PHYSICS

BOOKS - NEW JYOTHI PHYSICS (TAMIL ENGLISH)

DUAL NATURE OF RADIATION AND MATTER

Solved Problems

1. What is the energy of an α particle that has been accelerated through 50,000 V ?

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2. Monochromatic light of frequency $6.0 \times 10^{14} Hz$ is produced by a laser. The power emitted is 2.0×10^{-3}W. (a). What is the energy of a photon in the light beam? (b) How many photons per second, on an average are emitted by the source?

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3. The work function of caesium is 2.14 eV. Find (a) the threshold frequency for caesium, and (b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potential of 0.60 V.

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4. In an accelerator experiment on high energy collisions of electrons with positron, a certain event is interprected as annihilation of an electron-positron pair of total energy 10.2 BeV into two γ-rays of equal energy. What is the wavelength associated with each γ-ray ?

$\left(1BeV = 10^9 eV\right)$

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5. Light of wavelength 3500 A° is incident on two metals A and B. Which metal will yield photoelectrons, if their work functions are 4.2 eV and 1.9 eV respectively ?

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6. Calculate the wavelength associated with electrons whose speed is 2% of the speed of light.

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7. Calculate the de Broglie wavelength associated with a proton of kinetic energy $8 \times 10^{-17} J$.

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8. Obtain the de Broglie wavelength associated with thermal neutron at roon temperature $30^{\circ} C$.

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9. What is the de Broglie wavelength associated with (a) an electron moving with a speed of $5.4 \times 10^6 m/s$, and (b) a ball of mass 150 g travelling at 30.0 m/s ?

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10. An electron and proton are possessing the same amount of kinetic energy. Which of the two has greater wavelength?

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11. What is the de Broglie wave lenght of an electron, which is accelerated from the rest, through a potential difference of 100 V?

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12. A particle is moving three times as fast as an electron. The ratio of the de Broglie wavelength of the particle to that of the electron is 1.813×10^{-4}. Calculate the particle's mass and identify the particle.

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Solutions To Exercises From Ncert Text

1. Find the

a. maximum frequency, and

b. minimum wavelength of X-rays produced by 30 kV electrons.

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2. The work function of caesium metal is 2.14 eV. When light of frequency $6 \times 10^{14} Hz$ is incident on the metal surface, photoemission of electrons occurs. What is the

a. maximum kinetic energy of the emitted electrons,

b. stopping potential, and

c. maximum speed of the emitted photoelectrons ?

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3. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted?

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4. Monochromatic light of wavelength 632.8 nm is produced by a helium-neon laser. The power emitted is 9.42 mW.

a. Find the energy and momentum of each photon is the light beam.

b. How many photons per second, on the average, arrive at a target irradiated by this beam? (Assume the beam to have uniform cross-section which is less than the target area).

c. How fast does a hydrogen atom have to travel in order to have the same momentum as that of the photon?

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5. The energy flux of sunlight reaching the surface of the earth is $1.388 \times 10^3 W/m^2$. How many photons (nearly) per square metre are incident on the earth per second? Assume

that the photons in the sunlight have an average wavelength of 550 nm.

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6. In an experiment on photoelectric effect, the slope of the cut-off voltage versus frequency of incident light is found to be $4.12 \times 10^{-15} V$ s. Calculate the value of Planck's constant.

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7. A 100W sodium lamp radiates energy uniformly in all directions. The lamp is located at the centre of a large sphere that absorbs all the sodium light which is incident on it. The wavelength of the sodium light is 589 nm. (a) What is

the energy per photon associated with the sodium light? (b) At what rate are the photons delivered to the sphere?

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8. The threshold frequcney for a certain metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on the metal, predict the cut-off voltage for the photoelectric emission.

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9. The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?

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10. Light of frequency $7.21 \times 10^{14} Hz$ is incident on a metal surface. Electrons with a maximum speed of 6.0×10^5 m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?

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11. Light of wavelength 488 nm is produced by an argon laser which is used in the photo-electric effect. When light from this spectral line is incident on the emitter, the stopping (cut-off) potential of photoelectrons is 0.38 V. Find the work function of the material from which the emitter is made.

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12. Calculate the

a. momentum, and

b. de Broglie wavelength of the electrons accelerated through a potential difference of 56V.

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13. What is the

a. momentum, b. speed, and

c. de Broglie wavelength of an electron with kinetic energy of 120 eV.

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14. The wavelength of light from the spectral emission line of sodium is 589 nm. Find the kinetic energy at which

a. an electron, and

b. a neutron, would have the same de Broglie wavelength.

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15. What is the de Broglie wavelength of

a. a bullet of mass 0.040 kg travelling at the speed of 1.0 km/s,

b. a ball of mass 0.060 kg moving at a speed of 1.0 m/s, and

c. a dust particle of mass 1.0×10^{-9} kg drifting with a speed of 2.2 m/s ?

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16. An electron and a photon each have a wavelength of 1.00 nm. Find

a. their momenta,

b. the energy of the photon, and

c. the kinetic energy of electron.

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17. a. For what kinetic energy of a neutron will the associated de Broglie wavelength be $1.40 \times 10^{-10} m$?

b. Also find the de Broglie wavelength of a neutron, the thermal equilibrium with matter, having an average kinetic energy of (3/2) k T at 300 K.

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18. What is the de Broglie wavelength of a nitrogen molecule in air at 300 K ? Assume that the molecule is moving with the root-mean square speed of molecules at this temperature. (Atomic mass of nitrogen = 14.0076 u)

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Practice Problems For Self Assessment

1. What is the energy of an α particle that has been accelerated through 50,000 V ?

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2. A photon has a wavelength 6400 Å. Calculate, i. its frequency, ii. Its energy, iiii. Its momentum.

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3. Calculate the photoelectric work function of a metal whose threshold wavelength is 5200 Å.

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4. Calculate the momentum of an electron whose wavelength is 2 A° .

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5. Estimate de Broglie wavelength is nm associated with an iron ball of mass 66 g moving with a velocity of $2.5 \times 10^5 ms^{-1}$.

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Evaluation Questions And Answers

1. What are different methods to release electrons ?

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2. What happens when a negative potential is applied to the anode?

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3. In Photo electric effect, What happens when the negative potential is increased?

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4. What happens if intensity of light is increased, when the frequency is less than threshold value?

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5. What happens to the energy of the photon incidenting on metal surface?

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6. If radiation possesses dual nature, what is the nature of matter? Justify.

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7. How can you increase KE and intensity of electron beam?

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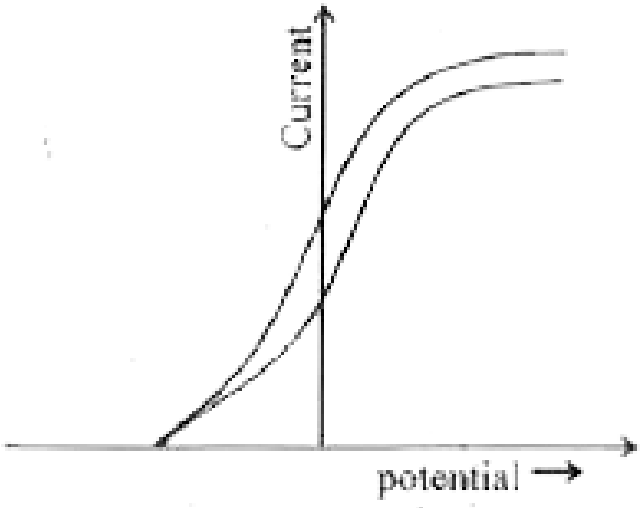
8. The figure below represents the variation of current with potential for a metal.



a. Identify the situation.

c. Even when the potential is zero, there is current. Explain.

d. Current is zero for a particular potential. How does this potential help in determining the velocity of electrons?

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9. The size of the bacteria can be magnified 60,0000 times using an electron microscope. The wave nature of electron is used in electron microscope.

a. Name the type of waves used here

c. Why is this wave character not observed in large bodies?

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10. a. Name the experiment which establishes the wave nature of moving electrons.

b. In that experiment, electrons are accelerated through a potential of 54 V and is made to fall normally on the nickel crystal of interatomic separation 0.91 A. Draw the polar graph showing the variation of intensity of the scattered electrons electrons and latitude angle at this potential.

c. Calculate the d-Broglie wavelength of the electron.

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11. Pick the odd one out.

A. Interference

B. Diffraction

C. Polarisation

D. Photoelectric effect

Answer: D

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12. Classify the following properties of the waves into de Broglie wave, e.m wave and sound wave.

i. Associated with the moving moving particle

ii. Longitudinal wave

iii. Electric field and magnetic field are perpendicular to each

other

iv. Can produce photoelectric effect

v. Wavelength is inversely proportional to mass of the moving particle

vi. Velocity in vacuum is $3 \times 10^8 m/s$

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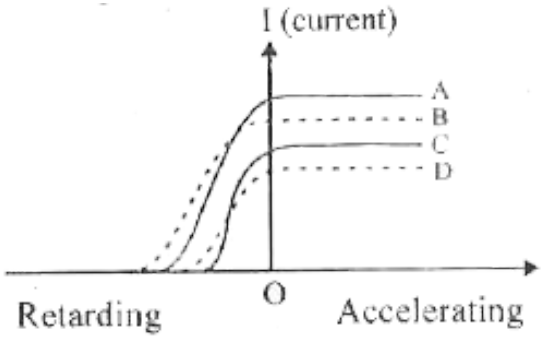
13. Pick the odd one out

Figure shows results of an experiment involving photoelectric effect.



A. Beam B has the highest frequency

B. Beam C has the largest wavelength

C. Beam A has the highest rate of photoelectric emission

D. Beam D has the least frequency

Answer: D

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14. Fill in the blanks.

	A	B	C
a.	Photoelectric effect	Experimental study by	.....
b.	Photoemissive cell	.....	Burglar's alarm
c.	de-Broglie wavelength	$\lambda = \frac{h}{mv}$	λ = ...
d.	$h\upsilon = \frac{1}{2} m v_{max}^2 + \phi_0$	$h\upsilon$ = ...	$\frac{1}{2} m v_{max}^2 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

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15. Match the following

A	B
a. Intensity of radiation	i. electron volt
b. Photo voltaic cell	ii. shorter the de-Broglie wavelength
c. Larger mass	iii. is directly proportional to current
d. Work function	iv. no battery is required
	v. is inversely proportional to current
	vi. larger the de-Broglie wavelength

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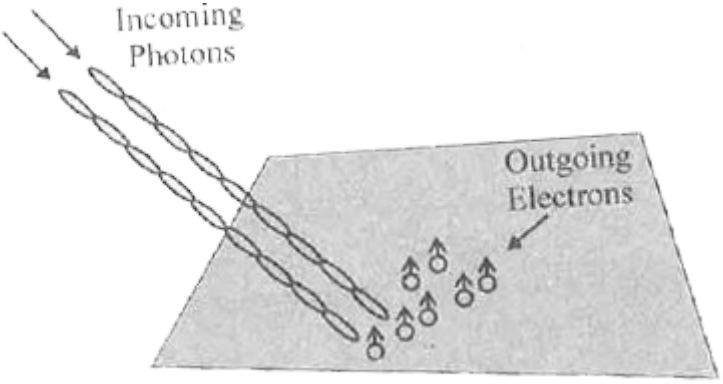
16. It has been determined experimentally that when light falls on a metal surface, the surface emits electrons. For example, you can start a current in a circuit just by shining a light on a metal plate.



a. What is your explanation?

b. Mention some other methods in which electron emission is possible.

c. Are stopping potential and cut off potential the same?

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17. a. Draw the graph showing the variation of potential with frequency of incident radiation.

b. What does the slope of the graph represent?

c. From the slope how will you find the value of 'h' ?

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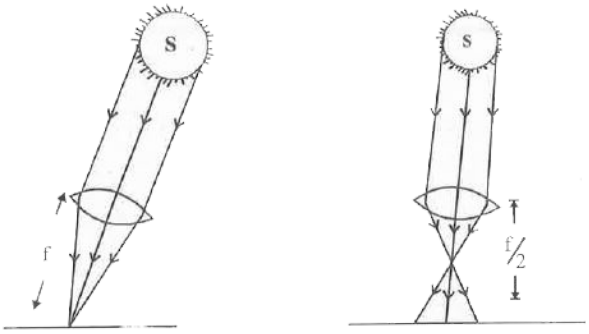
18. 

An image of the sun is formed on the metal surface of the photoelectric cell and it produces of current. The lens forming the image is then replaced by another of the same diameter but only half in focal length.

a. What will be the effect on the photoelectric current?

b. Is photoelectric emission possible at all frequencies ?

c. If not give your explanation.

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19. All the photoelectrons are not emitted with same energy. Give reason.

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20. Light is incident on the cathode of a photocell and the stopping voltages are measured for light of two different wavelengths, are given below.

Wavelength (A°)	*Stopping voltage* (V)
4000	1.3
4500	0.9

a. Determine the work function of the metal of the cathode in eV.

b. Find the value of the universal constant $\frac{hc}{e}$.

c. Define stopping potential and work function.

d. Can you suggest a mathematical relation between kinetic energy and stopping potential?

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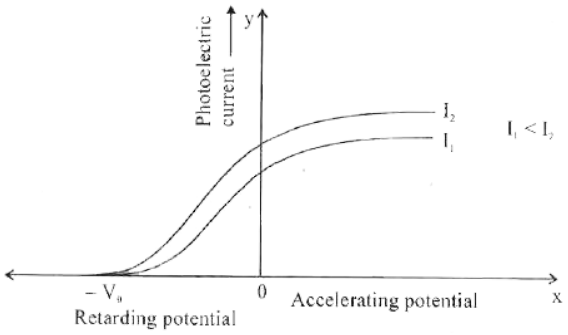
21.



The graph shows the variation of photoelectric current with accelerating potential of different intensities.

a. What conclusion do you arrive from the graph?

b. Photoelectric current is not zero even if the accelerating voltage is zero. Justify your answer.

c. Why two curves meet at one point on the retarding potential axis ?

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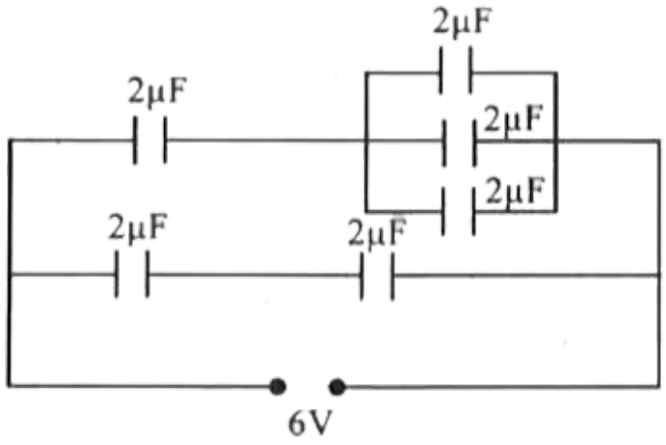
22. Find the effective capacity of the combination shown below :



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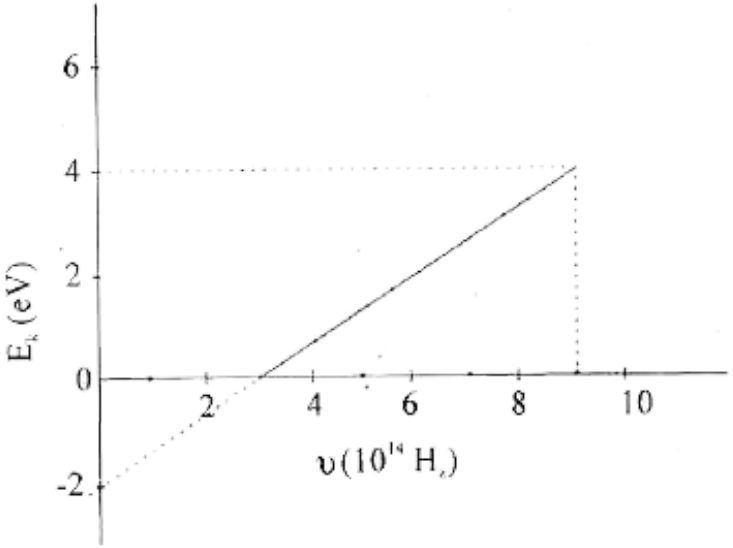
23. The above graph shows frequency of an incident photon and maximum kinetic energy of a photoelectric effect



a. What is the value of threshold frequency and threshold wave-length?

b. What is the work function of the cathode in eV?

c. Find the maximum kinetic energy, if the frequency of photon is 9×10^{14}Hz.

d. Also find the value of Planck's constant (h).

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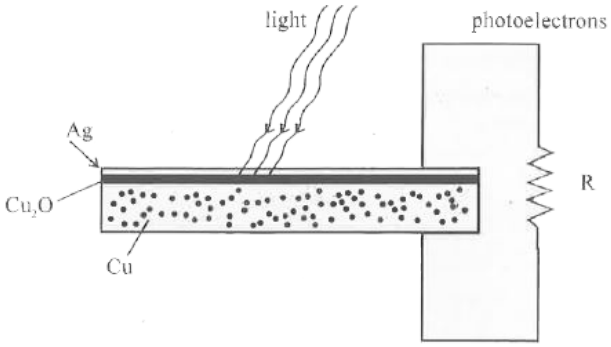

24.

a. What is the purpose of Cu_2?

b. Which plate becomes positive?

c. Which plate becomes negative?

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25. a. Why de-Broglie wave associated with a moving car is not visible ?

b. What is de-Broglie hypothesis?

c. Give expressions for de-Broglie wavelength.

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26. a. Give the expression showing the relation between energy and momentum of a photon.

b. "de-Broglie wavelength supports Bohr's model of stationary orbits." Comment on this statement.

c. Is there any difference between the wavelength of the radiation and d-Broglie wavelength of a photon of that radiation? Explain.

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27. a. The wave nature of matter is not noticeable in our daily observations. Justify your answer.

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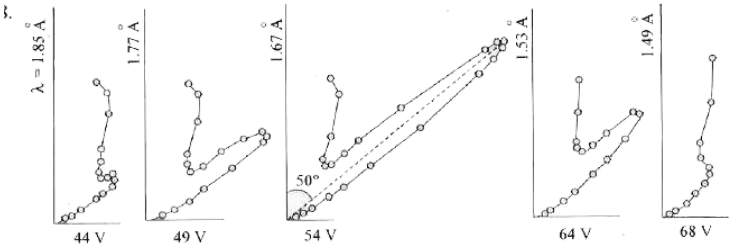

28.

What do the graphs represent?

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29. Which of the following statements are is not correct about a photon?

A. Photon exerts no pressure.

B. Momentum of photon is $\frac{hv}{c}$.

C. Rest mass of a photon is zero.

D. Energy of a photon is hv.

Answer: A::C::D

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30. a. Every metal has a definite work function. Why all photoelectrons do not come out with the same energy of incident radiation in monochromatie ? Why there is an energy distribution of photoelectrons?

b. The energy and momentum of an electron are related to the frequency and wave-length of the associated matter wave by the relations,

$$E = h\upsilon, p = \frac{h}{\lambda}$$

But while the value of λ is physically significant, the value of υ (and therefore the value of the phase speed $\upsilon\lambda$ has no physical significance. Why?

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31. Eventhough metals have free electrons, they cannot escape from metal surface. Why?

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32. Define 1 eV.

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33. What are the factors on which the rate of thermionic emission depends?

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34. Does photoelectric effect violate the law of conservation of energy?

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35. Give examples for metals sensitive to UV rays and then for visible light.

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36. Why is photocurrent proportional to intensity?

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37. What is saturation current?

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38. How does a fire alarm work?

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39. Does wave theory give proper explanation for photoelectric effect?

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40. Why is light not deflected by electric and magnetic fields?

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41. Why are alkali metal most suited for photoelectric emission?

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42. Why wooden surface does not exhibit photoelectric effect?

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43. A fast moving bullet is not diffracted by a crystal surface, while an electron diffracts. Why?

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44. An electron and a proton have same speed. How are their wavelength related?

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45. Millikan verified Einstein's photoelectric equation. How?

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46. If a proton and electron have the same de-Broglie wavelength, then

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Continuous Evaluation Assignment

1. Discuss the various modes of emission of electron.

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2. Explain the phenomenon photoelectric effect.

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3. Mention the applications of photoelectric cell.

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4. Write a note on dual nature of matter.

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Previous Year Questions

1. Albert Einstein, the great physist proposed a clear picture to explain photoelectric effect.

a. Explain Einstein's photo electric equation.

b. Name the quanta of light.

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2. De Broglie proposed the wave nature of electrons suggesting matter waves.

Find the momentum, speed and De-Broglie wavelength of an electron with Kinetic energy of 120 eV.

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3. A Work function of a metal is the

a. energy required by an electron to get absorbed in the metal surface.

b. minimum energy required by an electron to escape from the metal surface.

c. energy required by an electron to be retained in the metal surface.

d. maximum energy required by an electron to escape from

the metal surface.

B. Write Einstein's Photo-Electric Equation and explain the terms in it.

C. All photo electrons are not emitted with the same energy as the incident photons. Why?

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4. A. What is de Broglie hypothesis?

B. Write the formula for de Broglie wavelength.

C. Calculate de Broglie wavelength associated with an electron accelerated by a potential difference of 100 volts.

Given mass of the electron $= 9.1 \times 10^{-31} kg, h = 6.634 \times 10^{-34} JS, 1eV = 1.6 \times 10^{-19} J$

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Competitive Exam Corner

1. If 'm' is the mass of an electron and 'c' is the speed of light, the ratio of the wavelength of a photon of energy E to that of the electron of the same energy is

A. a. $c\sqrt{\frac{2m}{E}}$

B. b. $\sqrt{\frac{2m}{E}}$

C. c. $\sqrt{\frac{2m}{cE}}$

D. d. $\sqrt{\frac{m}{E}}$

Answer: A

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2. In a photoelectric experiment, if both the intensity and frequency of the incident light doubled, then the saturation photoelectric current

A. a. remains constant

B. b. is halved

C. c. is doubled

D. d. becomes four times

Answer: C

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3. If e/m of electron is $1.76 \times 10^{11} Ckg^{-11}$ and the stopping potential is 0.71 V, then the maximum velocity of the

photoelectron is

A. a. 150 km s^{-1}

B. b. 200 km s^{-1}

C. c. 500 km s^{-1}

D. d. 250 km s^{-1}

Answer: C

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4. If a proton and electron have the same de-Broglie wavelength, then

A. a. kinetic energy of electron lt kinetic energy of proton

B. b. kinetic energy of electron = kinetic energy of proton

C. c. momentum of electron gt momentum of proton

D. d. momentum of electron = momentum of proton

Answer: D

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5. If alpha particle, proton and electron move with the same momentum, then their respective de Broglie wavelengths $\lambda_\alpha, \lambda_p, \lambda_e$ are related as

A. a. $\lambda_\alpha = \lambda_p = \lambda_e$

B. b. $\lambda_\alpha < \lambda_p < \lambda_e$

C. c. $\lambda_\alpha > \lambda_p > \lambda_e$

D. d. $\lambda_p > \lambda_e > \lambda_\alpha$

Answer: A

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6. The de Broglie wavelength associated with an electron accelerated by a potential of 64 V is

A. a)1.227 nm

B. b) 0.613 nm

C. c) 0.302 nm

D. d) 0.153 nm

Answer: D

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7. The de Broglie wavelength and kinetic energy of a particle is 2000 Å and 1 eV respectively. If its kinetic energy becomes 1 MeV, then its de Broglie wavelength is

A. 2 Å

B. 1 Å

C. 4 Å

D. 10 Å

Answer: A

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8. The work functions of two metals are 2.75 eV and 2 eV respectively. If these are irradiated by photons of energy 3

eV, the ratio of maximum momenta of the photoelectrons emitted respectively by them is

A. $1:2$

B. $1:3$

C. $1:4$

D. $2:1$

Answer: A

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9. The maximum kinetic energy of photoelectrons

A. a. depends on collector plate

B. b. is independent of emitter plate material

C. c. is independent of frequency of incident radiation

D. d. depends on the frequency of light source and the nature of emitter plate material

Answer: D

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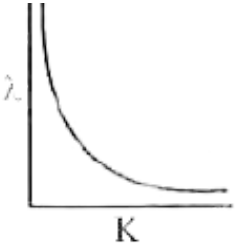
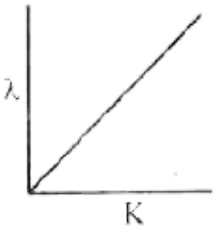
10. Identify the graph depicting the variation of the de Broglie wavelength λ of an electron with its kinetic energy K.



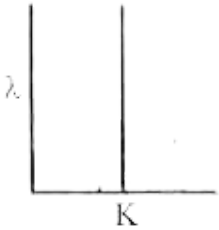
A. a.

B. b.



C. c.

D. d.



Answer: A

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11. Photo cells convert

A. a. heat energy into electrical energy

B. b. light energy into mechanical energy

C. c. thermal energy into mechanical energy

D. d. light energy into electrical energy

Answer: D

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12. An electron of mass m_e and a proton of mass m_p are accelerated through the same potential. Then the ratio of their de Broglie wavelengths is

A. 1

B. $\sqrt{\frac{m_e}{m_p}}$

C. $\frac{m_e}{m_p}$

D. $\sqrt{\frac{m_p}{m_e}}$

Answer: D

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13. If the frequency of incident light falling on a photosensitive metal is doubled, the kinetic energy of the emitted photoelectron is

A. unchanged

B. halved

C. doubled

D. more than twice its initial value

Answer: D

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14. If the wavelength of incident light falling an a photosensitive material decreases, then

A. photoelectric current increases

B. stopping potential decreases

C. stopping potential remains constant

D. stopping potential increases

Answer: D

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15. The maximum velocities of the photoelectrons ejected are v and 2v for the incident light of wavelength 400 nm and 250 nm on a metal surface respectively. The work function of the metal in terms of Planck's constant h and velocity of light c is

A. a. $hc \times 10^6 J$

B. b. $2hc \times 10^6 J$

C. c. $1.5hc \times 10^6 J$

D. d. $2.5hc \times 10^6 J$

Answer: B

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