

Show All Work - Feel Free To Ask Questions
Put All Answers On Answer Sheet - Put Name On Test And Answer Sheet
Please Remain In Your Seat Until 8:50am So As Not To Disturb Others

A Relatively Fast Baseball Game (40 points)

1.) The pitcher throws a blistering fastball to the plate at 0.99 c. With a mighty swing, ex-basketball superstar Michael Jordan smashes the ball 125 m into right field at 0.95 c. He then runs around the bases at 0.92 c (30 m on each side of the square). The outfielder scoops up the ball and throws it back the 125 m to home plate at 0.90 c. Ignoring any times to start or stop or change direction, assuming all velocities are constant and all lines are straight, we want to find out who reaches home plate first: MJ or the ball. The umpire stands behind the catcher at home plate the entire time. (a) From the pitcher's hand to home plate, the fastball sees a distance of 2.8 m. Who sees the proper length: the pitcher or the baseball? Who has the proper time? Why?

(b) The umpire says that the ball took this many seconds for the ball to streak out to right field and then return to homeplate.

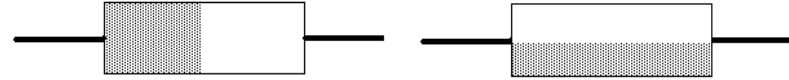
(c) The baseball says that it took this many seconds.

(d) Mike says it took him this many seconds to run around the bases.

(e) The umpire says that it took this many seconds for Mike to run around the bases. Do you think that MJ is safe? Or is he out?

Half a Loaf is Better Than The Other Half of a Loaf (40 points)

2.) A resistor is made half of carbon ($\rho = 60 \times 10^{-5} \Omega \cdot \text{m}$) and half of copper ($\rho = 1.68 \times 10^{-8} \Omega \cdot \text{m}$). Find the resistance of the resistor if it is 5.00 cm (0.0500 m) long and has a diameter of 1.00 cm (0.0100 m) and ...



(a) ... in one case, each material is half the length.

(b) ... the other, the resistor is split in half lengthwise.

(c) What would be the resistivity of the half carbon/half copper wire in part b? Does your answer depend on the diameter of the wire?

A capacitor is made with its gap half filled with dielectric (glass $\kappa = 7$). The capacitor is 5.00 cm \times 5.00 cm (0.0500 m \times 0.0500 m) with a 1.00 cm (0.0100 m) gap. Find the capacitance for the cases where the dielectric fills (d) the bottom half and (e) the left half. Hint: Try making 2 capacitors and connecting them...



The Atoms Family Values II (40 points)

2

He

4.0026

3.) A positive helium ion consists of a single electron in orbit around a nucleus with two protons and two neutrons. The neutron has approximately the same mass as the proton, but has no charge. The two protons are only about 10^{15} m from each other, while the electron is about 10^{10} m from the nucleus.

$$m_p = 1.67 \times 10^{-27} \text{ kg}; m_e = 9.11 \times 10^{-31} \text{ kg}$$

(a) Find F_E between the nucleus and the electron, and also between the two protons. Indicate whether each is attractive (-) or repulsive (+).

(b) Find the radius and energy for the $n = 1$ and $n = 2$ states of the electron according to the Bohr model.

(c) Find the energy and wavelength of the photon for $\Delta n = 1 \rightarrow 2$. Is the photon emitted or absorbed by the electron?

(d) Bohr hypothesized that the angular momentum is quantized: $L = m v r_n = n \hbar = n h/2\pi$. Find the velocities v_1 and v_2 for the $n = 1$ and $n = 2$ electrons.

(e) deBroglie guessed that the electron's orbit must be an integer number of wavelengths around. Find the deBroglie wavelengths λ_1 and λ_2 for the $n = 1$ and $n = 2$ electrons. Compare λ 's with the circumference of the orbits.

Okay, The Gloves are off now; No More Mister Nice Guy... (40 points)

4.) A spherical metal conductor of radius 0.100 m is charged with a hundred billion (100,000,000,000) excess electrons. Find (a) the charge Q on the sphere and (b) the surface charge σ . Of course you remember that all the charge on a conductor is on the surface...

$$\text{Area of a sphere} = 4\pi r^2; \text{ volume of a sphere} = (4/3)\pi r^3$$

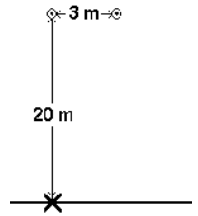
(c) Find the magnitude of the E-field of the sphere at its surface. Does it point in or out? E for the outside of a conducting sphere is the same as for a point charge.

(d) If we zoom in real close to the surface of a sphere, it appears flat. (If you've ever been to Nebraska...) Can the Gauss' Law solution for a flat surface give us the same answer for the E-field as the solution for a sphere? Gauss' Law gave us $E = 2\pi k\sigma$ for the electric field near a thin sheet of charge, but a thick conductor has an inside with $E = 0$, so (trust Dr. Phil on this one), $E = 4\pi k\sigma$. Use this formula to find the magnitude of the electric field near a flat surface with the same σ as the sphere.

(e) Do b and d give the same solution? Why or why not?

Magnetic Field (20 points)

5.) Two parallel wires carry $I = 500$ A each out of the paper. They are 3 m apart and 20 m off the ground. (a) Find the magnetic force, \vec{F}_E , between the two wires. (b) Find the magnetic field, $\mathbf{B}_{\text{TOTAL}}$, due to the two wires at a place on the ground directly below the left wire at the point X.

**Star Trek vs. Gilligan's Island (20 points)**

Still unclear about Modern Physics, Ensign Gilligan asks Scotty about those matter-anti-matter warp engines on the U.S.S. Enterprise. Compare (c) D-D (deuterium-deuterium) fusion with (d) matter-anti-matter annihilation. Anti-deuterium has same mass as regular deuterium, but it is made solely of anti-particles: anti-protons and anti-neutrons. The energy released is the difference in mass between the whole and the sum of the parts, converted into energy using $E = mc^2$. Give answers in MeV.

$$1 \text{ u converts to } 931.5 \text{ MeV} = 931.5 \times 10^6 \text{ eV}$$

${}^1_0\text{n}$	neutron	1.008665 amu	${}^1_1\text{H}$	proton	1.007825 amu
${}^2_1\text{H}$	deuterium	2.014102 amu	${}^4_2\text{He}$	helium	4.002603 amu

