PHYSICS II Golden Rod
JANUARY 12, 2017 Corrections:

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. Use: g =10 m/s^2. As prescribed by the College Board for AP Physics, the work done *on* a gas is a *positive* quantity; $\Delta U = Q + W$

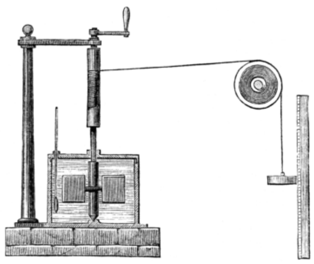
$c_{water} = 4200 \, {}^{J}\!/_{kg \cdot K}$, $c_{steam} = 2010 \, {}^{J}\!/_{kg \cdot K}$, & $c_{ice} = 2090 \, {}^{J}\!/_{kg \cdot K}$

$c_{copper} = 387 \, {}^{J}\!/_{kg \cdot K}$, $c_{mercury} = 140 \, {}^{J}\!/_{kg \cdot K}$, & $c_{air} = 1006 \, {}^{J}\!/_{kg \cdot K}$

1. In the classic 1983 *A Christmas Story*, a child named Flick (played by Scott Schwartz) stuck his tongue on a metal (presumably steel) pole on a freezing cold December day after receiving the dreaded *Triple Dog Dare*. Had the pole been wooden, Flick's tongue probably would not have frozen and stuck to it. Why is this?

(A) Steel has a higher specific heat than wood.
(B) Steel has a higher specific gravity than wood.
(C) Steel has a lower specific heat than wood.
(D) Steel is a better heat conductor than wood.

2. Below is a patent diagram from James Prescott Joule's famous experiment. As the mass on the right falls due to gravity, the connecting string causes the paddle wheels in the water to turn like a propeller. This then causes an increase in the temperature of the water. This apparatus determined



(A) the specific heat of water.
(B) the thermal conductivity of water.
(C) the efficiency of heat engines.
(D) the mechanical equivalent of heat.

3. An ideal gas undergoes an adiabatic process during which the internal energy increases by 100 J. Which choice below correctly indicates the heat exchange and the work done on/by the system?

	Heat Exchanged	***Work done***
(A)	None	100 J on the system
(B)	None	100 J by the system
(C)	100 J removed	None
(D)	100 J added	None

4. A 0.6-kg hunk of metal alloy initially at 100^{o}C is dropped into an insulated container holding 0.8-kg of water initially at 30^{o}C. Once thermal equilibrium is reached, the water is at 50^{o}C. What is the specific heat of the metal alloy?

(A) $2{,}240 \, {}^{J}\!/_{kg^oC}$
(B) $5{,}600 \, {}^{J}\!/_{kg^oC}$
(C) $7{,}800 \, {}^{J}\!/_{kg^oC}$
(D) $14{,}000 \, {}^{J}\!/_{kg^oC}$

5. Which of the following is a unit for linear coefficient of expansion?

(A) $m/{}^{o}C$ (B) $1/{}^{o}C$ (C) ${}^{o}C/m$ (D) ${}^{o}C$

6. A tire gauge measures 190 kPa on a day when the atmospheric pressure is 100 kPa. What is the absolute pressure in the tire?

(A) 90 kPa (B) 100 kPa (C) 190 kPa (D) 290 kPa

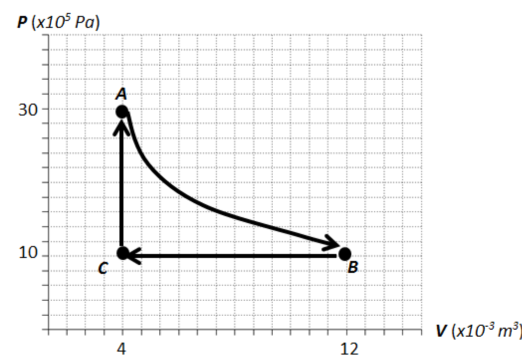
7. An ideal gas absorbs 865 J of heat and does 625 J of work. What is the resulting change in temperature of the gas if there are 1.5 moles present?

(A) 11 K (B) 13 K (C) 15 K (D) 17 K

8. Which of the following is an acceptable unit for the ***PV*** quantity in the Ideal Gas Law?

(A) $kg \cdot m^2/s^2$ (B) $kg \cdot m/s^2$ (C) kg/s^2 (D) $kg \cdot m^3/s^2$

Use the following information for Questions #9 – 11. As shown in the ***P-V*** diagram below, an ideal monatomic gas is taken through three processes; ***A→B→C→A***. Beginning at state ***A***, it is expanded to state ***B***, then compressed to state ***C***, then finally taken back to state ***A***. The temperature at state ***C*** is 400 K.



9. What is the temperature of the gas when at state ***B***?

(A) 400 K (B) 800 K
(C) 1200 K (D) 1600 K

10. How much work is done in moving from state ***B*** to state ***C***?

(A) -8000 J (B) +8000 J
(C) +12,000 J (D) Zero J

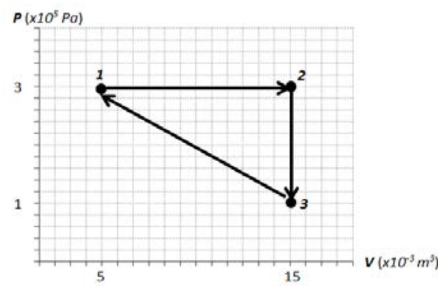
11. The process in moving the gas from ***A→B*** is

(A) isovolumetric (B) isobaric
(C) adiabatic (D) isothermal

12. The pressure, ***P***, of a monatomic ideal gas in terms of the average kinetic energy, ***K***, per unit volume, ***V***, is

(A) $\frac{K}{V}$ (B) $\frac{2K}{3V}$ (C) $\frac{3K}{2V}$ (D) $\frac{3K}{2V}T$

13. An ideal gas is taken through three distinct processes in a repeating cycle as shown; ***1→2→3→1***. How much heat must be exchanged during each complete cycle? All Full credit: graph hard to read.



(A) 1000 J added (B) 1000 J expelled
(C) 2000 J added (D) 2000 J expelled

14. A heat engine operating at 40% efficiency performs useful work at a rate of 10-kW. How much heat is exhausted per second?

(A) 4,000 J (B) 10,000 J (C) 15,000 J (D) 25,000 J

15. A sample of helium gas of mass ***M*** is in a rigid container of constant volume ***V***. It is initially at pressure ***P*** and absolute temperature ***T***. A mass of 2***M*** of additional helium is then forced into the container. After this helium addition, the temperature of the gas is measured to be 2***T***. What is the gas pressure?

(A) $\frac{2}{3}P$ (B) $2P$ (C) $3P$ (D) $6P$

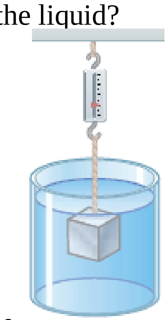
16. An object is thrown off a pier into the clean water of Asbury Park. If the object eventually displaces a volume of water equal to its own volume, it must

(A) be floating (B) be partially submerged (C) be fully submerged (D) be hollow

17. As shown below, a cube of iron is suspended from a spring scale calibrated in Newtons and then fully submerged in an unknown liquid. The iron cube measures 4-cm on each side and has a density of $7{,}874\,{}^{kg}\!/_{m^3}$.

When the cube is fully submerged and stationary, the scale reads exactly 3-N. What is the density of the liquid?

(A) $1{,}000\,{}^{kg}\!/_{m^3}$ (B) $2{,}250\,{}^{kg}\!/_{m^3}$ (C) $3{,}125\,{}^{kg}\!/_{m^3}$ (D) $6{,}250\,{}^{kg}\!/_{m^3}$



18. A hydraulic press has pistons of 4-cm and 4-m diameters respectively. If a force of 500-N is applied to the smaller piston, what force is applied to the larger piston?

(A) 5-N (B) 500-N (C) $5\text{x}10^4$-N (D) $5\text{x}10^6$-N

19. The full Bernoulli Equation is written as $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$, where ρ is the density of the fluid. It is considered a statement of

(A) the Conservation of Energy. (B) the Conservation of Linear Momentum.

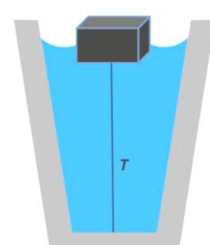
(C) the Continuity of Flow Rate. (D) the Conservation of Matter.

20. Water of density ***D*** flows with speed v_1 through a wide pipe of radius r_1. The water then enters a smaller pipe of radius r_2 and a new speed v_2. The ratio of the speeds ${}^{v_1}\!/_{v_2}$ is

(A) ${}^{r_1}\!/_{r_2}$ (B) ${}^{r_2}\!/_{r_1}$ (C) $\left({}^{r_1}\!/_{r_2}\right)^2$ (D) $\left({}^{r_2}\!/_{r_1}\right)^2$

21. A 3-kg mass displaces 10-kg of water when fully submerged under water. When tied by a light string to the bottom of a container full of water, the partially submerged object reaches equilibrium as shown and displaces only 4-kg of water.
What is the tension in the string?

(A) 10-N (B) 20-N (C) 30-N (D) 40-N



22. Believe it or not, the world's saltiest body of water is the *Don Juan Pond* of Antarctica. It is so salty, it has never been observed frozen. Of course, humans haven't been there to observe it very often, but… Ocean water has an average salt content of 3.5%; Don Juan Pond is 44% salinity. An object of unknown material is thrown into the Pond and is partially submerged with 95% of its volume under the surface. The density of this water is about $1400\,{}^{kg}\!/_{m^3}$. What is the density of the unknown object?

(A) $616\,{}^{kg}\!/_{m^3}$ (B) $1330\,{}^{kg}\!/_{m^3}$ (C) $1400\,{}^{kg}\!/_{m^3}$ (D) $1473\,{}^{kg}\!/_{m^3}$

23. A 6-N force larger than the average atmospheric force is required to rupture a typical human eardrum that has a cross-sectional area of only 1-cm^2. Calculate the maximum depth a typical person could descend under fresh water without ear/pressure protection and *not* shatter his/her eardrum.

(A) 3-m (B) 6-m (C) 9-m (D) 12-m

24. An air mattress commonly used by campers measures 100-cm x 200-cm x 10-cm when inflated and has a mass of 4-kg. What is the maximum number of children, each of mass 30-kg, who could successfully float on fresh water using this air mattress and not be submerged themselves?

(A) 4 children (B) 5 children (C) 6 children (D) 7children

25. Mt. Washington in New Hampshire, the highest peak in New England, holds the world record for a directly measured non-cyclone produced wind speed at $231\,{}^{mi}\!/_{hr}$, $372\,{}^{km}\!/_{hr}$, measured in 1934. Under these wind speeds, what is the force due to the Bernoulli Effect on the $220m^2$ roof of the observatory building? The building is at an elevation of 6288-ft, so the air density is only $1.1\,{}^{kg}\!/_{m^3}$ and the associated atmospheric pressure is $8.1x10^4\,Pa$. Ignore any turbulence effects by assuming smooth wind flow.

(A) $1.0x10^5\,N$ (B) $1.3x10^5\,N$ (C) $1.0x10^6\,N$ (D) $1.3x10^6\,N$

The Mt. Washington Observatory Building
(Shows chains anchored to ground to prevent the building from blowing away…)

PHYSICS II **Golden Rod**

JANUARY 12, 2017
SOLUTIONS Corrections:

1. D	14. C
2. D	15. D
3. A	16. C
4. A	17. C
5. B	18. D
6. D	19. A
7. B	20. D
8. A	21. A
9. C	22. B
10. B	23. B
11. D	24. C
12. B	25. D
13. A(all full credit: graph)	

PHYSICS II: for all students currently enrolled in AP physics II. 25 multiple choice per exam.
January: Heat & Thermodynamics, Fluid Statics and Dynamics
February: Electrostatics: electric force, fields, & potential, DC Circuits and RC Circuits, plus January Topics
March: Magnetics and Electromagnetic induction, Geometric & Physical optics, plus Jan and Feb Topics
April: Quantum physics, atomic and nuclear physics, plus Jan, Feb and March topics.

Dates for 2017 Season
Thursday January 12, 2017 Thursday February 9, 2017
Thursday March 9, 2017 Thursday April 13, 2017
All areas and schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: newjsl@ptd.net
Web address: http://entnet.com/~personal/njscil/html/

What is to be mailed back to our office?
PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).
If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season
Thursday January 11, 2018 Thursday February 8, 2018
Thursday March 8, 2018 Thursday April 12, 2018

AP I and AP 2 PHYSICS FORMULAE Updated 12-16-2016

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27} kg$	Fundamental charge	$e = 1.6x10^{-19} C$
Electron Mass	$m_e = 9.11x10^{-31} kg$	Electron Volt	$1eV = 1.6x10^{-19} J$
Avogadro's #	$6.02x10^{23} mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11} Nm^2/kg^2$
Universal gas constant	$R = 8.31 J/mol \cdot K$	Speed of Light	$c = 3.00x10^8 m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23} J/K$	Magnetic constant	$k' = 1x10^{-7} T \cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27} kg = 931 MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34} J \cdot s = 4.14x10^{-15} eV \cdot s$ $hc = 1.99x10^{-25} J \cdot m = 1240 eV \cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9 N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12} C^2/N \cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2}at^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$U_g = G\frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

Δx = displacement (change of position)

$\bar{v}$ = average velocity

$\bar{a}$ = average acceleration

v_i = initial velocity

v_f = final velocity

F = force

F_f = force of friction

F_N = normal force

F_g = gravitational force

G = Universal Gravitational Constant

ρ = momentum

μ = coefficient of friction

r = distance between center of masses

W = weight

m = mass

U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = ...$

$V_T = V_1 + V_2 + V_3 + ...$

$R_T = R_1 + R_2 + R_3 + ...$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ...$

$V_T = V_1 = V_2 = V_3 = ...$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...}$

C = Capacitance

E = electric field intensity

I = electric current

k = electrostatic constant

P = Power

q = charge

R = resistance

U_E = electric potential Energy

U_C = energy stored in capacitor

V = electric potential difference

W = Work

$C = Q/\Delta V$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x \cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2}mv^2$

$F = -kx$

$PE_s = \frac{1}{2}kx^2$

h = height

k = spring constant

KE = kinetic energy

PE_g = gravitational potential energy

PE_s = potential energy stored in a spring

P = power

W = work

x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fxr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2}I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

a_c = centripetal acceleration

F_c = centripetal force

τ = Torque

I = Rotational Inertia

α = Angular acceleration

ω = Angular velocity

K_{rot} = Rotational KE

x = position

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat

L_f = latent heat of fusion

L_V = latent heat of vaporization

Q = amount of heat

ΔT = change in temperature

α = coefficient of linear expansion

L_o = original length

$c_{water} = 4186 \frac{J}{kg°K}$

K = kinetic energy

L = thickness

U = internal energy

W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum

d = distance between slits

$f = \nu$ = frequency

L = distance from slit to screen

n = index of absolute refraction

T = period

v = speed

x = distance from central maximum to first-order maximum

λ = wavelength

θ = angle

θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length

d_i = image distance

d_o = object distance

h_o = object size

h_i = image size

β = Sound level

I = Sound Intensity

I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_S$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength

I_P = current in primary

I_S = current in secondary

N_P = number of turns in primary coil

N_S = number of turns in secondary coil

V_P = voltage of primary

V_S = voltage of secondary

L = length of conductor

V = electric potential difference

v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area

F = force

h = depth

P = pressure

V = volume

v = speed

y = height

ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

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

$E = mc^2$

E = energy

f = frequency

K = kinetic energy

m = mass

p = momentum

λ = wavelength

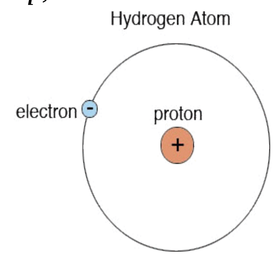
ϕ = work function

PHYSICS II **Golden Rod**

FEBRUARY 9, 2017 **Corrections:**

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. *Use: g =10 m/s²*. As prescribed by the College Board for AP Physics, the work done *on* a system is a *positive* quantity. Formulae sheet end of test.

1. The Bohr model of the hydrogen atom depicts a positively charged nucleus (a proton) and a negatively charged electron orbiting the nucleus in a circular orbit. Given the radius of such an atom is R, the mass of the nucleus is M with an electric charge of Q,and the mass of an electron is m and charge is q, what is the ratio of the electrostatic force to the gravitational force of this Bohr hydrogen atom, $\frac{F_E}{F_G}$?



(A) $\frac{kQq}{GMmR^2}$ (B) $\frac{kQqR^2}{GMm}$ (C) $\frac{kQq}{GMm}R^2$ (D) $\frac{kQq}{GMm}$

2. An electrical insulator is a material that has which of the following properties?
(A) It has no extra electrons. (B) It is neutral at all times
(C) It contains extra protons. (D) It inhibits the flow of electrons.

3. The following steps/procedures are written in no particular order.

1. Ground the electroscope
2. Remove the ground from the electroscope.
3. Bring a charged object close to, but not touching, the electroscope.
4. Make contact between a charged object and the electroscope.
5. Remove the charged object.

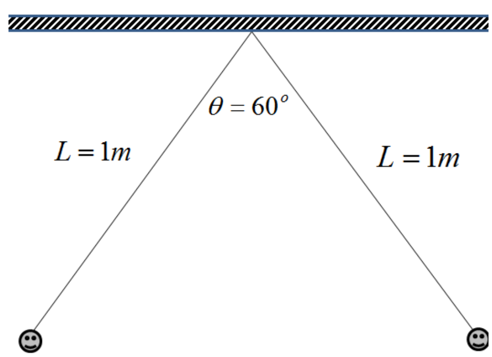
To charge an electroscope of unknown initial charge (could have one, could have none…) by induction, which of the following numerical steps of the above procedures would work?
(A) *1-3-4-5* (B) *1-3-2-5* (C) *4-1-5-2* (D) *1-2-3-5-1-2*

4. A negatively charged conductor attracts a small object at a close range. Which of the following could explain this?

1. The small object is a positive conductor.
2. The small object is a conductor with zero net charge.
3. The small object is an insulator with a zero net charge.

(A) *1* only (B) *1* & *2* only (C) *2* & *3* only (D) *1*, *2*, & *3*

Use the following information for Questions #5-7: As shown below, two 50-gram objects are suspended from massless insulated strings. They push away from each other and settle into static equilibrium.

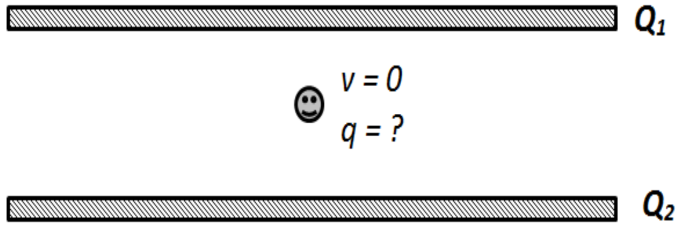


5. What is the tension in the string holding the object on the right?
(A) 0.25-N (B) 0.50-N
(C) 0.58-N (D) 1.00-N

6. What is the magnitude of the electrostatic charge of each object?
(A) $2.8\mu C$ (B) $5.7\mu C$
(C) $8.5\mu C$ (D) $11.4\mu C$

7. Which one of the following *must be true* of the nature of the charges on the two objects?
(A) The charges are equal in magnitude and positive.
(B) The charges are equal in magnitude and negative.
(C) The charges are equal in magnitude, but one is positive and one is negative.
(D) None of the above three choices *must* be true.

Use the following information for Questions #8-10: During a *Milliken Oil Drop* Experiment, you observe an oil drop of mass 0.5-grams and unknown electrical charge suspended; neither falling nor rising. It is suspended between two equally charged plates, one plate positively charged and the other plate negatively charged.



8. Which of the following relationships between $\boldsymbol{Q_1}$, $\boldsymbol{Q_2}$, and $\boldsymbol{q}$ correctly fits this description?

	Q_1	Q_2	q
1	Positive	Negative	Positive
2	Negative	Positive	Positive
3	Positive	Negative	Negative
4	Negative	Positive	Negative

(A) 1 & 3 only (B) 2 & 4 only (C) 2 & 3 only (D) 1 & 4 only

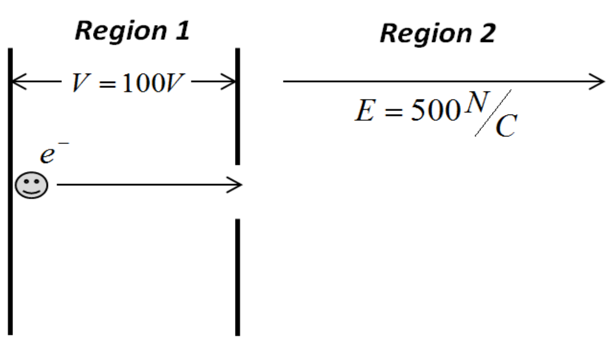
9. What is the magnitude and direction of the electric field between the charged plates that causes the oil drop to be suspended if the drop has a net charge of negative $10\mu C$?

(A) $500\,N/C$ downward (B) $500\,N/C$ upward (C) $0.002\,N/C$ downward (D) $0.002\,N/C$ upward

10. Using the aforementioned $q = -10\mu C$, what is the excess or deficiency of electrons on the oil drop?

(A) $6.25x10^{13}$ deficient (B) $6.25x10^{13}$ excess (C) $6.25x10^{7}$ deficient (D) $6.25x10^{7}$ excess

Use the following information for Questions #11-14: As shown below, an electron initially at rest is accelerated horizontally through a potential difference of $100V$, ***Region 1***. It then moves into a region, ***Region 2***, where a uniform electric field of strength $500\,N/C$ is oriented to the right.



11. What is the polarity of the left and right sides, respectively, of ***Region 1***?

(A) Positive, Positive (B) Negative, Negative
(C) Positive, Negative (D) Negative, Positive

12. With what speed does the electron enter the electric field region, ***Region 2***?

(A) $6x10^{6}\,m/s$ (B) $6x10^{7}\,m/s$

(C) $7x10^{6}\,m/s$ (D) $7x10^{7}\,m/s$

13. What is the direction and magnitude of the force acting on the electron while traveling in ***Region 2***?

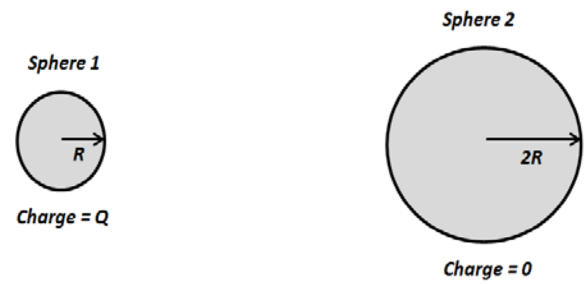
(A) $8x10^{-17}\,N$ to the right (B) $8x10^{-17}\,N$ to the left

(C) $8x10^{-17}\,N$ to the top of the page (D) $8x10^{-17}\,N$ to the bottom of the page

14. Slight changes are made to the power supply creating the potential difference in ***Region 1*** so that if the electron is replaced with a proton and it is also accelerated to the right across ***Region 1***. ***Region 2*** is left unchanged. Which of the following sets of descriptors, compared to those of the electron, is correct?

	Velocity Entering Region 1	***Magnitude of F in Region 1***	***Direction of F in Region 1***
(A)	Same	Smaller	To the Left
(B)	Smaller	Smaller	To the Right
(C)	Smaller	Same	To the Left
(D)	Smaller	Same	To the Right

15. As shown below, two conducting spheres are isolated from each other at a distance very large compared to the individual sizes of the spheres. One has a radius ***R*** and a charge of ***Q*** while the other has a radius of 2***R*** and has no net charge. If you connect the spheres, without moving them, with a long conducting wire, which of the following happens?



(A) Charge will flow until both spheres have the same potential.
(B) Charge will flow until Sphere 2 has twice the potential as Sphere 1.
(C) Charge will flow until Sphere 2 has eight times the potential as Sphere 1.
(D) Charge will flow until both spheres have the same charge.

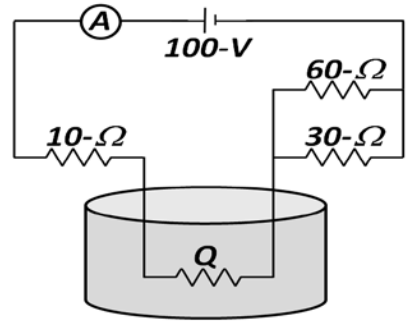
16. A 4***μF*** capacitor is connected in series with a 2 ***μF*** capacitor and fully charged with a battery. The *charges* stored in the two capacitors while in series are ***W*** & ***X***, respectively. The capacitors are then disconnected and discharged. Now, each capacitor is charged individually with the same battery and attain stored charges of ***Y*** and ***Z***, respectively. What is the relationship between the stored charges ***W***, ***X***, ***Y***, & ***Z***?
(A) $Y > Z > W = X$ (B) $W > X > Y = Z$ (C) $Y > W = X > Z$ (D) $Y = W > Z = X$

17. A 4***μF*** capacitor is connected in series with a 2 ***μF*** capacitor and fully charged with a battery. The *energies* stored in the two capacitors while in series are ***W*** & ***X***, respectively. The capacitors are then disconnected and discharged. Now, each capacitor is charged individually with the same battery and attain stored energies of ***Y*** and ***Z***, respectively. What is the relationship between the stored energies ***W***, ***X***, ***Y***, & ***Z***?
(A) $Y > W > Z > X$ (B) $W > Y > Z > X$ (C) $W > X > Y > Z$ (D) $Y > Z > X > W$

18. While studying for this exam, you turned on your desk lamp rated at 60-W and 120-V at 6 PM. Unfortunately, you fell asleep at your desk, woke up at 6 AM the next morning and turned it off. During that time, how much electrical charge in Coulombs passed through the lamp?
(A) 6-C (B) 21,600-C (C) 43,200-C (D) 86,400-C

19. Assuming PSE&G, NJ's electricity company, charges 10¢ ($0.10) per Kilowatt-Hour (kW-hr), how much did the electricity cost to run the lamp mentioned in #18 above from 6 PM to 6 AM?
(A) $0.07 (B) $0.70 (C) $7.00 (D) $70.00

Use the following information for Questions #20-22: The schematic below represents the electrical circuit associated with a submersible heater, represented as resistor ***Q***, used to heat water in an insulated container. Before the circuit is turned on, the 2-kg of water is initially at room temperature of 20°C. Assume no heat loss to the environment. Use:



$c_{water} = 4200 \,{}^{J}\!/_{kg\cdot K}$, $c_{steam} = 2010 \,{}^{J}\!/_{kg\cdot K}$, $c_{ice} = 2090 \,{}^{J}\!/_{kg\cdot K}$,

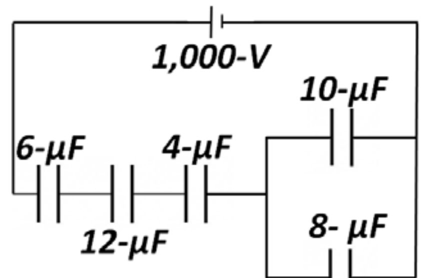
$L_{Fusion} = 334{,}000 \,{}^{J}\!/_{kg}$, and $L_{Vaporization} = 2{,}265{,}000 \,{}^{J}\!/_{kg}$

20. If the ammeter reading is 2-A, what is the value of ***Q***?
(A) 10-Ω (B) 20-Ω
(C) 50-Ω (D) 100-Ω

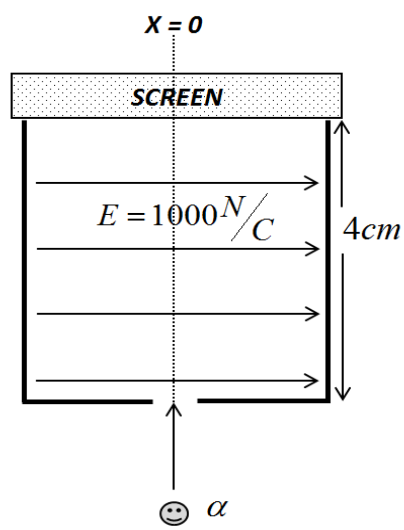
21. Assuming all the heat produced by ***Q*** is absorbed by the water,
what is the temperature of the water 14 minutes after the circuit is turned on?
(A) 20.1°C (B) 22°C
(C) 28°C (D) 56°C

22. **Approximately**, how long does it take for the heater to turn all the water into steam at 100°C?
(A) 140 minutes (B) 940 minutes (C) 1100 minutes (D) 1400 minutes

23. What is the total energy stored in all capacitors in the circuit to right? 10J all full credit. No correct answer.
(A) 0.09-*J* (B) 0.9-*J*
(C) 1.3-*J* (D) 13.2-*J*



Use the following information for Questions #24 & 25: As shown below, an alpha particle is shot into a region with a constant electric field of strength $1{,}000 \,{}^{N}\!/_{C}$ oriented to the right of the page. The alpha particle is essentially a Helium nucleus consisting of two protons and two neutrons. The alpha particle has an initial speed of $4x10^{6} \,{}^{m}\!/_{s}$ as it enters the $4cm$ long region. After passing through the electric field, the alpha particle strikes a screen. The center of the screen is labeled as $X = 0$.



24. What is the magnitude and direction of the acceleration of the alpha particle as it travels through the electric field?
(A) $9.6x10^{10} \,{}^{m}\!/_{s^2}$ to the left of the page
(B) $9.6x10^{10} \,{}^{m}\!/_{s^2}$ to the right of the page
(C) $4.8x10^{10} \,{}^{m}\!/_{s^2}$ to the left of the page
(D) $4.8x10^{10} \,{}^{m}\!/_{s^2}$ to the right of the page

25. Where does the alpha particle strike the screen after traveling through the electric field?
(A) $4.8x10^{-6}\,m$ to the left of $X = 0$. (B) $4.8x10^{-6}\,m$ to the right of $X = 0$.
(C) $2.4x10^{-6}\,m$ to the left of $X = 0$. (D) $2.4x10^{-6}\,m$ to the right of $X = 0$.

PHYSICS II **Golden Rod**

FEBRUARY, 2017

SOLUTIONS Corrections:

1. D	14. D
2. D	15. A
3. B	16. A
4. D	17. D
5. C	18. B
6. B	19. A
7. D	20. B
8. C	21. C
9. A	22. C
10. B	23. ~~B~~ (all full credit 10 J)
11. D	24. D
12. A	25. D
13. B	

PHYSICS II: for all students currently enrolled in AP physics II. 25 multiple choice per exam.
January: Heat & Thermodynamics, Fluid Statics and Dynamics
February: Electrostatics: electric force, fields, & potential, DC Circuits and RC Circuits, plus January Topics
March: Magnetics and Electromagnetic induction, Geometric & Physical optics, plus Jan and Feb Topics
April: Quantum physics, atomic and nuclear physics, plus Jan, Feb and March topics.

Dates for 2017 Season
Thursday January 12, 2017 Thursday February 9, 2017
Thursday March 9, 2017 Thursday April 13, 2017
All areas and schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: newjsl@ptd.net
Web address: http://entnet.com/~personal/njscil/html/

What is to be mailed back to our office?
PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).
If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season
Thursday January 11, 2018 Thursday February 8, 2018
Thursday March 8, 2018 Thursday April 12, 2018

AP I and AP 2 PHYSICS FORMULAE Updated 12-16-2016

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27} kg$	Fundamental charge	$e = 1.6x10^{-19} C$
Electron Mass	$m_e = 9.11x10^{-31} kg$	Electron Volt	$1eV = 1.6x10^{-19} J$
Avogadro's #	$6.02x10^{23} mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11} Nm^2/kg^2$
Universal gas constant	$R = 8.31 J/mol \cdot K$	Speed of Light	$c = 3.00x10^8 m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23} J/K$	Magnetic constant	$k' = 1x10^{-7} T \cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27} kg = 931 MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34} J \cdot s = 4.14x10^{-15} eV \cdot s$ $hc = 1.99x10^{-25} J \cdot m = 1240 eV \cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9 N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12} C^2/N \cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2}at^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$U_g = G\frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

Δx = displacement (change of position)

$\bar{v}$ = average velocity

$\bar{a}$ = average acceleration

v_i = initial velocity

v_f = final velocity

F = force

F_f = force of friction

F_N = normal force

F_g = gravitational force

G = Universal Gravitational Constant

ρ = momentum

μ = coefficient of friction

r = distance between center of masses

W = weight

m = mass

U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = ...$

$V_T = V_1 + V_2 + V_3 + ...$

$R_T = R_1 + R_2 + R_3 + ...$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ...$

$V_T = V_1 = V_2 = V_3 = ...$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...}$

C = Capacitance

E = electric field intensity

I = electric current

k = electrostatic constant

P = Power

q = charge

R = resistance

U_E = electric potential Energy

U_C = energy stored in capacitor

V = electric potential difference

W = Work

$C = Q/\Delta V$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x \cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2}mv^2$

$F = -kx$

$PE_s = \frac{1}{2}kx^2$

h = height

k = spring constant

KE = kinetic energy

PE_g = gravitational potential energy

PE_s = potential energy stored in a spring

P = power

W = work

x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fxr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2}I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

a_c = centripetal acceleration

F_c = centripetal force

τ = Torque

I = Rotational Inertia

α = Angular acceleration

ω = Angular velocity

K_{rot} = Rotational KE

x = position

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat
L_f = latent heat of fusion
L_V = latent heat of vaporization
Q = amount of heat
ΔT = change in temperature
α = coefficient of linear expansion
L_o = original length
$c_{water} = 4186 \frac{J}{kg°K}$
K = kinetic energy
L = thickness
U = internal energy
W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum
d = distance between slits
$f = \nu$ = frequency
L = distance from slit to screen
n = index of absolute refraction
T = period
v = speed
x = distance from central maximum to first-order maximum
λ = wavelength
θ = angle
θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length
d_i = image distance
d_o = object distance
h_o = object size
h_i = image size
β = Sound level
I = Sound Intensity
I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_s$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength
I_P = current in primary
I_S = current in secondary
N_P = number of turns in primary coil
N_S = number of turns in secondary coil
V_P = voltage of primary
V_S = voltage of secondary
L = length of conductor
V = electric potential difference
v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area
F = force
h = depth
P = pressure
V = volume
v = speed
y = height
ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

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

$E = mc^2$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

PHYSICS II PHYSICS II Golden Rod No Corrections
MARCH 9, 2017

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. *Use: g =10 m/s²*. As prescribed by the College Board for AP Physics, the work done *on* a system is a *positive* quantity. Formulae sheets at the back.

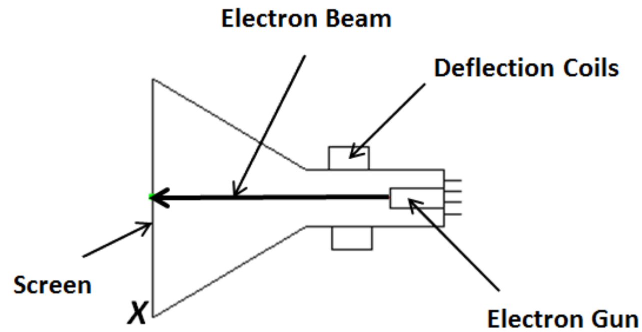
1. A magnetic field cannot
(A) exert a force on a charged particle. (B) accelerate a charged particle.
(C) change the momentum of a charged particle. (D) change the kinetic energy of a charged particle.

2. In a high-energy experiment a single proton and a single alpha-particle enter a magnetic field side-by-side perpendicularly to the field. They both experience the same force from the magnetic field upon entering. What is the ratio of the speed of the proton to the speed of the alpha, V_{Proton}/V_{Alpha}, upon entering the magnetic field?

(A) $1/2$ (B) 1 (C) 2 (D) 4

3. Below is a schematic of a cathode ray tube where the deflector coils are turned off. This is what your parents know as a TV picture tube. It is simply a high-energy beam of electrons that can be deflected in different directions and when they hit a phosphorescent screen they create a blip of light. If the beam of electrons is deflected so they strike the bottom of the screen, labeled as the "***X***", in what direction relative to the diagram is the magnetic field created by the deflector coils?

(A) Toward the bottom of the page.
(B) Out from the page toward you.
(C) Toward the top of the page.
(D) Into the page away from you.



4. An alpha particle is emitted from a $^{238}_{92}U$ nucleus and enters a magnetic field labeled in *Figure 1* as ***B***. After entering the magnetic field region, the alpha particle follows the decreasing radius spiral path, also in the plane of the page, shown in *Figure 2*. Which of the following choices is a correct explanation for this?

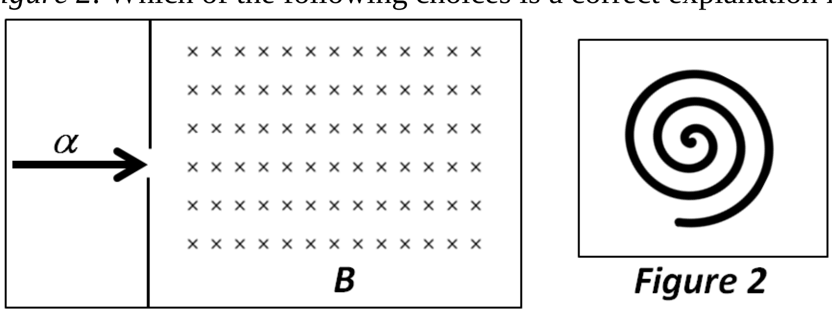


Figure 1 Figure 2

(A) The magnetic field strength is increasing. (B) The magnetic field strength is decreasing.
(C) The alpha particle is decreasing in charge. (D) The alpha particle is increasing in charge.

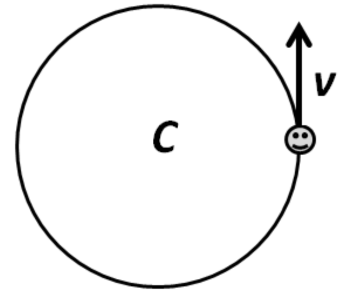
5. An electron and a proton are initially moving with identical velocities, both magnitude and direction, when they enter a uniform magnetic field perpendicularly to the field direction. The electron and the proton will experience magnetic forces that are
(A) equal in magnitude, but perpendicular to each other.
(B) equal in direction and magnitude.
(C) equal in magnitude, but opposite in direction.
(D) in opposite directions, but differing in magnitude by about 2000; the difference in masses between the particles.

6. An electron of mass $\boldsymbol{m}$ and charge $\boldsymbol{e}$ is accelerated from rest through a potential difference of $\boldsymbol{V}$ and then deflected as it moves perpendicularly into a uniform magnetic field $\boldsymbol{B}$. The radius of the ensuing electron path is

(A) $\sqrt{\frac{2eV}{B^2 m}}$ (B) $\sqrt{\frac{2mV}{B^2 e}}$ (C) $\sqrt{\frac{2eV}{m}}$ (D) $\sqrt{\frac{2mV}{e}}$

7. As shown below, a single electron is traveling counterclockwise along a circular path with a constant speed. In what direction is the magnetic field at the center of the circle, labeled 'C', caused by the electron motion?

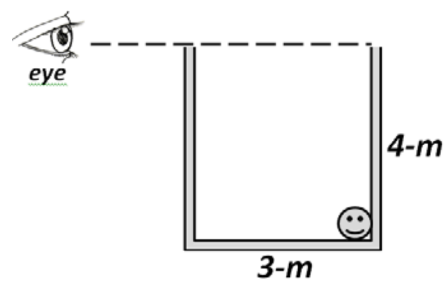
(A) Toward the top of the page.
(B) Toward the bottom of the page.
(C) Into the page away from you.
(D) Out of the page toward you.



8. On a hike, you walk under a high overhead power line that has a conventional current running through it heading due north. At your position under the wire, the magnetic field created by the current points
(A) East (B) West (C) Upward into the sky (D) Downward into the ground

9. You are driving your car on the Garden State Parkway at a speed of $75 \,{}^{km}\!/_{hr}$ in a region where the magnetic field of the Earth has a magnitude of $0.5x10^{-4}T$ vertically upward. What is the induced emf between the left and right sides of your 1.7-m wide car?
(A) Zero (B) $1.8mV$ (C) $3.6mV$ (D) $6.4mV$

10. Below is sketched a steel tank measuring 3-m x 4-m full of an unknown clear liquid. An observer, shown by the eyeball, is just level with the top left corner of the tank and can just barely see a smiling marble in the far corner. What is the index of refraction of the unknown liquid?
(A) 1.25 (B) 1.33
(C) 1.50 (D) 1.67

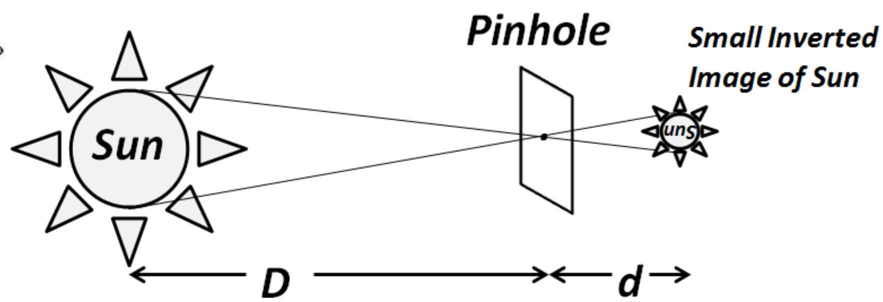


11. A diver underwater, index of n_1, shines a laser beam to the surface at exactly the critical angle for a water-air interface. However, there is a thin layer of oil, index of n_2, on top of the water surface. What is the refracted angle within the oil layer?

(A) $\sin^{-1}\left(\frac{n_1}{n_2}\right)$ (B) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$ (C) $\sin^{-1}\left(\frac{1}{n_1}\right)$ (D) $\sin^{-1}\left(\frac{1}{n_2}\right)$

Use the following information for Questions #12 & 13: The astronomical event of the decade is approaching. On Monday, 21 August 2017, there will be a total solar eclipse visible from everywhere in the continental United States with a wide path of totality from Oregon to South Carolina. This could be a proverbial "once-in-a-lifetime" event since the next country-wide total solar eclipse occurs in 2045; although one will occur in 2024 for only the east half of the USA from Texas to Maine.

A solar eclipse, as you know, occurs when the Moon blocks the Sun and casts a deep shadow on the face of the Earth. To view an eclipse safely and cheaply, one needs special "eclipse glasses" that will prevent the intense electromagnetic radiation from burning a hole through your skull or to set up a simple pin-hole camera with nothing more than a piece of cardboard and a screen. The image below (*NOT* drawn to scale) depicts one such pinhole camera where the Sun, at a distance $D = 1.5x10^{11} m$ from the pinhole, casts a small upside-down image of itself at a distance $d = 44cm$ from the pinhole.



12. In the case described above, the pinhole has the same effect as a converging lens with a focal length of

(A) 0.44-m (B) 0.88-m (C) $1.5x10^{11} m$ (D) Infinity

13. Knowing that the diameter of our Sun is approximately $1.4x10^6 km$, what is the diameter of the small inverted image?

(A) $4x10^{-3} m$ (B) $4x10^{-2} m$ (C) $0.15cm$ (D) $0.15m$

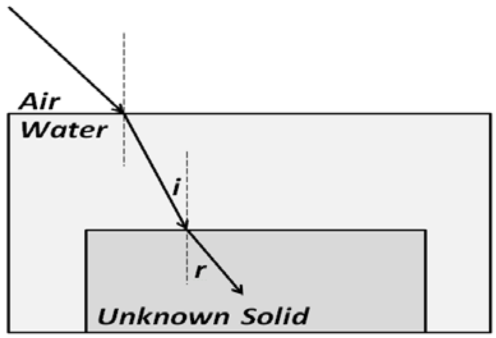
14. Which of the following correctly states the *Lens Maker's Equation*?

(A) $f = \frac{d_o d_i}{d_o - d_i}$ (B) $f = \frac{d_o + d_i}{d_o d_i}$ (C) $f = \frac{d_o d_i}{d_o + d_i}$ (D) $f = \frac{d_o - d_i}{d_o d_i}$

15. You are performing a Young's Double-slit experiment. You observe a specific interference pattern on a screen a distance ***L*** from the slit apparatus. You then double the distance between the slits. In order to maintain the same interference pattern with the same distances between the fringes, how must you change the distance to the screen, ***L***?

(A) $L/2$ (B) $L/\sqrt{2}$ (C) $L\sqrt{2}$ (D) $2L$

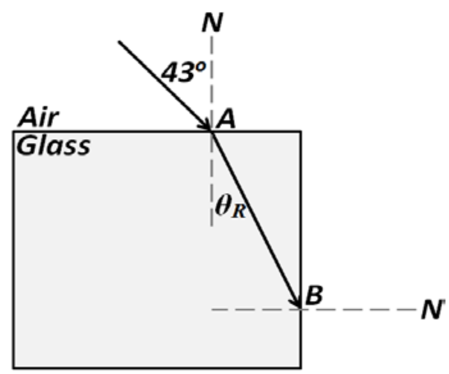
Use the following information for Questions #16 & 17: You are tasked with identifying an unknown transparent solid that your instructor has diabolically placed at the bottom of an aquarium full of water (index of refraction, $n_{water} = 1.33$). You are not permitted to touch the unknown solid. You then shine a laser from above the water surface toward the air-water interface below. After traveling through the water, the angle of incidence at the water/solid interface, labeled ***i***, is measured by your lab partner at 10^o and the angle of refraction, ***r***, into the unknown solid is measured at 15^o. See below.



16. After you complete your calculations, you realize something is terribly wrong. Which of the following is a valid explanation for your "terribly wrong" feeling?
(A) The angle of refraction can never be larger than the angle of incidence.
(B) Your results indicate that the speed of light through the unknown solid is larger than ***c***, the speed of light in a vacuum.
(C) The angle of incidence at this interface indicates total internal reflection, so the light stays in the water.
(D) Your results indicate that the necessary speed of light through the water is appreciably smaller than it should be.

17. Your lab partner suddenly realizes he recorded the angles backwards! The angle of *incidence* is 15^o and the angle of *refraction* is 10^o. Now, what is the correct index of refraction of this unknown liquid?
(A) 0.89 (B) 1.49 (C) 1.98 (D) 2.42

18. As shown below, a monochromatic laser beam held in air is aimed at a block of glass, $n = 1.50$, at an incident angle of 43^o. The beam makes contact with the glass at point ***A***. At what angle does the refracted beam escape the glass back out into air at point ***B***?
(A) 27^o
(B) 25^o
(C) 63^o
(D) It doesn't escape the glass at point ***B***, it reflects back into the glass.



19. A *hollow* lens is made from *very* thin glass as shown below to right. It can be filled with air ($n = 1.0003$), water ($n = 1.33$), or CS_2 (Carbon disulfide, $n = 1.63$). The lens will diverge parallel light beams if it is
(A) filled with CS_2 and immersed in water.
(B) filled with air and immersed in water.
(C) filled with water and immersed in CS_2.
(D) filled with CS_2 and surrounded by CS_2.

20. A shopper at local store glances up and sees his image in the convex spherical covering of a security camera 3-m away from him. His image is $\frac{1}{8}$ his actual size. What is the radius of curvature of this convex covering?

(A) $\frac{3}{8}m$ (B) $\frac{6}{8}m$ (C) $\frac{3}{7}m$ (D) $\frac{6}{7}m$

21. A diffraction grating has 2,000 lines/cm. At what angle will a green laser of 520-nm wavelength produce a second order maximum?

(A) 6^o (B) 12^o (C) 18^o (D) 24^o

22. Followers of science fiction are familiar with antimatter as a source of energy. Examples range from *Star Trek*'s di-lithium crystal antimatter drive to the deadly antimatter vial created by CERN in Dan Brown's *Angels & Demons* novel and 2009 blockbuster movie starring Tom Hanks. When coming in direct contact with regular matter, antimatter and matter annihilate into pure energy. Considering the antimatter vial of *Angels & Demons*, what is the strength of the magnetic field needed to safely contain the antimatter, consisting entirely of anti-protons, within the vial? The anti-protons have the same mass as "regular" protons, but have an opposite (negative) charge. They are confined to move in a 10-cm diameter circle at a speed of $5x10^6\ \frac{m}{s}$ by the magnetic field.

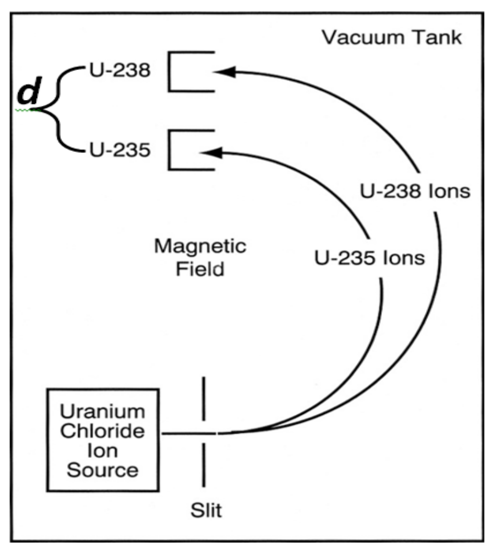
(A) $2.8x10^{-4}T$ (B) 0.52 T (C) 1.04 T (D) $5.04x10^{-4}T$

Use the following information for Questions #23 - 25: As pictured below, a mass spectrometer is used to separate $^{238}_{92}U$ (***U***-238) from the much rarer $^{235}_{92}U$ (***U***-235) used in nuclear power plants. The masses of the ***U***-238 and ***U***-235 ions are $3.90x10^{-25}kg$ and $3.95x10^{-25}kg$, respectively. Triply negatively charged ions are injected from the source into a magnetic field of strength $0.25T$ at a speed of $3x10^5\ \frac{m}{s}$.

23. In what direction is the magnetic field these ions are injected into?
(A) Perpendicularly out of the page.
(B) Perpendicularly into the page.
(C) To the right of the page.
(D) To the left of the page.

24. What is the separation distance, ***d***, from where the ions strike the detector?

(A) 1.25-cm (B) 2.50-cm
(C) 1.25-m (D) 2.50-m



25. If these triply negative ions were replaced with triply *positive* ions, which of the following happens?
(A) Nothing changes.
(B) The ***U***-238 & ***U***-235 switch places on the detector with ***U***-235 on top and ***U***-238 on bottom.
(C) The paths invert; they have the same radii but turn downward with ***U***-235 with the shorter radius.
(D) The paths invert and the ions switch positions; they turn downward with ***U***-235 with the larger radius.

PHYSICS II Golden Rod No Corrections

MARCH 9, 2017

SOLUTIONS

1. D	14. C
2. C	15. D
3. B	16. B
4. A	17. C
5. C	18. D
6. B	19. A
7. C	20. D
8. B	21. B
9. B	22. C
10. D	23. A
11. D	24. B
12. A	25. C
13. A	

PHYSICS II: for all students currently enrolled in AP physics II. 25 multiple choice per exam.
January: Heat & Thermodynamics, Fluid Statics and Dynamics
February: Electrostatics: electric force, fields, & potential, DC Circuits and RC Circuits, plus January Topics
March: Magnetics and Electromagnetic induction, Geometric & Physical optics, plus Jan and Feb Topics
April: Quantum physics, atomic and nuclear physics, plus Jan, Feb and March topics.

Dates for 2017 Season

Thursday March 9, 2017 Thursday April 13, 2017

All areas and schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League

PO Box 65 Stewartsville, NJ 08886-0065

phone # 908-213-8923 fax # 908-213-9391 email: newjsl@ptd.net

Web address: http://entnet.com/~personal/njscil/html/

What is to be mailed back to our office?

PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).

If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season

Thursday January 11, 2018 Thursday February 8, 2018

Thursday March 8, 2018 Thursday April 12, 2018

PHYSICS II **Golden Rod** No Corrections

APRIL, 2017

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. ***Use: g =10 m/s²*****. As prescribed by the College Board for AP Physics, the work done** ***on*** **a system is a** ***positive*** **quantity.**

1. The original atomic clock, built by Louis Essen in 1955 at the National Physical Laboratory in the UK, operated under the natural 9.2-GHz vibrations of Cesium-133, ${}^{55}_{133}Cs$. What is the difference in energy in eV between the allowable energy states that cause this vibration?

(A) $6.1x10^{-24}eV$ (B) $6.1x10^{-5}eV$ (C) $3.8x10^{-24}eV$ (D) $3.8x10^{-5}eV$

2. What is the longest wavelength of electromagnetic radiation that will eject an electron from the surface of a silver sample? The work function of silver is 4.73 eV.

(A) $263nm$ (B) $526nm$ (C) $1052nm$ (D) $2104nm$

3. Ultraviolet radiation of wavelength $120nm$ falls upon your 24-K gold iPhone™ while you are at the beach during Senior Cut Day. Electrons in gold are bound to the atoms with a 4.82eV work function. What is the maximum speed of the ejected photoelectrons?

(A) $8x10^{5}\ m/s$ (B) $1.4x10^{6}\ m/s$ (C) $1.4x10^{7}\ m/s$ (D) $8x10^{7}\ m/s$

Use the following information for Questions #4 & #5: A LASER with power output of $2mW$ shines UV light of wavelength $200nm$ onto the aluminum can surface of soda in your lab room. The work function of aluminum is $4.1eV$. The silver surface is the color of the Al can. No change for the answer.

4. How many electrons are ejected from the silver surface per second?

(A) $2x10^{12}$ (B) $2x10^{15}$ (C) $2x10^{21}$ (D) $2x10^{24}$

5. What power is carried away by the ejected photoelectrons?

(A) $0.34mW$ (B) $0.68mW$ (C) $1.0mW$ (D) $1.4mW$

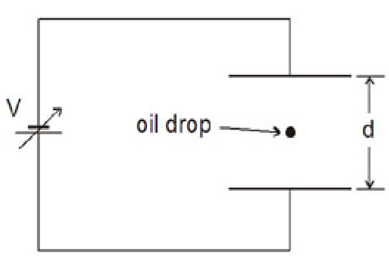
6. Calculate the accelerating voltage of an x-ray tube that produces hard x-rays of wavelength $0.01nm$.

(A) $1.24x10^{-4}V$ (B) $1.24V$ (C) $124V$ (D) $1.24x10^{5}V$

7. In 1911, Ernest Rutherford calculated the diameter of a gold nucleus to be $1x10^{-15}m$. Given the atomic mass of gold to be $197u$, what is the density of the gold nucleus?

(A) $6x10^{-10}\ kg/m^3$ (B) $6x10^{4}\ kg/m^3$ (C) $6.25x10^{10}\ kg/m^3$ (D) $6.25x10^{20}\ kg/m^3$

Use the following information for Questions #8 & #9: In 1909, Robert Millikan and Harvey Fletcher calculated the charge on an electron by performing the famous oil-drop experiment, simplified schematic shown below. Millikan won the 1923 Nobel Prize in Physics while Fletcher won a *Grammy Award* in 2016! Harvey Fletcher is the inventor of stereo sound and was awarded a Grammy last year; 35 years after his death. When the correct voltage is applied to the plates separated by distance *d*, an oil drop can be suspended motionless. When the voltage between the plates is set to $2kV$ and the distance $d = 2cm$, an oil drop with a diameter of $4x10^{-6}m$ is observed suspended. The density of this oil is $0.81\ g/cm^3$



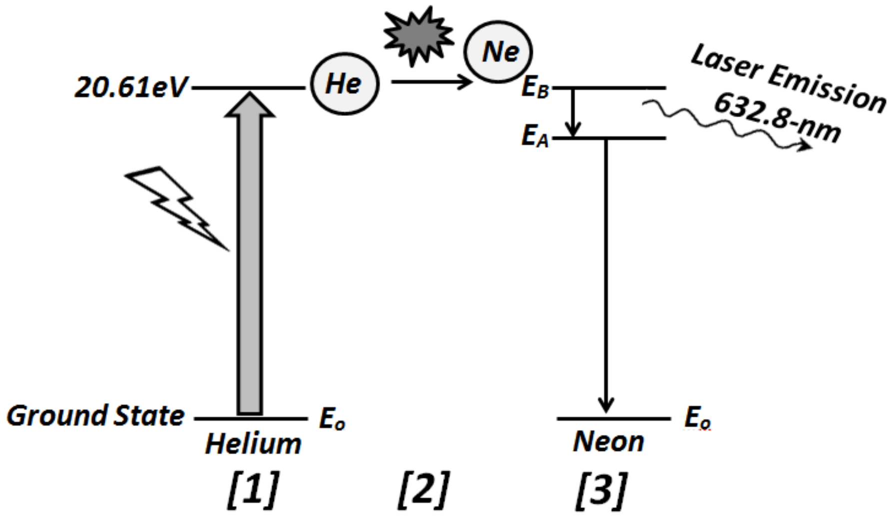
8. What is the magnitude of the electric charge on the oil drop?

(A) $1.6x10^{-18}C$ (B) $2.7x10^{-18}C$

(C) $1.6x10^{-19}C$ (D) $2.7x10^{-19}C$

9. Based on the convention of the symbol in the above diagram for a voltage source, how many electrons is this oil drop deficient or in excess of?
(A) 1 deficient (B) 1 in excess (C) 17 deficient (D) 17 in excess

Use the following information for Questions #10 - #12: The operation of a basic red Helium-Neon (*HeNe*) laser is outlined in three stages in the simplified diagram below. First in Stage ***[1]***, helium atoms are pumped to a higher energy level by electric bombardment; this adds 20.61eV to the helium atoms. Then in Stage ***[2]***, the excited helium atoms physically collide with lower energy neon atoms causing them to become excited. Lastly in Stage ***[3]***, electrons in the excited neon drop energy levels and emit certain photons of light including the familiar red 632.8-nm laser light.



10. In Stage ***[1]***, instead of using electricity, what wavelength photon could be absorbed by a helium atom so it gains the necessary 20.61eV?
(A) 30.1nm (B) 60.2nm (C) 90.3nm (D) 120.4nm

11. In Stage ***[3]***, what is the energy difference in eV between energy levels $\boldsymbol{E_B}$ and $\boldsymbol{E_A}$?
(A) 1.96eV (B) 9.1eV (C) 9.31eV (D) 20.61eV

12. Also in Stage ***[3]***, what frequency photon is emitted as the neon atom drops from $\boldsymbol{E_A}$ to ground state at $\boldsymbol{E_o}$ if $\boldsymbol{E_B}$ is at 20.66eV ?
(A) $4.5x10^{12}\,Hz$ (B) $4.5x10^{15}\,Hz$ (C) $2.8x10^{15}\,Hz$ (D) $2.8x10^{34}\,Hz$

Use the following information for Questions #13 - #15: When a particle of matter and a particle of anti-matter physically meet, they annihilate and produce two equal-energy photons. An electron and a positron (an anti-electron) are each headed straight toward the other each at a speed of $100{,}000\,{}^{m}\!/_{s}$ just before collision.

13. Find the energy of each photon produced by the annihilation of this electron and positron.
(A) 5.12eV (B) 0.512KeV (C) 0.512MeV (D) 0.512GeV

14. Calculate the momentum of each photon produced by this annihilation.

(A) $1.7x10^{-22}\ J\cdot s/m$ (B) $2.7x10^{-22}\ J\cdot s/m$ (C) $1.7x10^{-3}\ J\cdot s/m$ (D) $2.7x10^{-3}\ J\cdot s/m$

15. During the annihilation of matter and anti-matter mentioned in #13, why must the produced photons travel in exactly opposite directions?
(A) Conservation of Energy
(B) Conservation of Matter
(C) Conservation of Momentum
(D) Conservation of Electric Charge

16. Radium-222 ($^{222}_{88}Ra$), a highly radioactive isotope that is considered one of the main radioactive elements that ultimately killed its discoverer, Madam Marie Curie, has been observed very rarely to emit a nucleus of Carbon, $^{14}_{6}C$. The decay equation is $^{222}_{88}Ra \rightarrow X + ^{14}_{6}C$. What is the nuclide 'X'?

(A) $^{222}_{82}Pb$ (B) $^{236}_{82}Pb$ (C) $^{208}_{94}Pb$ (D) $^{208}_{82}Pb$

17. Given that the mass of $^{226}_{88}Ra = 226.025402u$, the mass of $^{222}_{86}Rn = 222.017570u$, and the mass of $^{4}_{2}He = 4.002603u$, find the energy released in the alpha decay of radium into radon; $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$.

(A) $5.3x10^{-3}eV$ (B) $4.87eV$ (C) $4.87MeV$ (D) $7.5GeV$

18. During a recent archeological dig, remains of an ancient campfire was uncovered. The ashes were found to contain just less than $1/1000$ the normal amount of carbon-14, $^{14}_{6}C$. Estimate the minimum age of this campfire noting that the half-life of carbon-14 is 5730 years.
(A) 5,730 years (B) 57,300 years (C) 573,000 years (D) 5,730,000 years

19. $^{238}_{92}U$ is quite abundant naturally and has a very long half-life at 4.5 Billion years. However, $^{235}_{92}U$, needed for nuclear power and weaponry, is less abundant at less than 1% of all Uranium and has a half-life of just over 700,000,000 years. $^{235}_{92}U$ decays through a long process of alpha and beta decays into stable $^{207}_{82}Pb$. Through this process, there are seven alpha releases. How many beta releases are there?
(A) 3 (B) 4 (C) 5 (D) 7

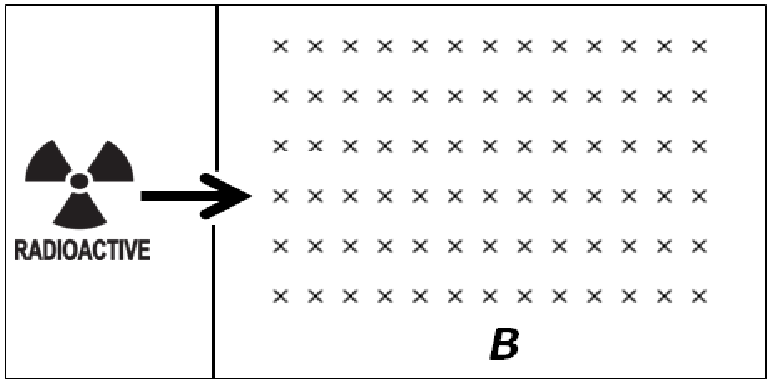
20. Nuclear beta decay, β^{-} , can be simplified by which of the following statements?
(A) A proton decays into a neutron, an electron, and a neutrino.
(B) A proton decays into a neutron, a positron, and an anti-neutrino.
(C) A proton decays into an anti-neutron, an electron, and an anti-neutrino.
(D) A proton decays into a neutron, and electron, and an anti-neutrino.

21. The binding energy of a nucleus of $^{12}_{6}C$ is $92.15MeV$. What is the mass defect?

(A) $0.009215u$ (B) $0.098931u$ (C) $0.98932u$ (D) $0.000921u$

22. Which of the following common quantities is *not necessarily* conserved in nuclear reactions?
(A) Energy (B) Number of nucleons (C) Electric charge (D) Angular momentum

23. As shown below, a radioactive source is placed in a box. There is a small opening to the right through which radiation and emitted particles can escape the box and enter a region where a strong magnetic field is located.



Consider the following nuclear radiations:

I. Alpha emission, α

II. Beta negative emission, β^-

III. Beta positive emission, β^+

IV. Gamma radiation, γ

Which one(s) of the above radiations will make it through the magnetic field *undeflected*?

(A) *I* & *III* only (B) *II* only (C) *II* & *III* only (D) *IV* only

24. The magnetic field mentioned in #22 is now removed and replaced with an electric field. When a beta negative particle, β^-, enters the region from the box, it is deflected outward from the plane of the page toward you. In what direction is the electric field?

(A) Outward from the plane of the page toward you.
(B) Inward from the plane of the page away from you.
(C) Upward toward the top of the page.
(D) Downward toward the bottom of the page.

25. There are two different radioisotopes that can produce the same daughter nucleus after a single nuclear emission. One radioisotope is Thallium-204 used in high-contrast CAT-scans, ${}^{204}_{81}Tl$. Thallium-204 undergoes a single β^- emission. Find the atomic number and atomic mass of the radioisotope that will undergo a single alpha, α , emission and produce the same daughter nucleus as the ${}^{204}_{81}Tl$ does.

	Atomic Number (Z)	***Atomic Mass (A)***
(A)	83	208
(B)	82	204
(C)	84	208
(D)	84	204

AP I and AP 2 PHYSICS FORMULAE Updated 3-22-2017

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27}\,kg$	Fundamental charge	$e = 1.6x10^{-19}\,C$
Electron Mass	$m_e = 9.11x10^{-31}\,kg$	Electron Volt	$1eV = 1.6x10^{-19}\,J$
Avogadro's #	$6.02x10^{23}\,mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11}\,Nm^2/kg^2$
Universal gas constant	$R = 8.31\,J/mol\cdot K$	Speed of Light	$c = 3.00x10^8\,m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23}\,J/K$	Magnetic constant	$k' = 1x10^{-7}\,T\cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27}\,kg = 931\,MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34}\,J\cdot s = 4.14x10^{-15}\,eV\cdot s$ $hc = 1.99x10^{-25}\,J\cdot m = 1240\,eV\cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9\,N\cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12}\,C^2/N\cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2}at^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$U_g = G\frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

Δx = displacement (change of position)

$\bar{v}$ = average velocity

$\bar{a}$ = average acceleration

v_i = initial velocity

v_f = final velocity

F = force

F_f = force of friction

F_N = normal force

F_g = gravitational force

G = Universal Gravitational Constant

ρ = momentum

μ = coefficient of friction

r = distance between center of masses

W = weight

m = mass

U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

C = Capacitance

E = electric field intensity

I = electric current

k = electrostatic constant

P = Power

q = charge

R = resistance

U_E = electric potential Energy

U_C = energy stored in capacitor

V = electric potential difference

W = Work

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = \ldots$

$V_T = V_1 + V_2 + V_3 + \ldots$

$R_T = R_1 + R_2 + R_3 + \ldots$

$C = Q/\Delta V$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + \ldots$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2$

$V_T = V_1 = V_2 = V_3 = \ldots$

$C_{parallel} = \Sigma C_i$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x\cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2}mv^2$

$F = -kx$

$PE_s = \frac{1}{2}kx^2$

h = height

k = spring constant

KE = kinetic energy

PE_g = gravitational potential energy

PE_s = potential energy stored in a spring

P = power

W = work

x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2}I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

a_c = centripetal acceleration

F_c = centripetal force

τ = Torque

I = Rotational Inertia

α = Angular acceleration

ω = Angular velocity

K_{rot} = Rotational KE

x = position

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat
L_f = latent heat of fusion
L_V = latent heat of vaporization
Q = amount of heat
ΔT = change in temperature
α = coefficient of linear expansion
L_o = original length
$c_{water} = 4186 \frac{J}{kg°K}$
K = kinetic energy
L = thickness
U = internal energy
W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum
d = distance between slits
$f = \nu$ = frequency
L = distance from slit to screen
n = index of absolute refraction
T = period
v = speed
x = distance from central maximum to first-order maximum
λ = wavelength
θ = angle
θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length
d_i = image distance
d_o = object distance
h_o = object size
h_i = image size
β = Sound level
I = Sound Intensity
I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_s$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength
I_P = current in primary
I_S = current in secondary
N_P = number of turns in primary coil
N_S = number of turns in secondary coil
V_P = voltage of primary
V_S = voltage of secondary
L = length of conductor
V = electric potential difference
v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho Vg$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area
F = force
h = depth
P = pressure
V = volume
v = speed
y = height
ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

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

$E = mc^2$

E = energy
f = frequency
K = kinetic energy
m = mass
ρ = momentum
λ = wavelength
ϕ = work function

PHYSICS 2 **Golden Rod** No Corrections

APRIL, 2017
SOLUTIONS

1. D	14. B
2. A	15. C
3. B	16. D
4. B	17. C
5. B	18. B
6. D	19. B
7. D	20. D
8. B	21. B
9. C	22. A
10. B	23. D
11. A	24. B
12. B	25. C
13. C	

PHYSICS II: for all students currently enrolled in AP physics II. 25 multiple choice per exam.
January: Heat & Thermodynamics, Fluid Statics and Dynamics
February: Electrostatics: electric force, fields, & potential, DC Circuits and RC Circuits, plus January Topics
March: Magnetics and Electromagnetic induction, Geometric & Physical optics, plus Jan and Feb Topics
April: Quantum physics, atomic and nuclear physics, plus Jan, Feb and March topics.

Dates for 2017 Season
Thursday April 13, 2017
All schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
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phone # 908-213-8923 fax # 908-213-9391 email: **newjsl@ptd.net**
Web address: **http://entnet.com/~personal/njscil/html/**

What is to be mailed back to our office?
PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).
If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season
Thursday January 11, 2018 ***Thursday February 8, 2018***
Thursday March 8, 2018 **Thursday April 12, 2018**