PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

X-Rays

Worked Out Examples

1. Find the maximum frequency, the X-ray emitted by an X-ray tube operating at $30kV$

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2. An X-ray tube operates at 20 kV. A particular electron loses 5% of its kinetic energy to emit an X-ray photon at the first collision. Find the wavelength corresponding to this photon.

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3. An x-ray tube is operated at $20kV$ and the current through the tube is $0 \cdot 5mA$. Find (a) the number of electrons hitting the target per second, (b) the energy falling on the target per second as the kinetic energy of the electrons and © the cutoff wavelength of the X-rays emitted.

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4. Find the constants a and b in Moseley's equation $\sqrt{v} = a(Z - b)$ from the following data.

Find the constants a and b in Moseley's equation $\sqrt{v} = a(Z - b)$ from the following data.

Element	Z	Wavelength of K_α X-ray
Mo	42	71 pm
Co	27	178·5 pm

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5. The $K\alpha$ X-ray of molybdenum has wavelength 71 pm. If the energy of a molybdenum atom with a K electron knocked out is 23.32 keV, what will be the energy of this atom when an L electron is knocked out?

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6. Show that the frequency of K_β X-ray of a material equals the sum of the frequencies of K_α and L_α X-rays of the same material.

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Short Answer

1. When a Coolidge tube is operated for some time it becomes hot. Where does the heat come from?

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2. In a Coolidge tube, electrons strike the target and stop inside it. Does the target get more and more negatively charged as time passes?

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3. can X-rays be used for photoelectric effect?

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4. Can X-rays be polarized?

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5. X-ray and visible light travel at the same speed in vacuum. Do they travel at the same speed in glass?

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6. Characteristics X-rays may be used to identify the element from which they are coming. Can continuous X-rays be used for this purpose?

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7. Is it possible that in a Coolidge tube characterstic L_{α} X-rays are emitted but not K_{α} X-rays?

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8. Can L_{α} X-ray of one material have shorter wavelength than K_{α} X-ray of another?

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9. Can a hydrogen atom emit characteristic X-ray?

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10. Why is exposure to X-ray injurious to health but exposure to visible light is not, when both are electromagnetic waves?

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Objective 1

1. X-ray beam can be deflected

A. by an electric field

B. by a magnetic field

C. by an electric field as well as by a magnetic field

D. neither by an electric field nor by a magnetic field

Answer: D

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2. Consider a photon of continuous X-ray coming from a Coolidge tube. Its energy comes from

A. the kinetic energy of the striking electron

B. the kinetic energy of the free electrons of the target

C. the kinetic energy of the ions of the target

D. an atomic transition in the target

Answer: A

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3. The energy of a photon of characteristic X-ray from a Coolidge tube comes from

A. the kinetic energy of the striking electron

B. the kinetic energy of the free electrons of the target

C. the kinetic energy of the ions of the target

D. an atomic transition in the target

Answer: D

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4. If the potential difference applied to tube is doubled and the separation between the filament and the target is also doubled, the cutoff wavelength

A. will remain unchanged

B. will be doubled

C. will be halved

D. will become four times the original

Answer: C

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5. If the current in the circuit for heating the filament is increased, the cutoff wavelength

A. will increase

B. will decrease

C. will remain unchanged

D. will change

Answer: C

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6. Moseley's law for characteristic X-rays is $\sqrt{v} = a(Z - b)$. In this,

A. both a and b are independent of the material

B. a is independent but b depends on the material

C. b is independent but a depends on the material

D. both a and b depend on the material

Answer: A

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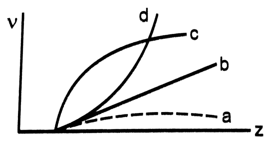
7. Frequencies of K_{α} X-rays of different materials are measured. Which one of the graphs in figure (44-Q1) may represent the relation between the frequency v and the atomic number Z.



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8. The X-ray beam coming from an X-ray tube

A. is monochromatic

B. has all wavelengths smaller than a certain maximum wavelength

C. has all wavelengths greater than a certain minimum wavelenth

D. has all wavelengths lying between a minimum and a maximum wavelength

Answer: C

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9. One of the following wavelength is absent and the rest are present in the X-rays coming from a Coolidge tube. Which one is the absent wavelength?

A. 25 pm

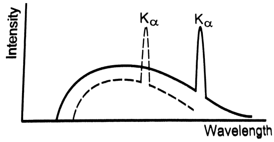
B. 50 pm

C. 75 pm

D. 100 pm

Answer: A

10. Figure shows the intensity-wavelength relations of X-rays coming from two different Coolidge tube. The solid curve represents the relation for the tube A in which the potential difference between the target and the filament is V_A and the atomic number of the target material is Z_A. These quantities are V_β and Z_β for the other tube. Then,



A. $V_A > V_B, Z_A > Z_B$

B. $V_A > V_B, Z_A < Z_B$

C. $V_A < V_B, Z_A > Z_B$

D. $V_A < V_B, Z_A < Z_B$

Answer: B

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11. 50% of the X-ray coming from a Coolidge tube is able to pase through a 0.1 mm thick aluminium foil. If the potential difference between the target and the filament is increased, the fraction of the X-ray passing through the same foil will be

A. 0

B. lt50%

C. 0.5

D. gt50%

Answer: D

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12. 50% of the X-ray coming from a Cooling tube is able to pass through a 0.1 mm thick aluminium foil. The potential difference between the target and the filament is increased. The thickness of aluminium foil, which will allow 50% of the X-ray to pass through, will be

A. zero

B. $< 0.1mm$

C. $0.1mm$

D. $> 0.1mm$

Answer: D

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13. X-ray from a Coolidge tube is incident on a thin aluminium foil. The intensity of the X-ray transmitted by the foil is found to be I_0. The heating current is increased so as to increase the temperature of the filament. The intensity of the X-ray transmitted by the foil will be

A. zero

B. $< I_0$

C. I_0

D. $> I_0$

Answer: D

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14. Visible light passing through a circular hole forms a diffraction disc of radius 0.1 mm on a screen. If X-ray is passed through the same set-up, the radius of the diffraction disc will be

A. zero

B. $< 0.1 mm$

C. $0.1 mm$

D. $> 0.1 mm$

Answer: B

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Objective 2

1. For harder X-rays,

A. the wavelength is higher

B. the intensity is higher

C. the frequency is heigher

D. the photon energy is higher

Answer: C::D

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2. Cutoff wavelength of X-rays coming from a Coolidge tube depends on the

A. target material

B. accelerating voltage

C. separation between the target and the filament

D. temperature of the filament

Answer: B

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3. mark the correct options.

A. An atom with a vacancy has smaller energy than a neutral atom.

B. K X-ray is emitted when a hole makes a jump from the K shell to some other shell.

C. The wavelength of K X-ray is smaller than the wavelength of L X-ray of the same material.

D. The wavelength of K_{α} X-ray is smaller than the wavelength of K_{β} X-ray of the same material.

Answer: B::C

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4. For a given material, the energy and wavelength of characterstic X-rays satisfy

A. $E(K_{\alpha}) > E(K_{\beta}) > E(K_{\gamma})$

B. $E(M_{\alpha}) > E(L_{\alpha}) > E(K_{\alpha})$

C. lambda(K_alpha) gt lambda(K_beta) gt lambda(K_gamma)

D. lambda(M_alpha) gt lambda(L_alpha) gt lambda(K_alpha)

Answer: C::D

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5. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation,

A. the intensity increases

B. the minimum wavelength increases

C. the intensity remains unchanged

D. the minimum wavelength decreases

Answer: C::D

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6. When an electron strikes the target in a Coolidge tube, its entire kinetic energy

A. is converted into a photon

B. may be converted into a photon

C. is converted into heat

D. may be converted into heat

Answer: B::D

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7. X-ray incident on a material

A. exerts a force on it

B. transfers energy to it

C. transfers momentum to it

D. transfers impulse to it

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

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8. Consider a photon of continuous X-ray and a photon of characteristic X-ray of the same wavelength. Which of the following is/are different for the two photons?

A. Frequency

B. Energy

C. Penetrating power

D. Method of creation

Answer: D

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Exercises

1. Find the energy, the frequency and the momentum of an X-ray photon of wavelength 0.10 nm.

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2. Iron emits K_α X-ray of energy 6.4 keV and Calcium emits K_α X-ray of energy 3.69 keV.

Calculate the times taken by an iron K_a photon and a calcium K_a photon to cross through a distance of 3 km.

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3. Find the cutoff wavelength for the continuous X-rays coming form an X-ray tube operating at 30 kV.

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4. What potential difference should be applied across an X-ray tube to get X-ray of wavelength not less than 0.10 nm? What is the maximum energy of a photon of this X-ray in joule?

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5. The X-ray coming from a Coolidge tube has a cutoff wavelength of 80 pm. Find the kinetic energy of the electrons hitting the target.

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6. If the operating potential in an X-ray tube is increased by 1%, by what percentage does the cutoff wavelength decrease?

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7. The distance between the cathode (filament) and the target in an X-ray tube is 1.5 m. If the cutoff wavelength is 30 pm, find the electric field between the cathode and the target.

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8. The short-wavelength limit shifts by 26 pm when the operating voltage in an X-ray tube is increased to 1.5 times the original value. What was the original value of the operating voltage?

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9. The electron beam in a colour TV is accelerated through 32 kV and then strikes the screen. What is the wavelength of the most energetic X-ray photon?

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10. When 40 kV is applied across an X-ray tube, X-ray is obtained with a maximum frequency of 9.7×10^{18} Hz. Calculate the value of Planck constant from these data.

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11. An X-ray tube operates at 40 kV. Suppose the electron converts 70% of its energy into a photon at each collision. Find the lowest three wavelengths emitted from the tube. Neglect the energy imparted to the atom with which the electron collides.

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12. The wavelength of K_{α} X-ray of tungsten is $21 \cdot 3$ pm. It takes $11 \cdot 3$ keV to knock out an electron from the L shell of a tungsten atom.

What shoulb be the minimum accelerating voltage across an X-ray tube having trungsten target which allows production of K_α X-ray?

A. The K_β X-ray of argon has a wavelength of 0.36 nm. The minimum energy needed to ionize an argon atom is 16 eV. Find the energy needed to knock out an electron from the K shell of an argon atom.

B.

C.

D.

Answer:

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13. The K_{β} X-ray of argon has a wavelength of 0.36 nm. The minimum energy needed to ironize an argon atom is 16 eV. Find the energy needed to knock out an electron from the K shell of an argon atom.

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14. The k_α X-rays of aluminium (Z = 13) and zinc (Z = 30) have wavelengths 887 pm and 146 pm respectively. Use Moseley's law $\sqrt{v} = a(Z - b) \rightarrow f \in dthewave \leq n > hofthe$ K_alpha` X-ray of iron (Z = 26).

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15. A certain element emits K_α X-ray of energy 3*69 keV. Use the data from the previous problem to identify the element.

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16. The k_{β} X-rays from certain elements are given below. Draw a Moseley-type plot of $\sqrt{v} versus Z f$ or K_beta` radiation

Element Ne P Ca Mn Zn Br

Energy (keV) 0*858 2*14 4*02 6*51 9*57 13*3.

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17. Use Moseley's law with b = 1 to find the frequency of the K_{α} X-ray of $La(Z=57)$ if the frequency of the K_{α} X-ray of $Cu(Z=29)$ is known to be $1\cdot 88\times 10^{18}$ Hz.

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18. The K_{α} and K_{β} X-rays of molybdenum have wavelengths $0\cdot 71A$ and$0\cdot 63A$ respectively. Find the wavelength of L_{α} X-ray of molybdenum.

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19. The wavelength of K_{α} and L_{α} X-rays of a meterial are 21*3 pm and 141 pm respectively. Find the wavelength of K_{β} X-ray of the material.

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20. The energy of a silver atom with a vacancy in K shell is 25*31 keV, in L shell is 3*56 keV and in M shell is 0*530 keV higher than the energy of the atom with no vacancy. Find the frequency of K_α, K_β and L_α X-rays of silver.

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21. Find the maximum potential difference which may be applied across an X-ray tube with tungsten target without emitting any characteristics K or L X-ray. The energy levels of the tungsten atom with an electron knocked out are as follows.

Cell containing vacancy K L M

Energy in keV 69.5 11.3 2.3

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22. The electric current in an X-ray tube (from the target to the filament) operating at $40kV$ is $10mA$. Assume that on an average, 1% of the total kinetic energy of the electrons hitting the target are converted into X-rays and (b) how much heat is produced in the target every second?

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23. Heat at the rate of 200 W is produced in an X-ray tube operating at 20 kV. Find the current in the circuit. Assume that only a small fraction of the kinetic energy of electron is converted into X-rays.

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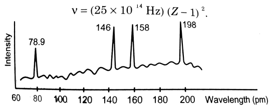
24. Continuous X-rays are made to strike a tissue paper soaked with polluted water. The incoming X-rays excite the atoms of the sample by knocking out the electrons form the inner shells. Characteristic X-rays are subsequently emitted. The emitted X-rays are analysed and the intensity is plotted against the wavelength (figure 44*E1). Assuming that only K_α intensities are detected, list the elements present in the sample from the plot. Use Moseley's equation.

$$v = \left(25 \times 10^{14} Hz\right)(Z-1)^2.$$



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25. A free atom of iron emits K_{α} X-rays of energy 6*4 keV. Calculate the recoil kinetic energy of the atom. Mass of and iron atom $= 9 \cdot 3 \times 10^{-26} kg.$

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26. The stopping potential in a photoelectric experiment is linearly related to the inverse of the wavelength $\left(\frac{1}{\lambda}\right)$ of the light falling on the cathode. The potential difference applied across an X-ray tube is linearly related to the inverse of the cutoff wavelength $\left(\frac{1}{\lambda}\right)$ of the X-ray emitted. Show that the slopes of the lines in the two cases are equal and find its value.

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27. Suppose a monochromatic X-ray beam of wavelength 100 pm is sent through a Young's double slit and the interference pattern is observed on a photographic plate placed 40 cm away from the slit. What should be the separation between the slits so that the successive maxima on the screen are separated by a distance of 0*1 mm?

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