104ex4s
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Physics 104 Final Exam (PRACTICE) May 13, 2001
Name DEL ID#__________
Section#__________ TA Name__________

1. A spaceship leaves our solar system at a constant speed of 0.900c and travels to a point in the Andromeda galaxy. According to astronomers in an inertial reference frame on Earth, the distance to the galaxy is 2.081×10^{22} m. What distance does the crew on the ship measure on its journey?
   - (A) 9.07×10^{21} m (circled)
   - B) 9.85×10^{21} m
   - C) 1.91×10^{22} m
   - D) 2.83×10^{22} m
   - E) 4.77×10^{22} m

$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} = \frac{1}{\sqrt{1-.81}} = 2.294$

$d/\gamma = \frac{2.081\times10^{22}}{2.294} = 0.907\times10^{22}$

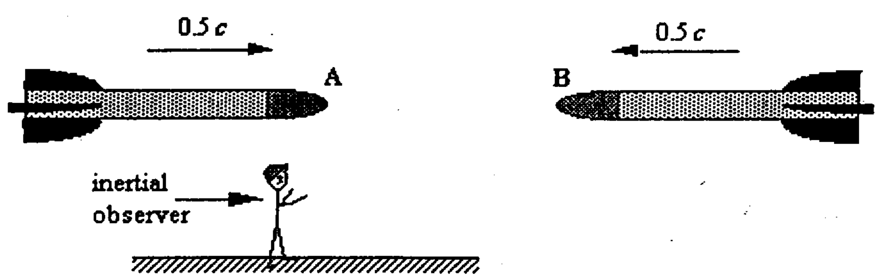
2. Determine the speed at which the kinetic energy of an electron is equal to twice its rest energy.
   - A) 0.45c
   - B) 0.63c
   - C) 0.87c
   - (D) 0.94c (circled)
   - E) 0.99c

$KE = \gamma mc^2 - mc^2 = 2mc^2$

$\gamma = 3 = \frac{1}{\sqrt{1-v^2/c^2}}$

$\frac{1}{1-v^2/c^2} = 9 \quad 1-\frac{v^2}{c^2} = \frac{1}{9} \quad \frac{v^2}{c^2} = 8/9 \quad \frac{v}{c} = \frac{2\sqrt{2}}{3}$

3. Two rockets, **A** and **B**, travel toward each other with speeds 0.5c relative to an inertial observer.



Determine the speed of rocket **A** relative to rocket **B**.
   - A) 0.2c
   - B) 0.4c
   - C) 0.6c
   - (D) 0.8c (circled)
   - E) c

$\frac{u+v}{1+uv/c^2} = \frac{0.5c+0.5c}{1+0.25c^2/c^2} = 0.8c$

4. When ultraviolet photons with a wavelength of 3.45×10^{-7} m are incident on an unknown metal surface in a vacuum, electrons with a maximum kinetic energy of 1.52 eV are emitted from the surface. What is the work function of the metal?

A) 3.60 eV
B) 3.11 eV
C) 2.59 eV
D) 2.08 eV
E) 1.98 eV

$E = hc/\lambda = \frac{6.63\times10^{-34} \times 3\times10^{8}}{3.45\times10^{-7}} \times \frac{1\ eV}{1.6\times10^{-19} J}$

$E = 3.59\ eV = \Phi + KE$

$KE = 1.52\ eV$ so $\Phi = 3.59 - 1.52 = 2.07\ eV$

5. A photon has a collision with a stationary electron ($h/mc = 2.43 \times 10^{-12}$ m) and loses 5.0% of its energy. The photon scattering angle is 180°. What is the wavelength of the incident photon in this scattering process?

A) 2.4×10^{-12} m
B) 4.6×10^{-11} m
C) 9.2×10^{-11} m
D) 1.9×10^{-10} m
E) 3.1×10^{-12} m

$E = hc/\lambda$ 5% energy loss $\rightarrow \lambda' = \lambda/0.95$

$\lambda' - \lambda = \Delta\lambda = (\frac{1}{.95} - 1)\lambda = \frac{h}{m_e c}(1 - \cos 180°)$

$= 4.86\times10^{-12}$

$\lambda = 9.23\times10^{-11}$

Use the following to answer question 6:

It is desired to obtain a diffraction pattern for electrons using a diffraction grating with lines separated by 10 nm. The mass of an electron is 9.11×10^{-31} kg.

6. Suppose it is desired to observe diffraction effects for a beam of electromagnetic radiation using the same grating. Roughly, what is the required energy of the individual photons in the beam?

A) 10^{-6} eV
B) 10^{-4} eV
C) 10^{-2} eV
D) 10^{2} eV
E) 10^{4} eV

DIFFRACTION WILL NOT OCCUR IF $\lambda > d = 10$ nm
THE MINIMUM REQUIRED ENERGY IS THEREFORE
$E = hc/\lambda$ WITH $\lambda = 10$ nm (ROUGHLY)

$E = \frac{6.63\times10^{-34} \times 3\times10^{8}}{1\times10^{-8}} \times \frac{1\ eV}{1.6\times10^{-19} J} = 1.2\times10^{2}$

7. Determine the maximum wavelength of incident radiation that can be used to remove the remaining electron from a singly ionized helium atom He^{+} ($Z = 2$). Assume the electron is in its ground state.

A) 6.2 nm
B) 12.4 nm
C) 22.8 nm
D) 45.6 nm
E) 54.4 nm

$E \propto Z^2$; FOR HYDROGEN $Z = 1$, $E = 13.6\,eV$

IF $Z = 2$ $E = 2^2 \times 13.6\,eV = 54.4\,eV$

$\lambda = hc/E = \dfrac{6.63\times10^{-34} \times 3\times10^{8}}{54.4\,eV \times 1.6\times10^{-19}\,J/eV} = 2.28\times10^{-8}\,m$

8. Determine the maximum number of electron states with principal quantum number $n = 3$?

A) 2
B) 3
C) 6
D) 9
E) 18

$n = 3$ $\ell = 0, 1, 2$

$m = 0$ | $0, +1, -1$ | $0, +1, -1, +2, -2$

$1+3+5 = 9$ LEVELS

2 ELECTRONS (SPIN UP, SPIN DOWN) PER LEVEL

9. Calculate the K_α X-ray wavelength for a gold atom ($Z = 79$).

A) 5.13×10^{-10} m
B) 8.54×10^{-10} m
C) 2.00×10^{-11} m
D) 3.60×10^{-11} m
E) 2.47×10^{-13} m

FOR THE HYDROGEN ATOM $E_n = \dfrac{-13.6\,eV}{n^2}$

FOR GOLD ($Z=79$) $E_n^{79} = \dfrac{-13.6\,eV\,(Z-1)^2}{n^2}$

SO THE L-SHELL ENERGY IS $E_2^{79} = -13.6\left(\dfrac{78^2}{2^2}\right) eV$

K-SHELL ENERGY IS $E_1^{79} = -13.6\left(\dfrac{78^2}{1^2}\right)$

$E_2 - E_1 = 62.1\,keV$ $\lambda = hc/(62.1\,keV \times 1.6\times10^{-19}\,J/eV)$

$\rightarrow \lambda = 2.00\times10^{-11}\,m$

10. $^{207}_{82}Pb$ has a mass of 3.4368×10^{-25} kg. What is the approximate density of this lead nucleus?

A) 2.3×10^{17} kg/m^3
B) 3.5×10^{18} kg/m^3
C) 4.8×10^{19} kg/m^3
D) 5.2×10^{20} kg/m^3
E) 6.1×10^{21} kg/m^3

RADIUS OF Pb NUCLEUS IS

$r = r_0 A^{1/3} = 1.2\times10^{-15}\,m \times 207^{1/3}$

$r = 7.10\times10^{-15}\,m$

VOLUME $= \frac{4}{3}\pi r^3 = 1.50\times10^{-42}\,m^3$

MASS $= 207 \times 1.67\times10^{-27}\,kg = 3.46\times10^{-25}\,kg$

DENSITY = MASS/VOLUME $= 2.30\times10^{17}\,kg/m^3$

11. Which one of the following isotopes is produced when $^{145}_{61}Pm$ decays by emitting an α particle?

A) $^{143}_{57}La$

B) $^{141}_{59}Pr$

C) $^{145}_{60}Nd$

D) $^{145}_{61}Pm$

E) $^{145}_{62}Sm$

α IS X^4_2 $X^4_2 + Pr^{141}_{59} = Pm^{145}_{61}$

12. The half-life of a particular isotope of iodine is 8.0 days. How much of a 10.0-g sample of this isotope will remain after 30 days?

A) 0.37 g
B) 0.45 g
C) 0.60 g
D) 0.74 g
E) 1.25 g

$10g \times (\frac{1}{2})^{30/8} = 10 \times .074 = 0.74g$

13. A beam of 4.5-MeV neutrons is directed at a 0.030-kg tissue sample. Each second, 1.5×10^6 neutrons strike the sample. If the relative biological effectiveness of these neutrons is 7.0, what biologically equivalent dose (in rem) is received by the sample in 65 seconds?

A) 0.23 rem
B) 0.55 rem
C) 1.6 rem
D) 19 rem
E) 33 rem

FIGURE THE JOULES OF RADIATION ENERGY ABSORBED PER kg OF TISSUE:

$65 s \times 1.5 \times 10^6 / s \times 4.5 \times 10^6 eV \times 1.6 \times 10^{-19} J/eV / .030 kg$ TISSUE

$= 2.34 \times 10^{-3} J/kg \times 100 RAD / (1 J/kg) = 2.34 \times 10^{-1} RAD$

DOSE IN REM $= 2.34 \times 10^{-1} RAD \times 7.0$ (RBE) $= 1.64$ REM

14. What is the importance of *thermal neutrons* in nuclear processes?

A) Thermal neutron capture results in uranium fission.
B) Thermal neutrons are released in radioactive decay.
C) Thermal neutrons are necessary in the fusion of deuterium.
D) Thermal neutrons are commonly released in fusion reactions.
E) Thermal neutrons are sources of gamma rays.

15. How many kilowatt • hours of energy are released from 25 g of deuterium $^{2}_{1}H$ fuel in the fusion reaction: $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + \gamma$ where $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + \gamma$ the masses are $^{2}_{1}H = 2.014\,102$ u and $^{4}_{2}He = 4.002\,603$ u.

Notes: Ignore the energy carried off by the gamma ray. Conversion factors: 1 kWh = 3.600×10^{6} J; 1 eV = 1.602×10^{-19} J.

A) 1×10^{6} kWh
B) 2×10^{6} kWh
C) 3×10^{6} kWh
D) 4×10^{6} kWh
E) 5×10^{6} kWh

FIND THE MASS DIFFERENCE!
$2 \times 2.014102 - 4.002603 = .025574$ u
$.025574$ u $\times 931.5$ MeV/u $= 23.82$ MeV FROM 2 NUCLEI
$25\,g = (25/2.014102)$ MOLES $= \frac{25 \times 6.022 \times 10^{23}}{2.014102} = 7.475 \times 10^{24}$
THIS IS THE # OF DEUTERIUM NUCLEI
ENERGY $= 7.475 \times 10^{24} \times \frac{1}{2} \times 23.82 \times 10^{6}$ eV $\times 1.6 \times 10^{-19}$ J/eV $= 1.426 \times 10^{13}$ J
→ NOW DIVIDE BY 3.600×10^{6} TO GET kWH → 3.96×10^{6} kWH

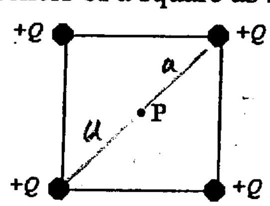
16. At what separation will two charges, each of magnitude 6 μC, exert a force of 1.4 N on each other?

A) 5.1×10^{-6} m
B) 0.23 m
C) 0.48 m
D) 2.0 m
E) 40 m

$F = \frac{k q_1 q_2}{r^2} = \frac{9 \times 10^{9} \times (6 \times 10^{-6} C)^2}{r^2} = 1.4 N$
$r^2 = \frac{9 \times 10^{9} (6 \times 10^{-6})^2}{1.4} = 0.23$
$r = 0.48$ m

Use the following to answer question 17:

Four point charges are placed at the corners of a square as shown in the figure.



Each charge has the identical value $+Q$. The length of the diagonal of the square is $2a$.

17. What is the electric potential at P, the center of the square?

A) kQ/a
B) $2kQ/a$
C) $4kQ/a$
D) $kQ/4a$
E) zero

FROM ONE CHARGE $V = \frac{kq}{r}$
IN THIS CASE THERE ARE 4 Q AND $r = a$
SO $V = \frac{4kQ}{a}$

18. A resistor dissipates 1.5 W when it is connected to a battery with a potential difference of 12 V. What is the resistance of the resistor?

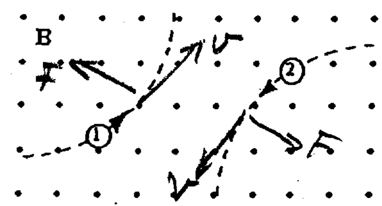
A) 0.13 Ω
B) 220 Ω
C) 18 Ω
D) 8.0 Ω
E) 96 Ω

$P = I^2 R \quad V = IR$ so $I = V/R$

so $P = (V/R)^2 R = V^2/R = 12^2/R = 1.5$

$R = 12^2/1.5 = 144/1.5 = 96\,\Omega$

19. Two particles move through a uniform magnetic field that is directed out of the plane of the page. The figure shows the paths taken by the two particles as they move through the field. The particles are not subject to any other forces or fields.



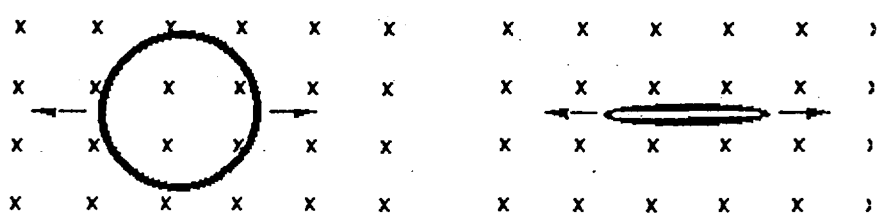
Which one of the following statements concerning these particles is true?

A) The particles may both be neutral.
B) Particle 1 is positively charged; 2 is negative.
C) Particle 1 is positively charged; 2 is positive.
D) Particle 1 is negatively charged; 2 is negative.
E) Particle 1 is negatively charged; 2 is positive.

IF YOU CURL YOUR FINGERS (RIGHT HAND!) FROM THE DIRECTION OF V TOWARD THE DIRECTION OF B, YOUR THUMB POINTS OPPOSITE F INDICATING NEGATIVE CHARGE.

Use the following to answer question 20:

A flexible, circular conducting loop of radius 0.15 m and resistance 4.0 Ω lies in a uniform magnetic field of 0.25 T. The loop is pulled on opposite sides by equal forces and stretched until its enclosed area is essentially zero, as suggested in the drawings. It takes 0.30 s to close the loop.



initial situation — final situation

20. Determine the magnitude of the emf induced in the loop.

A) 1.2×10^{-1} V
B) 1.8×10^{-2} V
C) 1.8×10^{2} V
D) 5.9×10^{-2} V
E) 5.9×10^{2} V

$$|\mathcal{E}| = \left|-\frac{\Delta \Phi}{\Delta t}\right| = \frac{\Delta (BA)}{\Delta t} = \frac{B\,\Delta A}{\Delta t} = \frac{B\,\Delta(\pi r^2)}{\Delta t}$$

$$= \frac{0.25\,\text{T}\,(\pi \times 0.15^2)}{0.30\,\text{s}} = 5.89 \times 10^{-2}\,\text{V}$$

21. A variable inductor is connected to an ac source. What effect does *increasing* the inductance have on the reactance and current in this circuit?

	Reactance	*Current*
A)	no change	no change
B)	decreases	no change
C)	increases	increases
D)	decreases	increases
(E)	increases	decreases

$X_L = 2\pi f L$

SO IF $L\uparrow$, $X_L\uparrow$

$V = I X_L$ SO $I = V/X_L$

THEN IF $X_L\uparrow$, $I\downarrow$

22. An FM radio station generates radio waves that have a frequency of 95.5 MHz. The frequency of the waves from a competing station have a frequency of 102.7 MHz. What is the difference in wavelength between the waves emitted from the two stations?

(A) 0.220 m
B) 0.454 m
C) 0.844 m
D) 2.39 m
E) 41.7 m

$f\lambda = c$ so $\lambda = c/f$ $\lambda_1 = 3\times10^8/95.5\times10^6 = 3.139$ m

$\lambda_2 = 3\times10^8/102.7\times10^6 = 2.919$ m

$3.139 - 2.919 = 0.220$ m

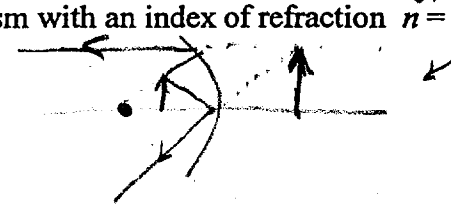
23. A concave mirror is found to focus parallel rays at a distance of 9.0 cm. Where is the image formed when an object is placed 6.0 cm in front of the mirror?

A) 11 cm in front of the mirror
(B) 18 cm behind the mirror
C) 3.6 cm in front of the mirror
D) 5.6 cm behind the mirror
E) 9.2 cm in front of the mirror

FOCUS IS AT $f = 9.0$ cm, $f > 0$ BECAUSE MIRROR CONVERGES THE RAYS. OBJECT DISTANCE $p = 6.0$ cm

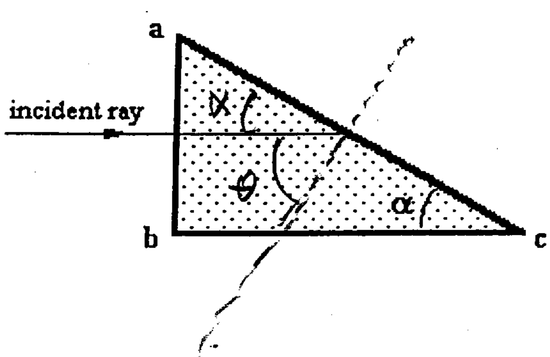
$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{6} + \frac{1}{q} = \frac{1}{9}$

$\frac{1}{q} = \frac{1}{9} - \frac{1}{6} = -\frac{1}{18}$ $q = -18 < 0$ SO VIRTUAL



Use the following to answer question 24:

A ray of light is normally incident on face **ab** of a plastic prism with an index of refraction n = 1.20 as shown.



24. Determine the largest value of the angle α so that the ray is totally reflected at the face **ac** if the prism is immersed in a liquid with refractive index 1.12.

(A) 21° (circled)
B) 34°
C) 69°
D) 78°
E) Total internal reflection will not occur for any value of α.

$\theta_c = 90 - \alpha$ MUST BE THE CRITICAL ANGLE

$n_1 \sin 90 = n_2 \sin\theta_c \quad n_1 = 1.12$ (LIQ) $\quad n_2 = 1.20$ (PRISM)

$\sin\theta_c = \frac{1.12}{1.20} \quad \theta_c = 69^\circ \quad \alpha = 90 - 69 = 21^\circ$

25. In a Young's double slit experiment, the separation between the slits is 1.20×10^{-4} m; and the screen is located 3.50 m from the slits. The distance between the central bright fringe and the second-order bright fringe is 0.0415 m. What is the wavelength of the light used in this experiment?

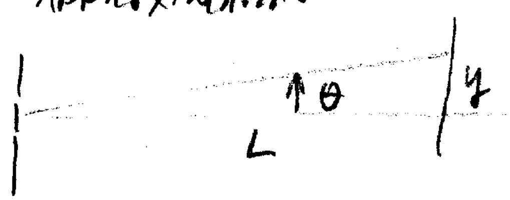
A) 428 nm
B) 474 nm
C) 517 nm
D) 642 nm
(E) 711 nm (circled)

2ND ORDER ; $m = 2$ $\quad d = 1.20 \times 10^{-4}$ m

$m\lambda = d \sin\theta$ $\quad y = .0415$ m

$L = 3.50$ m

$y/L \ll 1$ SO WE CAN USE THE SMALL ANGLE APPROXIMATION



$y/L = \tan\theta \cong \sin\theta$, THEN

$m\lambda = d\,y/L$ OR $\lambda = dy/Lm$

$$\lambda = \frac{1.2 \times 10^{-4} \times .0415}{2 \times 3.5} = 7.11 \times 10^{-7} \text{ m}$$