AP2 Exam #3 Chapters 11 - 19 Free-Response Section

DIRECTIONS: Same as all ***FR*** Exams; choose any THREE of the following FIVE problems to turn in for grading. Each problem counts the same (10 pts) regardless of the number of individual steps and/or questions involved.
SHOW ALL WORK AND MAKE REASONING CLEAR. NO CREDIT awarded for "miracles!"

The following information might come in handy.
1. ***Submitting Solutions***: The exam is officially due at 12:45 PM ET FRIDAY 11/06/2015. I'll be in my room with my *hand out* so you can *hand in*. (See what I did there? I crack myself up…) ***GRADE IS A ZERO IF NOT ON TIME***!

A. All forms of submission are considered late if it arrives physically or electronically after 12:45 PM ET FRIDAY 11/06/2015.
B. All electronic submissions must have a SUBJECT akin to "AP2 EXAM #3" or similar.
C. All electronic submissions must include your full name on each and every photo, scan, or other image.
D. All electronic submissions must utilize 100% certified recycled electrons! We only have a limited number of them and they must be preserved at all costs.

2. ***HELP***! Following is my X3 Helpline hours:

6:00 – 7:30 AM Wed – Fri, 11/04 – 11/06/2015
Email anytime…

I am also available any WHITE or GREY Block on my schedule.

AP2 Information & Equation List

ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, 1 eV $= 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^8$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg$\cdot$s^2
Universal gas constant, $R = 8.31$ J/(mol$\cdot$K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}$ kg $= 931$ MeV/c^2
Planck's constant,	$h = 6.63 \times 10^{-34}$ J$\cdot$s $= 4.14 \times 10^{-15}$ eV$\cdot$s
	$hc = 1.99 \times 10^{-25}$ J$\cdot$m $= 1.24 \times 10^3$ eV$\cdot$nm
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N$\cdot$m^2
Coulomb's law constant,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9$ N$\cdot$m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T$\cdot$m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7}$ (T$\cdot$m)/A
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^5$ N/m^2 $= 1.0 \times 10^5$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan\theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.

II. In all situations, positive work is defined as work done <u>on</u> a system.

III. The direction of current is conventional current: the direction in which positive charge would drift.

IV. Assume all batteries and meters are ideal unless otherwise stated.

V. Assume edge effects for the electric field of a parallel plate capacitor unless otherwise stated.

VI. For any isolated electrically charged object, the electric potential is defined as zero at infinite distance from the charged object.

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$|\vec{F}_f| \le \mu|\vec{F}_n|$

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

$\vec{p} = m\vec{v}$

$\Delta\vec{p} = \vec{F}\,\Delta t$

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

$\Delta E = W = F_{\parallel}d = Fd\cos\theta$

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

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$x = A\cos(\omega t) = A\cos(2\pi f t)$

$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$

$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$\tau = r_{\perp}F = rF\sin\theta$

$L = I\omega$

$\Delta L = \tau\,\Delta t$

$K = \frac{1}{2}I\omega^2$

$|\vec{F}_s| = k|\vec{x}|$

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

$\Delta U_g = mg\,\Delta y$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

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

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$|\vec{F}_g| = G\frac{m_1 m_2}{r^2}$

$\vec{g} = \frac{\vec{F}_g}{m}$

$U_G = -\frac{Gm_1 m_2}{r}$

a = acceleration
d = distance
E = energy
F = force
f = frequency
h = height
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
v = speed
W = work done on a system
x = position
α = angular acceleration
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed

ELECTRICITY AND MAGNETISM

$|\vec{F}_E| = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2}$

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

$|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$

$\Delta U_E = q\Delta V$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$|\vec{E}| = \left|\frac{\Delta V}{\Delta r}\right|$

$\Delta V = \frac{Q}{C}$

$C = \kappa\varepsilon_0\frac{A}{d}$

$E = \frac{Q}{\varepsilon_0 A}$

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

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

$R = \frac{\rho\ell}{A}$

$P = I\,\Delta V$

$I = \frac{\Delta V}{R}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = separation
t = time
U = potential (stored) energy
V = electric potential
v = speed
ρ = resistivity
θ = angle
Φ = flux

$\vec{F}_M = q\vec{v} \times \vec{B}$

$|\vec{F}_M| = |q\vec{v}||\sin\theta||\vec{B}|$

$\vec{F}_M = I\vec{\ell} \times \vec{B}$

$|\vec{F}_M| = |I\vec{\ell}||\sin\theta||\vec{B}|$

$\Phi_B = \vec{B}\cdot\vec{A}$

$\Phi_B = |\vec{B}|\cos\theta|\vec{A}|$

$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t}$

$\mathcal{E} = B\ell v$

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

FLUID MECHANICS AND THERMAL PHYSICS

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

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

$P = P_0 + \rho g h$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

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

$PV = nRT = Nk_B T$

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

$W = -P\Delta V$

$\Delta U = Q + W$

A = area
F = force
h = depth
k = thermal conductivity
K = kinetic energy
L = thickness
m = mass
n = number of moles
N = number of molecules
P = pressure
Q = energy transferred to a system by heating
T = temperature
t = time
U = internal energy
V = volume
v = speed
W = work done on a system
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

WAVES AND OPTICS

$\lambda = \frac{v}{f}$

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

$n_1\sin\theta_1 = n_2\sin\theta_2$

$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$

$|M| = \left|\frac{h_i}{h_o}\right| = \left|\frac{s_i}{s_o}\right|$

$\Delta L = m\lambda$

$d\sin\theta = m\lambda$

d = separation
f = frequency or focal length
h = height
L = distance
M = magnification
m = an integer
n = index of refraction
s = distance
v = speed
λ = wavelength
θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2}bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

Rectangular solid
$V = \ell wh$

Cylinder
$V = \pi r^2\ell$
$S = 2\pi r\ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

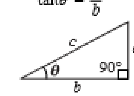
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



1. (10 pts) Everyone knows my sign is negative. That is because I have a large amount of excessive negative charges and I produce a large uniform electric field around me. I have a small plastic sphere suspended from a string that is taped to my nose. The plastic sphere has a mass of 15-g and has a -60×10^{-6}C charge. The string is made of non-conducting insulated massless material and is 50 cm long. Because of the nature of my electric charge and the charge of the sphere, the string hangs at an angle away from my nose once it reaches equilibrium. The electric force on the sphere has a magnitude of 45 ***mN***.

(A) On the smiley sphere below, draw and label the forces acting on the sphere.

(B) Calculate the electric field strength caused by me at the sphere position and clearly state its direction.

(C) Calculate the ***horizontal*** distance the sphere is away from my nose along a normal line to my nose.

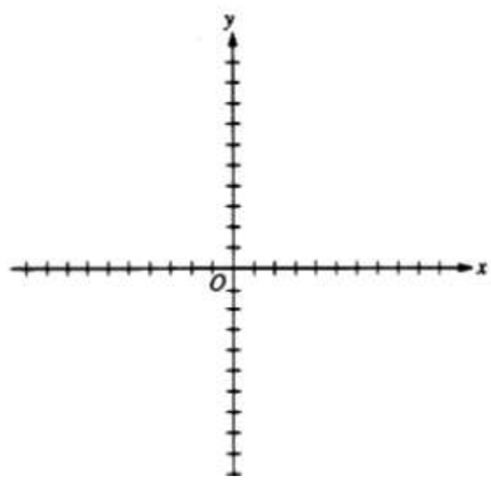
(D) I sneeze and the string breaks. Calculate the acceleration of the sphere after the string breaks and describe completely the path of the sphere till it strikes the ground.

2. (10 pts) There are two point charges on an x-y axis. Q_1 has a magnitude of negative 0.0016 ***C*** and is located on the x-axis at (4,0). Q_2 has magnitude positive 0.0009 ***C*** and is located on the y-axis at (0,3).

(A) Calculate the magnitude of the electric field at the origin of the x-y axis caused by Q_1.

(B) Calculate the magnitude of the electric field at the origin of the x-y axis caused by Q_2.

(C) On the axis below, draw and label the electric field vectors you found in parts (A) & (B) and determine the net electric field strength at the origin.



(D) Another charge, Q_3, of magnitude 0.0004 ***C***, is brought from very far away and placed at the origin. Calculate the magnitude and direction of the net force on Q_3 caused by the other two charges.

3. (10 pts) We did an example just like this one in class. There are two charges. $\boldsymbol{Q_1}$ of magnitude 8 $\boldsymbol{\mu C}$ is located at the zero mark of a number line. $\boldsymbol{Q_2}$, of unknown magnitude, is located 20 cm to the right. The net electric field is zero at a point exactly 20 cm to the right of $\boldsymbol{Q_2}$.

(A) Calculate the magnitude and polarity of $\boldsymbol{Q_2}$.

(B) Calculate the net force acting on $\boldsymbol{Q_1}$.

(C) Determine the electrostatic potential energy of the entire set-up.

(D) Find the position between the two charges where the electric potential is zero.

4. (10 pts) There is a water pump in my neighborhood that a guy runs with an old gasoline engine from a 1965 Mustang. The engine uses 0.0005 kg of fuel each and every second. When gasoline burns, it releases thermal energy at a rate of 4.75×10^7 J/kg.

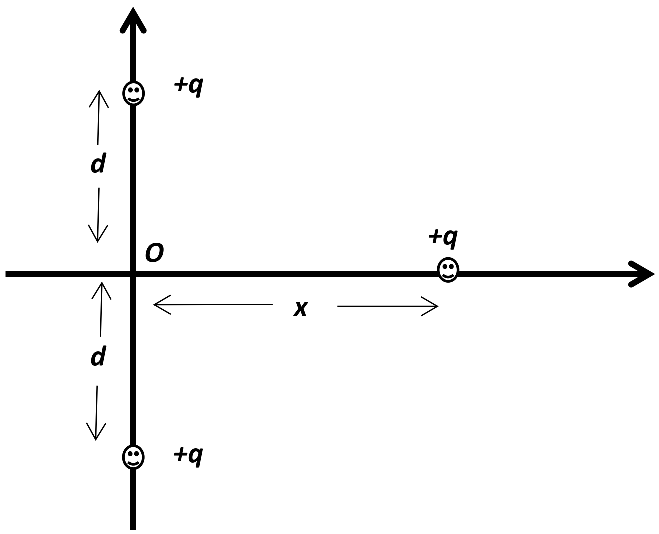
(A) Calculate how much thermal energy is available in 30 seconds.

The efficiency of this Mustang engine is only 18%.

(B) How much work does the engine do in one minute?

(C) How much thermal energy is wasted each minute?

5. (10 pts)



There are two very small charged objects, each with charge ***+q***, located equidistant on the y-axis above; one above the origin and one below. Another charge of identical magnitude is brought in from an infinite distance along the x-axis. This 3rd charge can be moved anywhere along that x-axis. All solutions are to be in terms of the variables provided and any universal physical constants.

(A) Derive an expression for the electric potential energy, ***U***, of the movable 3rd charge as a function of its position on the x-axis.

(B) Calculate the force acting on the movable charge when it is located at the position ***x = d.***

(C) Determine the work done by the electric field_as the charge moves from infinity to the origin.