

Score

Problem 1: _____ (15 pts)

Problem 2: _____ (15 pts)

Problem 3: _____ (15pts)

Problem 4: _____ (15 pts)

Problem 5: _____ (15 pts)

TOTAL: _____ (75 pts) × 3 multiplier = 225 pts (adjusted)

*To receive full credit, you must show all your work
(including steps taken, calculations and formulas used).*

If you do not wish your test to be placed on the public shelves in the Quiz Return Room, write your name *instead* of your code number at the top of each page. If you choose this option, your test will be held in a locked cabinet in the Quiz Return Room for pick-up with valid identification only.

Quiz Return Room

WLH 2126 (downstairs from the lab)

Mon - Fri, 10 AM - 12:30 PM, 1:00 PM - 2:00 PM

Problem 1 (15 pts)*"Anybody seen my jacket?"*

When you first show up at the after-final party, you notice that there is a Helium balloon with a radius of 18.0 cm. Before the host can actually find a radio station playing music, you hear the weather reporter say that the outside temperature is 74 °F (23 °C). Several hours later, you look up at the same balloon and notice that the radius has now decreased to 10.0 cm.

Assuming that none of the He leaked out, what is the temperature (in °F) outside now?

GIVEN:

$$r_1 = 18.0 \text{ cm}$$

$$r_2 = 10.0 \text{ cm}$$

$$T_1 = 23^\circ\text{C} = 296 \text{ K}$$

$$n_1 = n_2 \quad (\text{since no He leaks out})$$

$$P_1 = P_2 = P_{\text{atm}}$$

SOLUTION:

$$PV = nRT$$

$$\frac{P}{nR} = \text{constant} = \frac{T}{V} \Rightarrow \frac{T_1}{V_1} = \frac{T_2}{V_2}$$

V = volume of sphere

$$V = \frac{4}{3}\pi r^3 \quad \text{or} \quad V \propto r^3$$

$$\Rightarrow T_2 = T_1 \left(\frac{V_2}{V_1} \right) = T_1 \left(\frac{r_2^3}{r_1^3} \right) = T_1 \left(\frac{r_2}{r_1} \right)^3$$

$$T_2 = T_1 \left(\frac{r_2}{r_1} \right)^3$$

$$= (296 \text{ K}) \left(\frac{10.0 \text{ cm}}{18.0 \text{ cm}} \right)^3 = 51 \text{ K} = -222^\circ\text{C}$$

$$\rightarrow T_2 = -222^\circ\text{C}$$

$$T_F = \frac{9}{5} T_C + 32^\circ$$

$$= \frac{9}{5} (-222^\circ) + 32^\circ$$

$$T_2 = -365^\circ\text{F}$$

Problem 2 (15 pts)*"Dark side of the Moon, maybe."*

An environmental Expert and Futurist is claiming during a talk show interview that, "One day, we will have internal combustion engines that are 80% efficient!"

Assuming that these "futuristic" engines operate at an internal temperature of 100 °C (as many do today), at least how low would the outside (environmental) temperature have to be in order for this claim to be true?

Ideal or max. efficiency is given by Carnot efficiency:

$$\eta = 1 - \frac{T_c}{T_H} \quad \text{where } T_c \text{ and } T_H \text{ are the temperatures, in Kelvin, of the hot and cold reservoirs, respectively.}$$

$$\eta = 1 - \frac{T_c}{T_H} = \frac{T_H - T_c}{T_H}$$

$$\eta T_H = T_H - T_c$$

$$T_c = T_H - \eta T_H$$

$$T_c = T_H (1 - \eta)$$

$$T_H = 100^\circ\text{C} = 373\text{K}$$

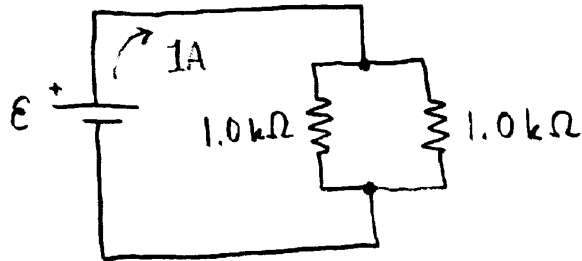
$$\eta = 80\% = 0.8$$

$$T_c = (373\text{K})(1 - 0.8)$$

$$T_c = 75\text{K} \\ = -198^\circ\text{C}$$

Problem 3 (15 pts total) "Hey, nice circuit you have there."

Two resistors are in a circuit with an ideal battery as shown:



(a) If the current supplied by the battery is 1.00 A, what is the *emf* of the battery?

(i.e., What is its ideal voltage?) (9 pts)

The voltage of the battery depends on the current it produces and the load that it faces. In this case, the load consists of the two resistors in parallel whose equivalent resistance is

$$\frac{1}{R_{eq}} = \frac{1}{1k\Omega} + \frac{1}{1k\Omega} = \frac{2}{1k\Omega} \Rightarrow R_{eq} = \frac{1}{2} k\Omega = 0.5 k\Omega$$

$$\Rightarrow \mathcal{E} = IR_{eq} = (1.0A)(0.5 \times 10^3 \Omega) = \boxed{500 V = \mathcal{E}}$$

(b) What power is the battery supplying to the circuit? (6 pts)

$$P = VI = \mathcal{E}I$$

$$= (500V)(1.0A)$$

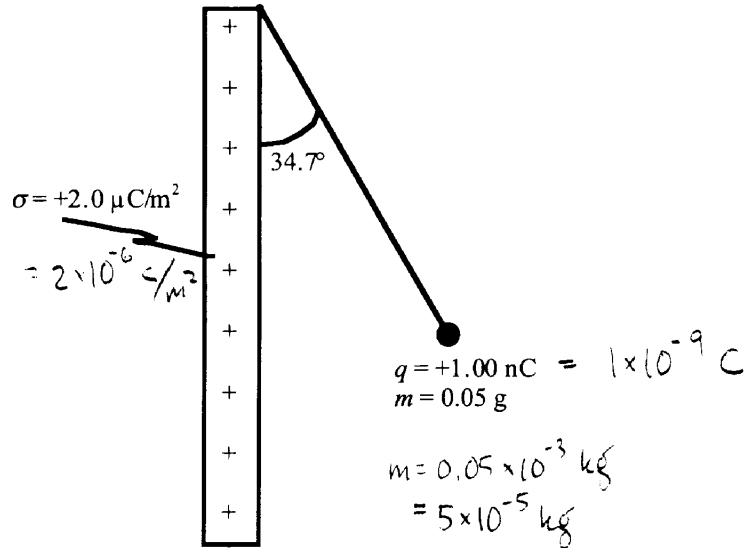
$$\boxed{P = 500 W}$$

Problem 4 (15 pts)

"Lunatics!"

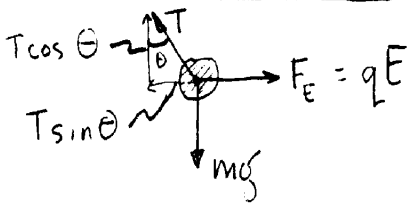
Your friend Luna, who lives on the Moon, is trying to figure out the acceleration due to gravity in her part of the universe. Not surprisingly, you suggest that she try an experiment by hanging a pith ball on a massless string from the top of a large sheet of charge (as shown below). Luna finds that the pith ball hangs at an angle of $\theta = 34.7^\circ$ from the vertical.

*Don't do
quiz question
only were solving
for g.*



What is the acceleration due to gravity on the Moon?

FREE-BODY DIAGRAM



FORCE BALANCE

vertical: $T \cos \theta = mg$

horizontal: $T \sin \theta = qE$

E is electric field due to a large sheet of charge:

$$E = \frac{\sigma}{2\epsilon_0}$$

$$\Rightarrow T \sin \theta = \frac{q\sigma}{2\epsilon_0}$$

SOLVE FOR UNKNOWN

Dividing the horz. equation by the vert. gives

$$\frac{T \sin \theta = \frac{q\sigma}{2\epsilon_0}}{T \cos \theta = mg} \Rightarrow \tan \theta = \frac{q\sigma}{2\epsilon_0 mg}$$

$$\Rightarrow g = \frac{q\sigma}{2\epsilon_0 m \tan \theta}$$

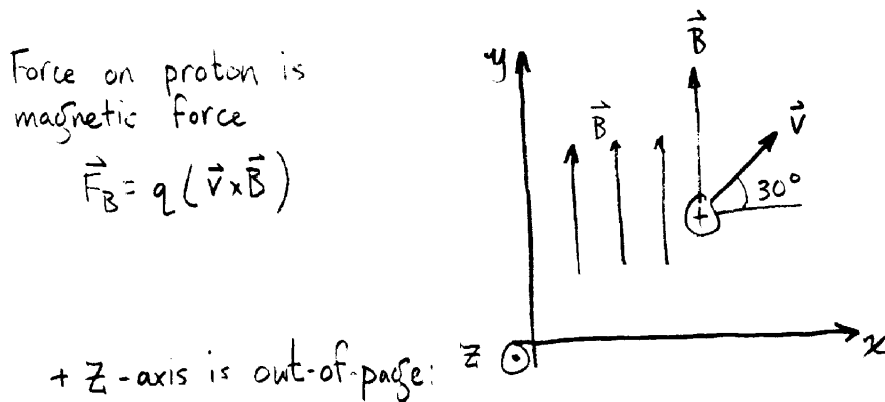
$$g = \frac{(1.00 \times 10^{-9} \text{ C})(2 \times 10^{-6} \text{ C/m}^2)}{2(8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2)(5 \times 10^{-5} \text{ kg}) \tan 34.7^\circ}$$

$$g = 3.26 \text{ m/s}^2$$

Problem 5 (15 pts total) "Someone's bound to ask..."

A proton is moving in the xy -plane with speed $v = 2.00 \times 10^6$ m/s, making an angle of 30° with the $+x$ -axis. There is a uniform B -field of magnitude 2.00 T, directed along the y -axis. Neglect gravitational effects.

(a) In what direction is the force on the proton? Use a diagram to show your answer. (8 pts)



- $\vec{v} \times \vec{B}$ is out-of-page (+z-axis) by right-hand rule.

- Since q is (+), \vec{F}_B is also out-of-page or in the $+\hat{z}$ -direction (along the $+z$ -axis)

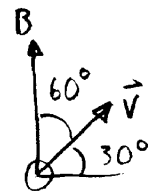
(b) What is the magnitude of the force on the proton? (7 pts)

Magnitude of $\vec{F}_B = q(\vec{v} \times \vec{B})$ is

$$F_B = qvB \sin \theta \quad \text{where } \theta \text{ is the angle between } \vec{v} \text{ and } \vec{B}$$

$$F_B = (1.6 \times 10^{-19} \text{ C})(2 \times 10^6 \text{ m/s})(2.00 \text{ T}) \sin 60^\circ$$

$$F_B = 5.5 \times 10^{-13} \text{ N}$$



Note that the charge of a proton, q , is the same as that of an electron, only positive.

$$q_+ = 1.6 \times 10^{-19} \text{ C}$$