Physics 55
Exam 1
September 17, 2012

Last Name ______________________ First Name ______________________

PUT YOUR NAME ON THE BACK OF THE LAST SHEET OF THIS EXAM

(100 points) Partial credit will be awarded.

Latent Heat of Vaporization of Water: 540 cal/g
Latent Heat of Fusion of Water: 80 cal/g
Specific Heat Capacity of Water: 1.0 cal/g-C
Specific Heat Capacities of Steam and Ice: 0.5 cal/g-C
$k = 9 \times 10^9$ N-m^2/C^2

SHOW ALL WORK. You may work on separate sheets of scratch paper, which will not be turned in, but all the work leading to your answers must be shown on this and the other examination sheets that are turned in.

1. An ideal gas initially at 300 K undergoes an isobaric (constant pressure) expansion at 2500 Pa. The volume increases from 1.00 m^3 to 3.00 m^3. During this expansion 12,500 J of thermal energy (heat) enters the gas.

(a) (10 points) What is the change in the internal energy of the gas, i.e., what is ΔE?

$\Delta E = Q - W$, where W = work done by the gas

$Q = 12{,}500\text{ J}$

$$W = \int_1^3 p\,dV = 2500\int_1^3 dV = 5000\text{ J}$$

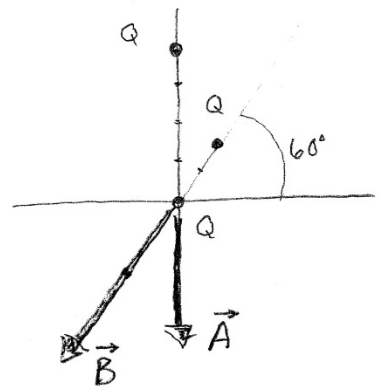
$\Delta E = 7{,}500\text{ J}$

(b) (10 points) What is the final temperature of the gas?

$$P_2 V_2 = nRT_2$$
$$P_1 V_1 = nRT_1$$
$$\div \quad \frac{V_2}{V_1} = \frac{T_2}{T_1}$$

$T_2 = 900\text{ K}$

2. Three identical charges, Q = 4.0 C each, lie in the x-y plane. The locations of the three charges are given in terms of "polar" coordinates (r,θ), where r is the magnitude of the position vector, **r**, that points from the origin to the charge, i.e., r is the distance of the charge from the origin, measured in meters, and θ is the angle the position vector makes with respect to the positive x-axis. One of the charges is at the origin, and the other two are at the polar coordinates (2, 60°) and (4, 90°).



(a) (14 points) What is the magnitude of the total electric force (in newtons) acting on the charge at the origin?

$A = \frac{kQ^2}{4^2}$, $B = \frac{kQ^2}{2^2}$ $A = 9\times10^9\,N$

$B = 36\times10^9\,N$

$\theta_A = 270°$, $\theta_B = 240°$

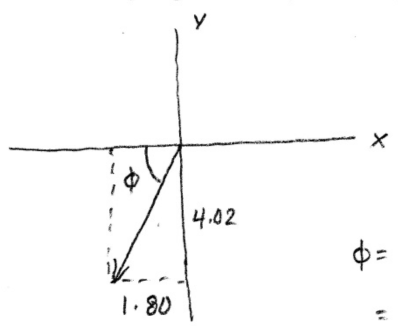
$S_x = A\cos 270 + B\cos 240 = -1.80\times10^{10}\,N$

$S_y = A\sin 270 + B\sin 240 = -4.02\times10^{10}\,N$

$S = (S_x^2 + S_y^2)^{1/2}$

$= 4.40\times10^{10}\,N$

(b) (6 points) What angle in degrees does the total force vector make with respect to the *negative* x-axis, i.e., how many degrees above, or below (state which)?



$\phi = \tan^{-1}\left(\frac{4.02}{1.80}\right)$

$= 65.88°$ below $-x$ axis

3. (20 points) If 70,000 cal of heat are removed from 90 grams of steam at 160 °C, what will remain (steam, water, ice: please state which), and what will be its temperature?

$Q_1 = 90(0.5)60 = 2{,}700$ cal

$Q_2 = 90(540) = 48{,}600$ cal

$Q_3 = 90(1)(100) = 9{,}000$ cal

$Q_4 = 90(80) = 7{,}200$ cal

67,500 cal removed
produces ice at 0°C

2500 more cal:

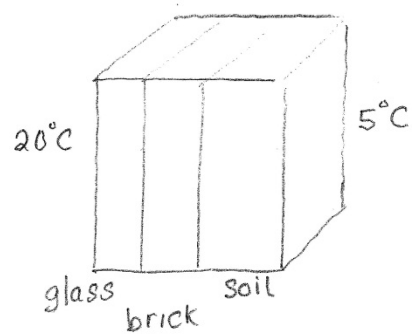
$$\Delta T = \frac{-2500}{90(0.5)} = -55.56\ C^\circ$$

$T = -55.56$°C

4. A wall consists of three layers. The layer on the left side is 2.0 cm of glass (k = 0.8 W/m-C), the middle layer is 3.0 cm of brick (k = 0.9 W/m-C), and the layer on the right side is 5.0 cm of soil (k = 0.5 W/m-C).

On the left side of the wall (left of the glass layer) is air at 20 °C, and on the right side of wall (to the right of the soil layer) is air at 5 °C.

Let **x** be the temperature at equilibrium of the interface between glass and brick, and let **y** be the temperature of the interface between brick and soil.



(a) (14 points) Obtain two equations for **x** and **y**. Simplify each equation so that neither equation contains a fraction.

Heat through glass = Heat through brick

$$\frac{0.8\,A\,(x-20)}{2\times10^{-2}} = \frac{0.9\,A\,(x-y)}{3\times10^{-2}} \Rightarrow \boxed{7x-3y=80}$$

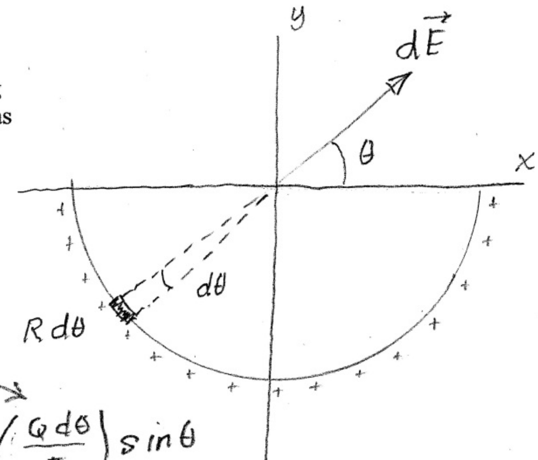
$$\boxed{x = 17.63\,^\circ C}$$

Heat through brick = Heat through soil

$$\frac{0.9\,A\,(x-y)}{3\times10^{-2}} = \frac{0.5\,A\,(y-5)}{5\times10^{-2}} \Rightarrow \boxed{3x-4y=-5}$$

(b) (6 points) Solve for x. See answer above

5. (20 points) A quantity Q of charge is spread along a semicircular (a half circular) arc whose radius is R, as shown in the figure.



(a) (14 points) Obtain an integral expression for the electric field intensity (E) at the origin.

$$\lambda = \frac{Q}{\pi R}$$

$$dQ = \left(\frac{Q}{\pi R}\right) R\,d\theta = \frac{Q}{\pi}\,d\theta$$

$$dE_y = \frac{k\left(\frac{Q\,d\theta}{\pi}\right)\sin\theta}{R^2}$$

$$E_y = \frac{kQ}{\pi R^2}\int_0^{\pi} \sin\theta\,d\theta = \frac{2kQ}{\pi R^2}$$

(x-components cancel)

(b) (6 points) Integrate the expression obtained above to obtain the electric field intensity E in terms of Q, R, and some constants.