Can we still write $E_0 - E_1/n^2$, or, $r_n = a_0 n^2$?



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7. The difference in the frequency of series limit of Lyman series and Balmer series is equal to the frequency of the first line of the Lyman series. Explain.



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8. The numerical value of ionization energy in eV equals the ionization potential in volts. Does this equality hold if these quantities are measured in some other units?



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9. We have stimulated and spontaneous emission. Do we also have stimulated absorption and spontaneous absorption?

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10. An atom is in its excited state, Does the probability of its coming to ground state depend on whether the radiation is already present or not? If yes, it also depends on the wavelength of the radiation present?

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Objective 1

1. The minimum orbital angular momentum of the electron in a hydrogen atom is

A. h

B. $h / 2$

C. $h / 2\pi$

D. h / λ

Answer: C



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2. Three photons coming from excited atoms hydrogen sample are picked up. Their energies are 12.1eV , 10.2eV and 1.9eV . These photons must come from

A. a single atom

B. two atoms

C. three atoms

D. either two atoms or three atoms

Answer: D



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3. Suppose the electron in a hydrogen atom makes transition from $n = 3 \rightarrow n = 2$, $\in 10^{-8} s$ The order of the torque acting on the electron in this period, using the relation between torque and angular momentum as discussed in the chapter on rotational mechanics is

A. $10^{-34} Nm$

B. $10^{-26} Nm$

C. $10^{-42} Nm$

D. $10^{-8} Nm$

Answer: B





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4. In which of the following transition will the wavelength be minimum ?

A. $n = 5 \rightarrow n = 4$

B. $n = 4 \rightarrow n = 3$

C. $n = 3 \rightarrow n = 2$

D. $n = 2 \rightarrow n = 1$

Answer: D



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5. In which of the following system will the radius of the first orbit($n = 1$) be maximum ?

- A. Hydrogen atom
- B. Deuterium atom
- C. single ionized helium
- D. Doubly ionized lithium

Answer: D



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6. In which of the following system will the wavelength corresponding to $n = 2 \rightarrow n = 1$ be

minimum ?

- A. Hydrogen atom
- B. Deuterium atom
- C. single ionized helium
- D. Doubly ionized lithium

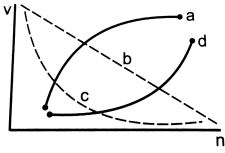
Answer: D



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7. Which of the following curve may represent the speed of the electron in a hydrogen atom as

a function of the principal quantum number n ?



A. 

B. 

C. 

D. 

Answer: C



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8. As one considers orbits with higher value of n in a hydrogen atom, the electron potential energy of the atom

A. decreases

B. increases

C. remain the same

D. does not increases

Answer: B



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9. The energy of an atom (or ion) in the ground state is

-54.4eV . It may be

A. Hydrogen

B. deuterium

C. He^+

D. Li^{++}

Answer: C



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10. The radius of the shortest orbit in a one electron system is 18 pm it may be

A. Hydrogen

B. deuterium

C. He^+

D. Li^{++}

Answer: D



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11. A hydrogen atom in ground state absorbs 10.2eV of energy. The orbital angular momentum of the electron is increased by

A. $1.05 \times 10^{-34} \text{ Js}$

B. $2.11 \times 10^{-34} \text{ Js}$

C. $3.16 \times 10^{-34} \text{ Js}$

D. $4.22 \times 10^{-34} \text{ Js}$

Answer: A



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12. Which of the following parameters are the same for all hydrogen like atoms and ions in their ground state?

- A. Radius of the orbit
- B. Speed of the electron
- C. Energy of the atom
- D. Orbital angular momentum of the electron

Answer: D



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13. In a laser tube all the photons

A. have same wavelength

B. have same energy

C. move in same direction

D. move with same speed

Answer: D



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Objective 2

1. In a laboratory experiment on emission from atomic hydrogen in a discharge tube only a small number of lines are observed whereas a large number of lines are present in the hydrogen spectrum of a star .This is because in a laboratory

A. the amount of hydrogen taken is smaller than that present in the star

B. the temperature of hydrogen is much smaller than that of the star

C. the pressure of hydrogen is much smaller than that of the star

D. the gravitational pull is much smaller than that
of the star

Answer: B



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2. An electron with kinetic energy $5eV$ is incident on a hydrogen atom in its ground state. The collision

- A. must be elastic
- B. may be partially elastic
- C. must be completely inelastic

D. may be completely inelastic

Answer: A



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3. Which of the following products in a hydrogen atom are independent of the principal quantum number n ? The symbols have their usual meanings

A. V_n

B. E_r

C. E_n

D. V_r

Answer: A::B



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4. Let A_n be the area enclosed by the n th orbit in a hydrogen atom. The graph of $\ln(A_n/A_1)$ against $\ln(n)$

- A. will pass through the origin
- B. will be a straight line with slope 4
- C. will be a monotonically increasing nonlinear curve
- D. will be a circle

Answer: A::B



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5. Ionization energy of a hydrogen like A is greater than that of another hydrogen like ion B. Let r , u , E and L represent the radius of the orbit, speed of the electron energy of the atom and orbital angular momentum of the electron respectively, in ground state

A. $r_A > r_B$

B. $u_A > u_B$

C. $E_A > E_B$

D. $L_A > l_B$

Answer: B



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6. When a photon stimulates the emission of another photon the two photon have

- A. same energy
- B. same direction
- C. same phase
- D. same wavelength

Answer: A::B::C::D

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Exercises

1. The bohrradius is given by $a_0 = \frac{\epsilon_0 h^2}{\pi m e^2}$ verify that the RHS has dimesions of length

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2. Find the wavelength of the radiation by hydrogen in the transition (a)

$$n = 3 \rightarrow n = 2, n = 5 \rightarrow n = 4 \text{ and } n = 10 \rightarrow n = 9$$



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3. Calculate the smaller wavelength of radiation that may be emitted by (a) hydrogen (b) He^+ and (c) Li^{++}



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4. Evaluate Rydberg constant by putting the value of the fundamental constants in its expression



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5. Find the binding energy of a hydrogen atom in the state $n = 2$



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6. Find the radius and energy of a He^+ ion in the states (a) $n = 1$, (b) $n = 3$ and (c) $n = 4$ is



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7. A hydrogen atom emits ultraviolet of wavelength 102.5nm what are the quantum number of the state involved in the transition?



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8. (a) Find the first excitation potential of He^+ ion

(b) Find the ionization potential of Li^{++} ion



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9. A group of hydrogen atom are prepared in $n = 4$ states list the wavelength that are emitted as the atoms make transition and return to $n = 2$ states



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10. A positive ion having just one electron ejects it if a photon of wavelength 228\AA or less is absorbed by it.

Identify the ion



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11. Find the maximum calculate force can act on the electron due to the nucleus in a hydrogen atom



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12. A hydrogen atom in a having a binding of $0.85eV$ makes transition to a state with excited energy

10.2 eV (a) identify the quantum number n of the upper and the lower energy state involved in the transition (b) Find the wavelength of the emitted radiation



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13. Whenever a photon is emitted by hydrogen in the Balmer series it is followed by another in the Lyman series. What wavelength does this latter photon correspond to?



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14. A hydrogen atom in state $n = 6$ makes two successive transition and reaches the ground state in the first transition a photon of $1.13eV$ is emitted (a) Find the energy of the photon emitted in the second transition (b) what is the value of n in the intermediate state?



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15. What is the energy of a hydrogen atom in the first excited state if the potential energy is taken to be zero in the ground state?



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16. A hot gas emits radiation of wavelength 46.0nm , 82.8nm and 103.5nm only. Assume that the atoms have only two excited states and the difference between consecutive energy levels decreases as energy is increased. Taking the energy of the highest energy state to be zero, find the energies of the ground state and the first excited state.



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17. A gas of hydrogen-like ions is prepared in a particular excited state A . It emits photons having

wavelength equal to the wavelength of the first line of the Lyman series together with photons of five other wavelengths identify the gas and find the principal quantum number of the state A



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18. Find the maximum angular speed of the electron of a hydrogen atom in a stationary orbit



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19. A spectroscopic instrument can resolve two nearly wavelength λ and $\lambda + \Delta\lambda$ if $\lambda/\Delta\lambda$ is smaller

than 8000 This is used to study the spectral lines of the balmer series of hydrogen Approximately how many lines will be resolved by the instrument?



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20. Suppose in certine condition only those transition are allowed to hydrogen atoms in which the principal quantum number a changes by 2 (a) Find the smaller wavelength emitted by hydrogen (b) list the wavelength emitted by hydrogen in the visible range ($380nm \rightarrow 780nm$)



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21. According to Maxwell's theory of electrodynamics, an electron going in a circle should emit radiation of frequency equal to the frequency of revolution. What should be the wavelength of the radiation emitted by a hydrogen atom in ground state if this rule is followed?



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22. The average kinetic energy of molecules in a gas at temperature T is $1.5kT$. Find the temperature at which the average kinetic energy of the molecules of hydrogen equals the binding energy of its atoms.

hydrogen remain in molecules form at this temperature ? Take $h = 8.62 \times 10^{-6} eVK^{-1}$



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23. Find the temperature at which the average thermal kinetic energy is equal to the energy needed to take a hydrogen atom from its ground state $n = 1$ state hydrogen can now emit red light of wavelength $653.1nm$ because of maxwellian distribution of speeds a hydrogen sample emits red light at temperature much lower than that obtained from this problem Assume that hydrogen that hydrogen molecules dissociate into atoms



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24. Average lifetime of a hydrogen atom excited to $n = 2$ state $10^{-6}s$ find the number of revolutions made by the electron on the average before it jump to the ground state



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25. calculate the magnetic dipolemoment corresponding to the motion of the electron in the ground state of a hydrogen atom



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26. Show that the ratio of the magnetic dipole moment to the angular momentum ($l = \mu r$) is a universal constant for hydrogen atom and ions find the value

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27. A beam of light having wavelength distributed uniformly between $450\text{nm} \rightarrow 550\text{nm}$ passes through a sample of hydrogen gas which wavelength will have the least intensity in the transition beam?

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28. Radiation coming from transition $n = 2 \rightarrow n = 1$ of hydrogen atoms falls on helium in $n = 1$ and $n = 2$ state what are the possible transition of helium ions as they absorb energy from the radiation?



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29. A hydrogen atom in ground state observe a photon of ultraviolet radiation of wavelength $50nm$. Assuming that the entire photon energy is taken up

by the electron with what kinetic energy will the electron be ejected?



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30. A parallel beam of light of wavelength 100nm passes through a sample of atomic hydrogen gas in ground state (a) Assume that when a photon suppose some of its energy to a hydrogen atom the rest of the energy appears as another photon moving in the same direction as the incident photon Neglecting the light emitted by the excited hydrogen atom in the direction of the incident beam, ? (b) A radiation detector is placed near the gas to detect radiation

coming perpendicular to the incident beam find the wavelength of radiation that may be detected by the detector



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31. A beam of monochromatic light of wavelength λ ejects photoelectrons from a cesium ($\phi = 1.9\text{eV}$) these photoelectron from a radius are made to cesium with hydrogen atoms in ground state find the maximum value of λ for which (a) hydrogen atoms may be ionised (b) hydrogen may get excited from the ground state to the first excited state and (c) the excited hydrogen atoms may emit visible light



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32. Electron are emitted from an electron gun at almost zero velocity and are accelerated by an electric field E through a distance of $1.0m$. The electron are now scattered by an atomic hydrogen sample in ground state what should be the minimum value of E so that red light of wavelength $656.5nm$ may be emitted by the hydrogen?



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33. A neutron having kinetic energy 12.5eV collides with a hydrogen atom at rest neglect the difference in mass between the neutron and the hydrogen atom and assume that the neutron does not leave its of motion find the possible kinetic energy of the neutron after the event



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34. a hydrogen atom moving at speed v collides with another hydrogen atom kept at rest .Find the minimum value of u for which one of the atoms may

get ionized the mass of a hydrogen atom
 $= 1.67 \times 10^{-27} \text{ kg}$



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35. A neutron moving with a speed u strikes a hydrogen atom in ground state in ground toward it with the same speed Find the minimum speed of the neutron for which inelastic (completely or partially) collision may take place .The mass of neutron = mass of hydrogen $= 1.67 \times 10^{-27} \text{ kg}$



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36. When a photon is emitted by a hydrogen atom , the photon carries a momentum with it (a) calculate the momentum carried by the photon when a hydrogen atom emits light of wavelength $656.3nm$ (b) with what speed does the atoms recoil during this transition? Take the mass of the hydrogen atom $= 1.67 \times 10^{-27}kg$ (c) Find the kinetic energy of recoil of the atom



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37. When a photon is emitted from an atom , the atom recoils The kinetic energy of recoils and the

energy of the photon come from the difference in energy between the state involved in the transition suppose a hydrogen atom change its state from $n = 3 \rightarrow n = 2$ calculate the fractional change in the wavelength of light emitted , due to the recoil



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38. The light emitted in the transition $n = 3 \rightarrow n = 2$ in hydrogen is called H_0 light .Find the maximum work fonction a metel one have so that H_0 light can emit photoelectrons from it



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39. Light from balmer series of hydrogen is able to eject photoelectron from a metal what can be the maximum work function of the metal?



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40. Radiation from hydrogen discharge tube falls on a cesium plate find the maximum possible kinetic energy of the photoelectron work function of cesium is 1.9eV



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41. A filter transmits only the radiation of wavelength greater than 440 nm. Radiation from a hydrogen discharge tube goes through such a filter and is incident on a metal of work function 2.0eV . Find the stopping potential which can stop the photoelectrons.



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42. The earth revolves round the sun due to gravitational attraction. Suppose that the sun and the earth are point particles with their existing masses and that Bohr's quantization rule for angular

momentum is valid in the case of gravitation (a)

Calculate the minimum radius the earth can have for

its orbit. (b) What is the value of the principle

quantum number n for the present radius ? Mass of

the earth = 6.0×10^{24} kg, mass of the sun =

2.0×10^{30} kg, earth-sun distance = $1.5 \times 10^{11} m$.



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43. Consider a neutron and an electron bound to each other due to gravitational force. Assuming Bohr's quantization rule angular momentum to be valid in this case, derive an expression for the energy of the neutron-electron system.



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44. A uniform magnetic field B exists in a region. An electron projected perpendicular to the field goes in a circle. Assuming Bohr's quantization rule for angular momentum, calculate (a) the smallest possible radius of the electron's (b) the radius of the n th orbit and (c) the minimum possible speed of the electron.



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45. Suppose in an imaginary world the angular momentum is quantized to be even integral multiples of $h/2\pi$. What is the longest possible wavelength emitted by hydrogen atoms in visible range in such a world according to Bohr's model?



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46. Consider an excited hydrogen atom in state n moving with a velocity v ($v \ll c$). It emits a photon in the direction of its motion and changes its state to a lower state m . Apply momentum and energy conservation principle to calculate the

frequency ν of the emitted radiation, compare this with the frequency ν_0 emitted if the atom were at rest.



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