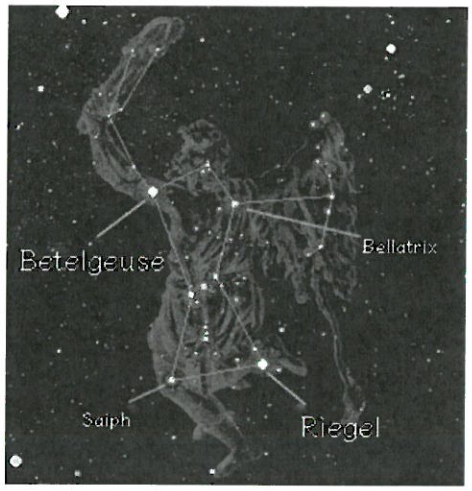
Student	8
Average	21.2 /50
Best	35.0 /50

12th Physics (2017 – 18)

(4thQ, #2 Mini Test) 5-14-2018

Class	No.	Name Solutions



In a calculation problem, describe equations clearly and systematically enough to show how to solve the problem. <u>If not enough, you won't get any point.</u>

4 pt/question x 13 questions = 52 pt Max 50 pt

/[Total 50 pt]

Physics Constants

The speed of light in vacuum	$c = 2.998 \times 10^8$ m/s
Gravitational acceleration rate	$g = 9.80$ m/s^2
Universal Gravitational Constant	$G = 6.674 \times 10^{-11}$ N・m^2/kg^2
Radius of the Earth	$R_E = 6.371 \times 10^6$ m
Mass of the Earth	$M_E = 5.972 \times 10^{24}$ kg
Mass of the Sun	$M_S = 1.9884 \times 10^{30}$ kg
Radius of the Mars	$R_M = 3.39 \times 10^6$ m
Mass of Mars	$M_M = 6.43 \times 10^{23}$ kg
Angular speed of Earth's Rotation	$\omega = 7.292 \times 10^{-5}$ rad/s
Volume of a sphere	$V = \frac{4}{3}\pi r^3$
Pi	$\pi = 3.1416$
Avogadro's Number	$N_A = 6.022 \times 10^{23}$ mol^{-1}
Universal Gas Constant	$R = 8.314$ J/(mol・K)
Boltzmann Constant	$k = 1.381 \times 10^{-23}$ J/K
Coulomb's Law constant	$k = 8.988 \times 10^9$ N・m^2/C^2
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/(N・m^2)
Elementary Charge	$e = 1.602 \times 10^{-19}$ C
Electron mass	$m_e = 9.109 \times 10^{-31}$ kg
Proton mass	$m_p = 1.673 \times 10^{-27}$ kg
Neutron Mass	$m_n = 1.675 \times 10^{-27}$ kg
calorie	1 cal = 4.186 J
The constant of the Wien's Displacement Law	5.88×10^{10} s^{-1}・K^{-1}
Planck's Constant	$h = 6.626 \times 10^{-34}$ J s
The constant in the Compton Shift	$h/m_ec = 2.43 \times 10^{-12}$ m
Rydberg Constant	$R = 1.097 \times 10^7$ m^{-1}

(1) A lighthouse sweeps its beam of light around in circle once every 6.5 s. To an observer in a spaceship moving away from Earth, the beam of light completes on full circle every 14 s. What is the speed of the spaceship relative to Earth?

(Equations)

$\Delta t_0 = 6.5\ s \quad \Delta t = 14\ s$

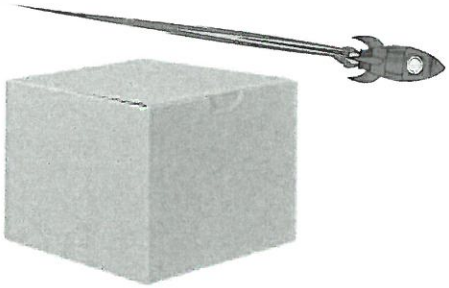
$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}} \rightarrow v = c\sqrt{1-\left(\frac{\Delta t_0}{\Delta t}\right)^2} = c\sqrt{1-\left(\frac{6.5}{14}\right)^2} = 0.886\,c$$

$\rightarrow 0.89\,c$

(1) Answer: $0.89\,c$ (83%)

or 2.7×10^8 m/s

(2) A cubital box is 0.75 m on a side. Find the volume of the box as measured by an observer moving with a speed of 0.88c parallel to one of the edge of the box.



(Equations)

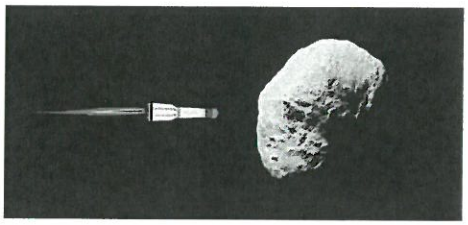
$$L = L_0\sqrt{1-\frac{v^2}{c^2}}$$

$$= 0.75\sqrt{1-\frac{0.88^2c^2}{c^2}} = 0.356$$

$0.75^2 \times 0.356 = 0.200$

(2) Answer: $0.20\ m^3$ (84%)

(3) A space probe with a rest mass of 5.5 x 10^7 kg and a speed of 0.50c smashes into an asteroid at rest and becomes embedded within it. If the speed of the probe-asteroid system is 0.24c after the collision, what is the mass of the asteroid?



(Equations)

rest

$m_0 = 5.5 \times 10^7$ kg $\qquad V = 0.24\,c$

$v = 0.50\,c$

Before

$$m = 5.5\times10^7 \times \frac{1}{\sqrt{1-0.50^2}} = 6.35\times10^7$$

After

$$m' = 5.5\times10^7 \times \frac{1}{\sqrt{1-0.24^2}} = 5.67\times10^7$$

$$M = M_0 \times \frac{1}{\sqrt{1-0.24^2}} = 1.03\,M_0$$

Relativistic conservation of momentum

$$mv = (M + m')V$$

$$mv = 1.03 M_0 V + m'V$$

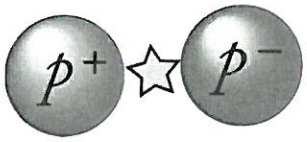
$$M_0 = \frac{mv - m'V}{1.03V} = \frac{6.35\times10^7 \times 0.50\,c - 5.67\times10^7 \times 0.24\,c}{1.03 \times 0.24\,c}$$

$$= \frac{1.814\times10^7\,c}{0.247} = 7.34\times10^7 \longrightarrow 7.3\times10^7$$

(3) Answer

7.3×10^7 kg (75%)

(4) What energy (eV) must a gamma ray have to create a proton-antiproton pair?
(Equations)



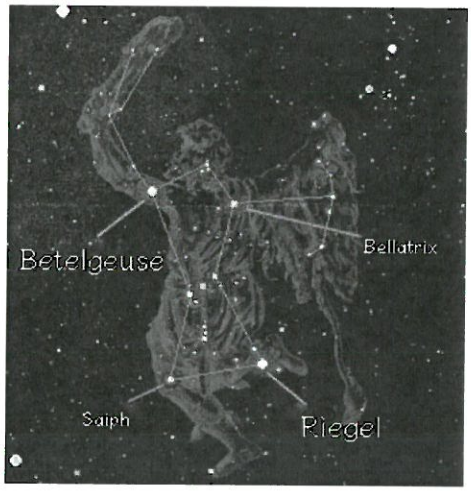
$$E = \frac{2mc^2}{e}$$

$$= \frac{2 \times 1.673 \times 10^{-27} \times 3.00^2 \times 10^{16}}{1.602 \times 10^{-19}} = 18.798 \times 10^7$$

$$= 1.88 \times 10^9 \longrightarrow 1.88 \times 10^9 \text{ (eV)}$$

(4) Answer
1.88 MeV (27%)

(5) Betelgeuse, red-giant star in the constellation Orion, has a peak in its radiation at a frequency of 1.82×10^{14} Hz. What is the surface temperature of Betelgeuse?
(Equations)



$$f_{peak} = 5.88 \times 10^{10} T$$

$$T = \frac{1.82 \times 10^{14}}{5.88 \times 10^{10}} = 0.3095 \times 10^4$$

$$\longrightarrow 3100$$

(5) Answer
3100 K (63%)

(6) How many photons are emitted per second by a He-Ne laser that emits 1.5 mW of power at a wavelength λ = 632.8 nm? (Equations)

$$E = n h f \quad , \quad f = \frac{c}{\lambda}$$

$$n = \frac{E}{hf} = \frac{E\lambda}{hc}$$

$$= \frac{1.5\times10^{-3} \times 632.8\times10^{-9}}{6.63\times10^{-34} \times 3.00\times10^{8}}$$

$$= 47.8\times10^{14} = 4.78\times10^{15}$$

(6) Answer

4.8×10^{15} photons (44%)

(7) A 65-kg jogger runs with a speed of 5.5 m/s. If the jogger is considered to be a particle, what is her de Broglie wavelength? (Equations)

~~(Equations)~~

$m = 65$ kg $\quad v = 5.5$ m/s

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$= \frac{6.63\times10^{-34}}{63 \times 5.5} = 0.0191\times10^{-34}$$

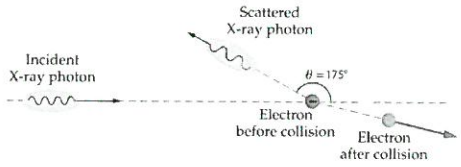
$$= 1.91\times10^{-36}$$

$$\rightarrow 1.9\times10^{-36}$$

(7) Answer

1.9×10^{-36} m (50%)

(8,9) An X-ray photon scatters from a free electron at rest at an angle of 175° relative to the incident angle, as shown in the figure. The scattered photon has a wavelength of 0.320 nm



(8) Find the wavelength of the incident photon?

(9) Find the kinetic energy of the electron after collision. Answer by eV.

(Equations)

Compton shift $\Delta\lambda = \lambda' - \lambda = 2.43\times10^{-12}(1-\cos\theta)$

(8) $\lambda = \lambda' - 2.43\times10^{-12}(1-\cos\theta)$

$= 0.320 - 2.43\times10^{-12}(1-\cos 175^\circ)$

$= 0.320 - 0.00485$

$= 0.31515 \longrightarrow 0.315$

(9) $hf = hf' + \left(\frac{1}{2}mv^2\right)$ (K)

$K = h(f-f')$

$= h\left(\frac{c}{\lambda} - \frac{c}{\lambda'}\right)$

$= hc\left(\frac{10^9}{0.31515} - \frac{10^9}{0.320}\right)$

$= hc\left(\overline{3.1731} - \overline{3.125}\right)$

$= 6.626\times10^{-34}\times3.00\times10^{8}\times\overline{0.0481}\times10^{9}$

$= 0.\bar{9}560\times10^{-17}$ (J)

$= \frac{0.9560\times10^{-17}}{1.602\times10^{-19}} = 0.5967\times10^{2}$ (eV)

$= 59.67 \longrightarrow 60$ (eV)

(8) Answer: 0.315 nm (33%)

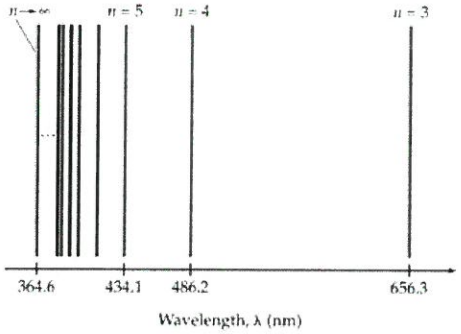
(9) Answer: 60 eV (11%)

(6 × 10 eV)

(10) Find the wavelength of the Balmer series spectral line corresponding to n =13.
(Equations)

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{13^2}\right)$$

$$\lambda = 373.47 \text{ (nm)}$$



(10) Answer

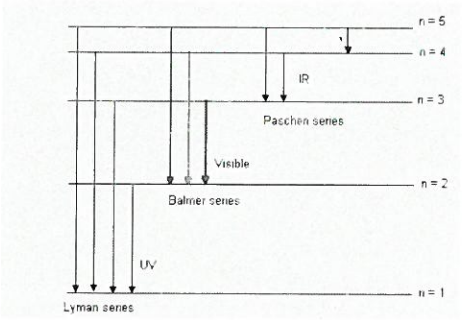
373.5 nm

(34%)

(11) Find the wavelength of the photon emitted by the electron in a hydrogen atom when it jumps from the initial state n =5 to the final state n' = 3.
(Equations)

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{5^2}\right)$$

$$\lambda = 1281.9 \text{ nm}$$

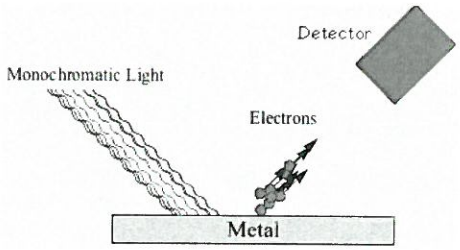


(11) Answer

1282 nm

(23%)

(12,13) When light with a wavelength of 545 nm shines on a metal surface, electrons are ejected with speeds of 3.10×10^5 m/s or less.
(12) Find the work function for this surface. Answer by eV.
(13) Find the cutoff frequency, the minimum frequency of the incident light to eject electrons..
(Equations)



(12) $K_{max} = E - W_0$

$\rightarrow \quad W_0 = E - K_{max}$

$= hf - K_{max}$

$= \frac{hc}{\lambda} - \frac{1}{2}mv^2$

$= \frac{6.626 \times 10^{-34} \times 3.00 \times 10^8}{545 \times 10^{-9}} - \frac{1}{2} \times 9.109 \times 10^{-31} \times (3.10 \times 10^5)^2$

$= 0.03647 \times 10^{-17} - 43.77 \times 10^{-21}$

$= 3.647 \times 10^{-19} - 0.4377 \times 10^{-19}$

$= 3.209 \times 10^{-19}$ (J)

$= \frac{3.209 \times 10^{-19}}{1.602 \times 10^{-19}}$ (eV) $= 2.003 \longrightarrow 2.00$ (eV)

(13)

$f_0 = \frac{W_0}{h}$

$= \frac{3.209 \times 10^{-19}}{6.626 \times 10^{-34}}$

$= 0.4843 \times 10^{15}$

$= 4.843 \times 10^{14}$

$\rightarrow 4.84 \times 10^{14}$

(12) Answer
2.00 eV (2%)

(13) Answer
4.84×10^{14} Hz (2%)