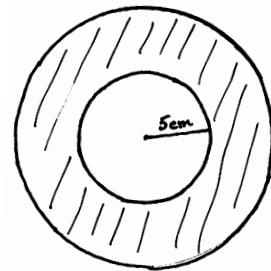


*Millions long for immortality who don't know what to do with themselves
on a rainy Sunday afternoon. –Susan Ertz*

All answers must be accompanied by clear and concise explanations, necessary calculations, and diagrams. Where appropriate, physical units must be included in answers. Partial credit can be earned if correct reasoning is clearly expressed. There is a total of 70 points on the exam.

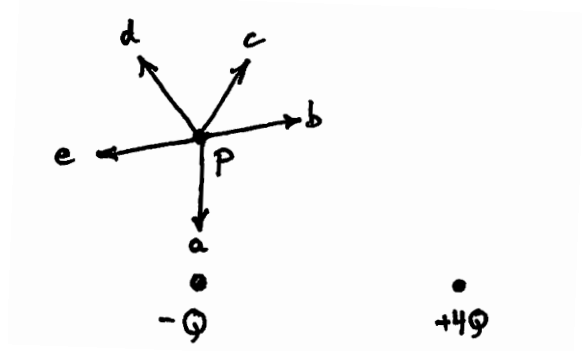
Shorter Answer Questions [worth 5 points each]

- 1 What is temperature?
- 2 Human body temperature is 98.6°F . What is human body temperature in $^{\circ}\text{C}$?
- 3 An aluminum washer with an inner radius of 5cm, initially at room temperature (20°C), is dropped into a container of liquid nitrogen. Does the hole get smaller, larger, or stay the same size? If the hole's radius changes, by how much?



- 4 A hunk of metal that has a mass 25 grams, initially at room temperature (20°C), is dropped into a well-insulated container of liquid nitrogen. 25 grams of liquid nitrogen vaporizes. What is the specific heat of the metal?
- 5 Is it possible for an engine operating between 1500°C and 500°C to have an efficiency of 50%? Explain why or why not (no credit earned without an explanation).

- 6 Circle the letter corresponding to the vector that best describes the electric field caused by the two charges $-Q$ and $+4Q$ at the point labeled P .



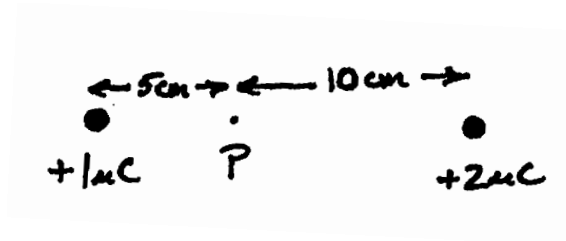
- 7 The size of an atomic nucleus is 10^{-15} m. If two protons are separated by this distance, what is the electrical force on each proton?
- 8 A charge of $-1.5\mu\text{C}$ is placed at a point where the electric field is $9 \times 10^6 \text{N/C}$ pointing East. What are the magnitude and direction of the electric force on the charge?

Longer Answer Questions

- 9** 1 mol of a monatomic ideal gas initially has a volume of $1 \times 10^{-3} \text{ m}^3$ and a pressure of 2 atm. The gas undergoes an isobaric expansion to $3 \times 10^{-3} \text{ m}^3$. This is followed by an isovolumetric reduction in pressure to 1 atm.
- a) Indicate the entire process on the a pV diagram.
 - b) How much work is done? Is the work done *on* or *by* the gas?
 - c) How much does the internal energy change?
 - d) How much heat *enters* or *leaves* the gas?

- 10** 1kg of water, initially at room temperature (20°C) is placed in a freezer unit that has a coefficient of performance of 4.9. The water is converted into ice at 0°C .
- a) How much work is done by the freezer to convert the water into ice?
 - b) How much heat is exhausted from the freezer?
 - c) If the power rating of the freezer unit is 100 Watts, how long will it take for the water to freeze?

- 11 Two charges, $+1\mu\text{C}$ and $+2\mu\text{C}$ are separated by a distance of 15cm , as shown in the diagram below.



- a) Calculate the electric field (direction and magnitude) at the point labeled P , which is 5cm from the $+1\mu\text{C}$ charge and 10cm from the $+2\mu\text{C}$ charge.
- b) If a $-2\mu\text{C}$ charge is placed at the point P , what force (direction and magnitude) does it experience?

$$T_C = \frac{5}{9}(T_F - 32) \quad T_F = \frac{9}{5}T_C + 32 \quad T_K = T_C + 273$$

$$\frac{\Delta L}{L} = \alpha \Delta T \quad pV = nRT \quad R = 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$$Q = mc\Delta T \quad Q = mL \quad P = \frac{W}{t}$$

$$\Delta U = Q - W \quad U = \frac{3}{2}nRT \quad W = \int p dV$$

$$e = \frac{W}{Q_H} \quad \text{for engines} \quad COP = \frac{Q_L}{W} \quad COP = \frac{Q_H}{W}$$

$$Q_H = W + Q_L \quad \frac{Q_L}{Q_H} = \frac{T_L}{T_H}$$

$$e_{th} = 1 - \frac{T_L}{T_H} \quad COP_{th} = \frac{T_H}{T_H - T_L} \quad COP_{th} = \frac{T_H}{T_H - T_L}$$

$$F_E = k \frac{q_1 q_2}{d^2} \quad k = 9 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}$$

$$\mathbf{E} = \frac{\mathbf{F}}{q} \quad E = k \frac{q}{r^2} \quad \mathbf{E}_{net} = \sum \mathbf{E}_i$$

$$\mathbf{F}_q = q\mathbf{E}$$

$$1 \text{ L} = 1 \times 10^{-3} \text{ m}^3$$

$$1 \text{ atm} = 1 \times 10^5 \text{ Pa}$$

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

Boiling Temperature of Liquid Nitrogen = -196°C

TABLE 13-1 Coefficients of Expansion, near 20°C

Material	Coefficient of Linear Expansion, α (C°) ⁻¹	Coefficient of Volume Expansion, β (C°) ⁻¹
<i>Solids</i>		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx 12 \times 10^{-6}$	$\approx 36 \times 10^{-6}$
Marble	$1.4-3.5 \times 10^{-6}$	$4-10 \times 10^{-6}$
<i>Liquids</i>		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
<i>Gases</i>		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

TABLE 14-1 Specific Heats
(at 1 atm constant pressure and 20°C unless otherwise stated)

Substance	Specific Heat, c	
	kcal/kg·C° (= cal/g·C°)	J/kg·C°
Aluminum	0.22	900
Alcohol (ethyl)	0.58	2400
Copper	0.093	390
Glass	0.20	840
Iron or steel	0.11	450
Lead	0.031	130
Marble	0.21	860
Mercury	0.033	140
Silver	0.056	230
Wood	0.4	1700
Water		
Ice (-5°C)	0.50	2100
Liquid (15°C)	1.00	4186
Steam (110°C)	0.48	2010
Human body (average)	0.83	3470
Protein	0.4	1700

Note: Units are kcal/kg and kiloJoules/kilogram

TABLE 14-3 Latent Heats (at 1 atm)

Substance	Melting Point (°C)	Heat of Fusion		Boiling Point (°C)	Heat of Vaporization	
		kcal/kg [†]	kJ/kg		kcal/kg [†]	kJ/kg
Oxygen	-218.8	3.3	14	-183	51	210
Nitrogen	-210.0	6.1	26	-195.8	48	200
Ethyl alcohol	-114	25	104	78	204	850
Ammonia	-77.8	8.0	33	-33.4	33	137
Water	0	79.7	333	100	539	2260
Lead	327	5.9	25	1750	208	870
Silver	961	21	88	2193	558	2300
Iron	1808	69.1	289	3023	1520	6340
Tungsten	3410	44	184	5900	1150	4800

[†]Numerical values in kcal/kg are the same in cal/g.