

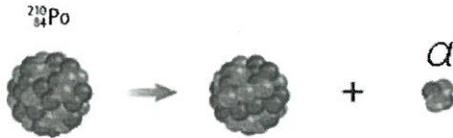
Student 8  
 Average 49.9 /100  
 Best 87 /100

# 12<sup>th</sup>G Physics (2017- 18)

## 4<sup>th</sup>Q Final Exam

(May 30, 2018)

Class	No.	Name	<i>Solutions</i>
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In calculation problems, describe equations clearly and systematically enough to show how to solve the problems. If not enough, you won't get any point.

5points/Problem x 21Problems= 105Points  
 Max 100Points

Exam

/[Total 100 点]

**Periodic Table of the Elements**

1 11A H Hydrogen 1.008	2 IIA 2A Be Beryllium 9.012											3 IIIA 3A B Boron 10.811	4 IVA 4A C Carbon 12.011	5 VA 5A N Nitrogen 14.007	6 VIA 6A O Oxygen 15.999	7 VIIA 7A F Fluorine 18.998	8 Ne Neon 20.180
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B Sc Scandium 44.956	4 IVB 4B Ti Titanium 47.88	5 VB 5B V Vanadium 50.942	6 VIB 6B Cr Chromium 51.996	7 VIIB 7B Mn Manganese 54.938	8 VIII 8 Fe Iron 55.933	9 VIII 9 Co Cobalt 58.933	10 VIII 10 Ni Nickel 58.693	11 IB 1B Cu Copper 63.546	12 IIB 2B Zn Zinc 65.39	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [285]	113 Uut Ununtrium [288]	114 Fl Flerovium [289]	115 Uup Ununpentium [288]	116 Lv Livermorium [293]	117 Uus Ununseptium [294]	118 Uuo Ununoctium [294]
			57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
			89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

## Physics Constants

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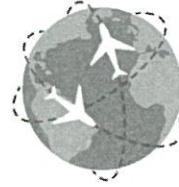
The speed of light in vacuum	$c = 2.998 \times 10^8 \text{ m/s}$
Gravitational acceleration rate	$g = 9.80 \text{ m/s}^2$
Universal Gravitational Constant	$G = 6.674 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$
Radius of the Earth	$R_E = 6.371 \times 10^6 \text{ m}$
Mass of the Earth	$M_E = 5.972 \times 10^{24} \text{ kg}$
Mass of the Sun	$M_S = 1.9884 \times 10^{30} \text{ kg}$
Radius of the Mars	$R_M = 3.39 \times 10^6 \text{ m}$
Mass of Mars	$M_M = 6.43 \times 10^{23} \text{ kg}$
Angular speed of Earth's Rotation	$\omega = 7.292 \times 10^{-5} \text{ rad/s}$
Volume of a sphere	$V = \frac{4}{3} \pi r^3$
Pi	$\pi = 3.1416$
Avogadro's Number	$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
Universal Gas Constant	$R = 8.314 \text{ J}/(\text{mol} \cdot \text{K})$
Boltzmann Constant	$k = 1.381 \times 10^{-23} \text{ J/K}$
Coulomb's Law constant	$k = 8.988 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$
Elementary Charge	$e = 1.602 \times 10^{-19} \text{ C}$
Electron mass	$m_e = 9.109 \times 10^{-31} \text{ kg}$
Proton mass	$m_p = 1.673 \times 10^{-27} \text{ kg}$
Neutron Mass	$m_n = 1.675 \times 10^{-27} \text{ kg}$
calorie	$1 \text{ cal} = 4.186 \text{ J}$
The constant of the Wien's Displacement Law	$5.88 \times 10^{10} \text{ s}^{-1} \cdot \text{K}^{-1}$
Planck's Constant	$h = 6.626 \times 10^{-34} \text{ J s}$
The constant in the Compton Shift	$h/m_e c = 2.43 \times 10^{-12} \text{ m}$
Rydberg Constant	$R = 1.097 \times 10^7 \text{ m}^{-1}$
Atomic Mass Unit and Energy	$1 \text{ u} = 931.5 \text{ MeV}/c^2$

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12thPhysics 4thQ FinalExam 2017-18

Atomic Number (Z)	Element	Symbol	Mass Number (A)	Atomic Mass*	Abundance (%) or Decay Mode <sup>†</sup> (if radioactive)	Half-Life (if radioactive)
0	(Neutron)	n	1	1.008665	$\beta^-$	10.6 min
1	Hydrogen	H	1	1.007825	99.985	
			2	2.014102	0.015	
			3	3.016049	$\beta^-$	12.33 y
2	Helium	He	3	3.016029	0.00014	
			4	4.002603	$\approx 100$	
81	Thallium	Tl	205	204.97441	70.5	
			210	209.990069	$\beta^-$	1.3 min
82	Lead	Pb	204	203.973044	$\beta^-, 1.48$	$1.4 \times 10^{17}$ y
			206	205.97446	24.1	
			207	206.97589	22.1	
			208	207.97664	52.3	
			210	209.98418	$\alpha, \beta^-, \gamma$	22.3 y
			211	210.98874	$\beta^-, \gamma$	36.1 min
			212	211.99188	$\beta^-, \gamma$	10.64 h
83	Bismuth	Bi	214	213.99980	$\beta^-, \gamma$	26.8 min
			209	208.98039	100	
			211	210.98726	$\alpha, \beta^-, \gamma$	2.15 min
			212	211.991272	$\alpha$	60.55 min
84	Polonium	Po	210	209.98286	$\alpha, \gamma$	138.38 d
			212	211.988852	$\alpha$	0.299 $\mu$ s
			214	213.99519	$\alpha, \gamma$	164 $\mu$ s
86	Radon	Rn	222	222.017574	$\alpha, \beta$	3.8235 d
87	Francium	Fr	223	223.019734	$\alpha, \beta^-, \gamma$	21.8 min
88	Radium	Ra	226	226.025406	$\alpha, \gamma$	$1.60 \times 10^3$ y
			228	228.031069	$\beta^-$	5.76 y
89	Actinium	Ac	227	227.027751	$\alpha, \beta^-, \gamma$	21.773 y
90	Thorium	Th	228	228.02873	$\alpha, \gamma$	1.9131 y
			231	231.036297	$\alpha, \beta^-$	25.52 h
			232	232.038054	100; $\alpha, \gamma$	$1.41 \times 10^{10}$ y
			234	234.043596	$\beta^-$	24.10 d
			234	234.043302	$\beta^-$	6.70 h
91	Protactinium	Pa	234	234.043302	$\beta^-$	6.70 h
92	Uranium	U	232	232.03714	$\alpha, \gamma$	72 y
			233	233.039629	$\alpha, \gamma$	$1.592 \times 10^5$ y
			235	235.043925	0.72; $\alpha, \gamma$	$7.038 \times 10^8$ y

(1) An airplane flies level to the ground toward the north pole. Is the induced emf from wing tip to wing tip when the plane is at the equator greater than, less than, or equal to the wing-tip-to-wing-tip emf when it is at the latitude of New York?



*At the equator, the field is horizontal.*

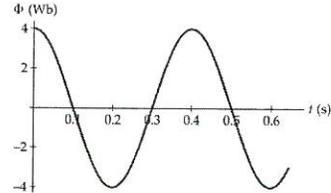
*At the latitude of NY, the vertical component is present.*

(1) Answer

*Less than*

(50%)

(2) The figure at the right shows the magnetic flux through a coil as a function of time. At what times shown do the induced emf have the greatest magnitude?



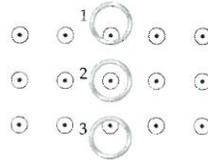
(2) Answer

*0.1 s, 0.3 s, 0.5 s*

(18%)

$$V = N \left| \frac{\Delta \Phi}{\Delta t} \right|$$

(3) A metal ring is dropped into a localized region of constant magnetic field, as indicated in the figure. The magnetic field is zero above and below the region. For each of the three indicated locations (1, 2 and 3), is the induced current clockwise (CW), counterclockwise (CCW), or zero (Z)?

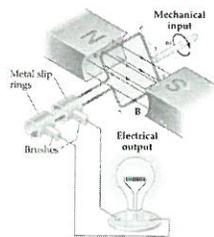


(3) Answer

*1: CW 2: Z 3: CCW*

(74%)

(4) The maximum induced emf in a generator rotating at 210 rpm is 45V.  
 How fast must the rotor of the generator rotates if it is to generate a  
 maximum induced emf of 55 V?  
 (Equations)



$$V_{max} = N \omega A B = NAB \times 210 = 45$$

$$\rightarrow NAB = 0.213$$

$$\omega' = \frac{55}{NAB} = \frac{55}{0.213} = 257 \rightarrow 260$$

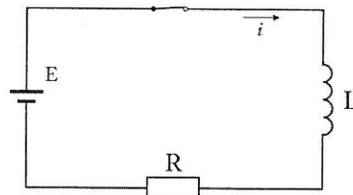
(5) Find the induced emf when the current in a 45.0-mH inductor  
 increases from 0 to 515 mA in 16.5 ms.  
 (Equations)

$$V = L \left| \frac{\Delta I}{\Delta t} \right|$$

$$= 45.0 \times 10^{-3} \times \left| \frac{515 \times 10^{-3}}{16.5 \times 10^{-3}} \right|$$

$$= 1.4045 \rightarrow 1.40 \text{ (V)}$$

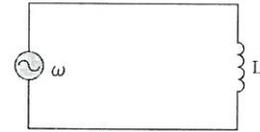
(4) Answer  
 260 rpm (63%)



(5) Answer  
 1.40 V (51%)

(6-a) An inductor has a reactance of  $56.5 \Omega$  at  $75.0 \text{ Hz}$ . What is its reactance at  $60.0 \text{ Hz}$ ?

(Equations)



$$X = 2\pi fL$$

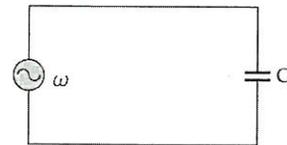
$$L = \frac{X}{2\pi f} = \frac{56.5}{2\pi \times 75}$$

$$X' = 2\pi f' L$$

$$= 2\pi \times 60.0 \times \frac{56.5}{2\pi \times 75} = 45.20 \rightarrow 45.2$$

(6-b) A  $105\text{-}\mu\text{F}$  capacitor is connected to an AC generator with an rms voltage of  $20.0 \text{ V}$  and a frequency of  $100.0 \text{ Hz}$ . What is the rms current in this circuit?

(Equations)



$$I = \frac{V}{X} = \frac{1}{\frac{1}{2\pi fC}}$$

$$= 20.0 \times 2\pi \times 100 \times 105 \times 10^{-6}$$

$$= 1.320 \rightarrow 1.32 \text{ (A)}$$

(6-a) Answer

$$45.2 \Omega$$

(6-b) Answer

$$1.32 \text{ A}$$

(69%)

(7-a) How fast does a 125-m spaceship move relative to an observer who measures the ship's length to be 65.0 m? Express your answer as a fraction of the speed of light,  $c$ .

(Equations)

$$L = L_0 \sqrt{1 - \left(\frac{v_0}{c}\right)^2}$$

$$\rightarrow v = c \sqrt{1 - \left(\frac{L}{L_0}\right)^2}$$

$$= c \sqrt{1 - \left(\frac{65}{125}\right)^2}$$

$$= 0,8542c \rightarrow 0,854c$$



(7-b) An apple falls from a tree, landing on the ground 3.7 m below. How long is the apple in the air, as measured by an observer moving toward Earth with a speed of  $0.89c$ ?

(Equations)

$$y = \frac{1}{2} g \Delta t_0^2$$

$$\Delta t_0 = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 3.7}{9.80}}$$

$$= 0.869$$



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

$$= \frac{0.869}{\sqrt{1 - (0.89)^2}}$$

$$= 1.906 \rightarrow 1.9 \text{ (s)}$$

(7-a) Answer

0,854 c

(7-b) Answer

1.9 s

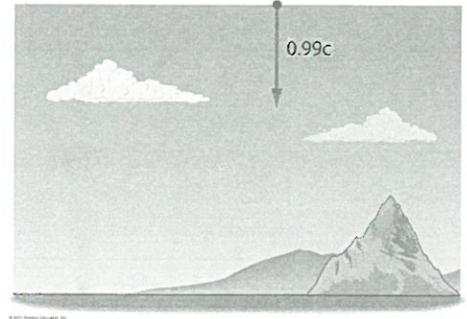
(58%)

(8,9) An elementary particle called a pi meson (or pion for short) has an average lifetime of  $2.6 \times 10^{-8}$  s when at rest. If a pion moves with a speed of  $0.99c$  relative to Earth, answer the following questions.

(8) Find the average lifetime of the pion as measured by an observer on Earth.

(9) Find the average distance traveled by the pion as measured by the same observer.

(Equations)



$$\begin{aligned}
 (8) \quad \Delta t &= \frac{\Delta t_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} \\
 &= \frac{2.6 \times 10^{-8}}{\sqrt{1 - 0.99^2}} \\
 &= \frac{2.6 \times 10^{-8}}{0.1411} = 18.43 \times 10^{-8} \\
 &\rightarrow 1.8 \times 10^{-7} \text{ (s)}
 \end{aligned}$$

$$\begin{aligned}
 (9) \quad d &= v \Delta t \\
 &= 0.99 \times 3.00 \times 10^8 \times 1.843 \times 10^{-7} \\
 &= 54.7 \\
 &\rightarrow 55 \text{ (m)}
 \end{aligned}$$

(8) Answer

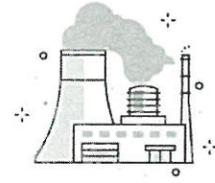
$$1.8 \times 10^{-7} \text{ s} \quad (76\%)$$

(9) Answer

$$55 \text{ m} \quad (25\%)$$

(10) A nuclear power plant produces an average of  $1.0 \times 10^3$  MW of power a year of operation. Find the corresponding change in mass of reactor fuel, assuming all of the energy released by the fuel can be converted directly to electrical energy. (In a practical reactor, only a relatively small fraction of the energy can be converted to electricity)

(Equations)



$$\Delta E = 1.0 \times 10^3 \times 10^6 \text{ J/y}$$

$$\Delta E = \Delta m c^2$$

$$\Delta m = \frac{\Delta E}{c^2}$$

$$= \frac{1.0 \times 10^9}{(3.00 \times 10^8)^2}$$

$$= 0.111 \times 10^{-8}$$

$$\rightarrow 1.11 \times 10^{-9} \text{ kg} \quad (= 1.11 \times 10^{-6} \text{ g} \rightarrow 1.1 \mu\text{g})$$

(10) Answer

1.1  $\mu\text{g}$  / y (26%)

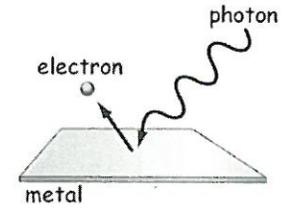
( $3.5 \times 10^{-16} \text{ g/s}$ )

(11,12) The work function of a particular metal is 2.00 eV. The metal is illuminated with light of 550 nm.

(11) Find the maximum energy (eV) of the emitted electrons.

(12) Find the maximum speed of the electrons.

(Equations)



$$(11) K = E - W_0$$

$$= hf \text{ [J]} - W_0$$

$$= \frac{hf}{e} \text{ [eV]} - W_0 = \frac{h \times \frac{c}{\lambda}}{e} - W_0$$

$$= \frac{hc}{e\lambda} - W_0$$

$$= \frac{6.626 \times 10^{-34} \times 2.998 \times 10^8}{1.602 \times 10^{-19} \times 550 \times 10^{-9}} - 2.00$$

$$= 2.2545 - 2.00$$

$$= 0.2545 \text{ (eV)} \rightarrow 0.25 \text{ eV}$$

$$(12) K = 0.2545 \text{ eV} = 0.2545 \times 1.602 \times 10^{-19} \text{ (J)}$$

$$v = \sqrt{\frac{2K}{m}}$$

$$= \sqrt{\frac{2 \times 0.2545 \times 1.602 \times 10^{-19}}{9.109 \times 10^{-31}}}$$

$$= \sqrt{8.952 \times 10^{-2+31-19}}$$

$$= 2.992 \times 10^5$$

$$\rightarrow 2.99 \times 10^5 \text{ (m/s)}$$

(11) Answer

$$0.25 \text{ eV}$$

(29%)

(12) Answer

$$2.99 \times 10^5 \text{ m/s}$$

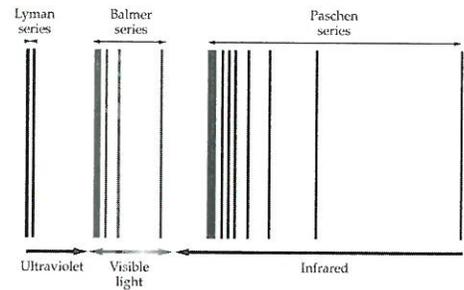
(23%)

(13,14) The figure shows the spectral lines in the spectrum of hydrogen atom.

(13) Calculate the longest wavelength (nm) of the Paschen series

(14) Calculate the ionization energy (eV) of hydrogen when it is in the ground-state, using the formula including the Rydberg constant.

(Equations)



$$\begin{aligned}
 (13) \quad \frac{1}{\lambda} &= R \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \\
 &= 1.097 \times 10^7 \left( \frac{1}{3^2} - \frac{1}{4^2} \right) \\
 \lambda &= 18.752 \times 10^{-7} \text{ m} \rightarrow 1875 \text{ nm}
 \end{aligned}$$

$$\begin{aligned}
 (14) \quad \frac{1}{\lambda} &= R \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \\
 &= R \left( \frac{1}{1^2} - 0 \right) = 1.097 \times 10^7 \\
 E &= \frac{hf}{e} = \frac{hc}{e\lambda} \\
 &= \frac{1.097 \times 10^7 \times 6.626 \times 10^{-34} \times 2.998 \times 10^8}{1.602 \times 10^{-19}} \\
 &= 13.603 \times 10^{2+8+19-34} \\
 &= 13.603 \rightarrow 13.60
 \end{aligned}$$

(13) Answer

1875 nm

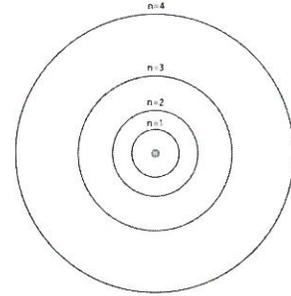
(21%)

(14) Answer

13.60 eV

(13%)

(15,16) The figure shows the first four Bohr orbits of hydrogen atom. Based on the Bohr's model, the radius of the smallest ( $n = 1$ ) is calculated as  $5.29 \times 10^{-11}$  m.



(15) Find the radius of the  $n = 4$  orbit.

(16) Find the de Broglie wavelength of an electron in the  $n = 4$  state of the hydrogen atom.

(Equations)

$$(15) r_4 = n^2 r_1$$

$$= 4^2 \times 5.29 \times 10^{-11} = 84.640 \times 10^{-11} \rightarrow 8.46 \times 10^{-10} \text{ m}$$

$$(16) d = 2\pi r_4 = 2\pi \times 84.640 \times 10^{-10}$$

$$\lambda_4 = \frac{d}{4} = \frac{2\pi}{4} \times 84.640 \times 10^{-10}$$

$$= 1.33 \times 10^{-9}$$

$$\rightarrow 1.33 \times 10^{-9} \text{ (m)}$$

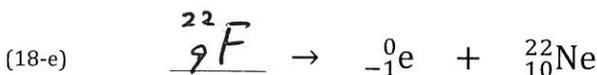
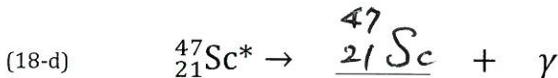
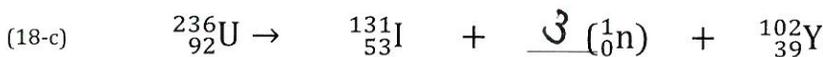
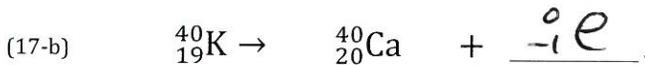
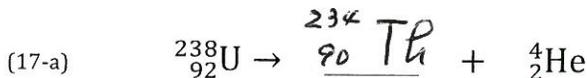
(15) Answer

$$8.46 \times 10^{-10} \text{ m} \quad (39\%)$$

(16) Answer

$$1.33 \times 10^{-9} \text{ m} \quad (25\%)$$

(17,18) Complete the following nuclear-decay equations:



(17-a) Answer

Complete the equation

(17-b) Answer

Complete the equation

(98%)

(18-c) Answer

Complete the equation

(18-d) Answer

Complete the equation

(18-e) Answer

Complete the equation

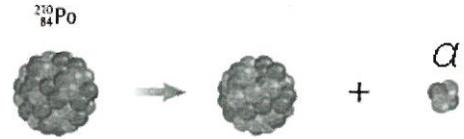
(58%)

(19) The nucleus  $^{212}_{84}\text{Po}$  is observed to decay by emitting an  $\alpha$  particle.

(19-a) Write out the decay process.

(19-b) Determine the energy released in the reaction.

(Equations)



$$m_i = 211.988852$$

$$m_f = 207.97664 + 4.002603$$

$$= 211.979243$$

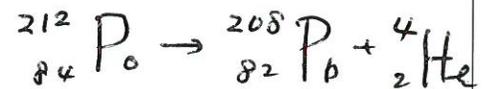
$$E = (m_i - m_f) c^2$$

$$= 0.009609 \text{ u} \times \frac{931.5 \text{ MeV}/c^2}{1 \text{ u}}$$

$$= 8.9508 \text{ (MeV)}$$

$$\rightarrow 8.95 \text{ MeV}$$

(19-a) Answer



(29%)

(19-b) Answer

$$8.95 \text{ MeV}$$

(20) A radioactive sample is placed in a closed container. Three days later only one-quarter of the sample is still radioactive. What is the half-life of this sample?

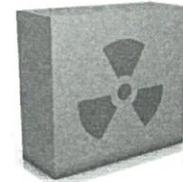
(Equations)

$$\frac{N}{N_0} = e^{-\lambda t} = \frac{1}{4}$$

$$\ln \frac{1}{4} = -\lambda t \quad \lambda = \frac{\ln 2}{T}$$

$$-\ln 4 = -\frac{\ln 2}{T} \times 3$$

$$T = \frac{\ln 2}{\ln 4} \times 3 = 1.5 \text{ (days)}$$



(20) Answer

$$1.5 \text{ days}$$

(40%)

You have one more question.

(21) Did you study 12<sup>th</sup> grade physics seriously and enjoy it?

(21) Answer

Circle your answer.

Yes                  No                  Neutral

(100%)

I am very happy to meet you!    Tohei

Please tell me which department and course you enter when it is decided officially.

Opinions	Your name: