Name: ______________________________________

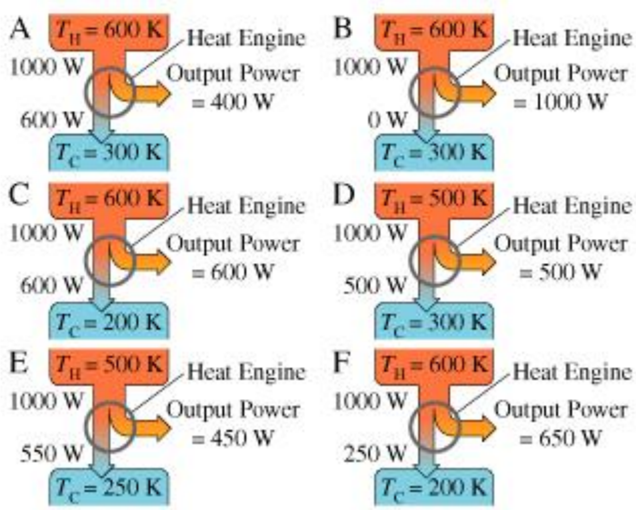
# PHYS 1220-02 Exam 2

Each question counts as one point unless otherwise indicated. (Point values are meaningful only when adding scores within the same standard: each standard counts the same toward your course grade.) You may use an 8.5"×11" note sheet written on both sides and a calculator. Please write your answers in the boxes provided. Show your work outside the boxes. If you need to change the answer you wrote in a box, erase it and write your intended answer. This is easiest if you write in pencil. You have 110 minutes.

Some physical constants you may find useful are

| | | |
|---|---|---|
| Coulomb constant | $k$ | $8.987 \times 10^{9}\,\frac{\text{N}\cdot m^2}{\text{C}^2}$ |
| Vacuum permittivity | $\varepsilon_0$ | $8.854 \times 10^{-12}\,\frac{\text{C}^2}{\text{N}\cdot\text{m}^2}$ |
| Elementary charge | $e$ | $1.602 \times 10^{-19}$ C |

1. The claimed specifications for six heat engines, labeled A–F, are shown in the figure below.




A. (3 points) Which of these engines cannot possibly deliver these specifications because they violate the first law of thermodynamics (conservation of energy)? Select each impossible choice by filling the box next to it.

☐ a. Engine A. ☐ b. Engine B. ☐ c. Engine C.
☐ d. Engine D. ☐ e. Engine E. ☐ f. Engine F.

B. (3 points) Which of the remaining engines (not selected in part A) cannot possibly deliver these specifications because they violate the second law of thermodynamics (entropy does not decrease)? Select each impossible choice by filling the box next to it.

☐ a. Engine A. ☐ b. Engine B. ☐ c. Engine C.
☐ d. Engine D. ☐ e. Engine E. ☐ f. Engine F.

C. (3 points) Which one of the remaining engines (not selected in parts A or B) has the greatest efficiency? Select the one best choice by filling its circle.

○ a. Engine A. ○ b. Engine B. ○ c. Engine C.
○ d. Engine D. ○ e. Engine E. ○ f. Engine F.

2. Refrigerators and heat pumps work by the same principles as heat engines, but they receive work $W$ to operate, absorb heat $Q_c$ from a low-temperature ($T_c$) reservoir, and expel heat $Q_h$ into a high-temperature ($T_h$) reservoir.

A. (3 points) In terms of $Q_h$, $Q_c$, $T_h$, or $T_c$, what is the condition that allows the operation of a refrigerator or heat pump to increase entropy overall?

B. (1 point) In terms of $W$, $Q_h$, or $Q_c$, what is the appropriate performance measure for a heat pump?

C. (1 point) In terms of $W$, $Q_h$, or $Q_c$, what is the appropriate performance measure for a refrigerator?

3. (3 points) Which of the following statements are true? Fill the boxes of all that are true.

☐ a. Electric charge is conserved.

☐ b. A positive charge and a negative charge attract each other.

☐ c. Electric charge is quantized.

☐ d. Two positive charges attract each other.

☐ e. A neutral object contains no charge carriers.

☐ f. Two negative charges repel each other.

4. Particle A, with a charge of $q_A = +700\ \mu C$, is located at (3.0 m, 0). Particle B, with a charge of $q_B = -200\ \mu C$, is located at (0, 12.0 m). The axes are defined in the familiar convention: $\rightarrow = +x$, $\uparrow = +y$.

   A. (2 points) What is the magnitude of the electric force between particles A and B?

   B. (2 points) What is the direction of the force on particle A from particle B? Express in the trigonometric convention, as degrees counterclockwise of the $+x$ axis.

5. (5 points) Which of the following statements are true? Fill the boxes of all that are true.

   ☐ a. Electric field lines and isopotential surfaces are always mutually perpendicular.

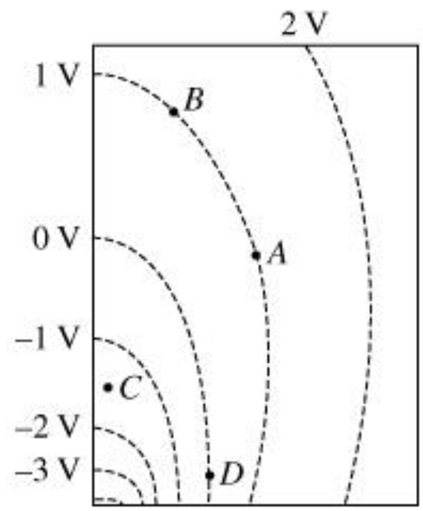
   ☐ b. When all charges are at rest, the surface of a conductor is always an isopotential surface.

   ☐ c. The potential energy of a test charge increases as it moves along an isopotential surface.

   ☐ d. The potential energy of a test charge decreases as it moves along an isopotential surface.

   ☐ e. An isopotential surface is a three-dimensional surface on which the electric potential is the same at every point.

6. Some isopotential surfaces in a region of space are shown as dashed curves in the illustration to the right. Four locations in this space are indicated by the labels *A*–*D*.




   A. (4 points) At which one of these points does the electric field have the greatest magnitude?

   ○ a. A ○ b. B ○ c. C ○ d. D

   B. (4 points) Draw arrows on the illustration to show the direction of the magnetic field at points *A*, *B*, *C*, and *D*.

7. Consider a Gaussian surface that is an imaginary cylinder with a radius of $r = 0.100$ m and a length of $l = 0.400$ m that has an infinite line of positive charge running along its axis. The charge per unit length on the line is uniformly $\lambda = +6.40$ μC/m.

   A. What amount of electric charge is enclosed by the imaginary cylinder?

   B. (2 points) What is the electric flux through the imaginary cylinder? Make certain that your answer has the correct sign.

   C. (2 points) What is the magnitude and direction of the electric field at the tubular face of the cylinder? (The curved surface, not the circular end caps.)

D. What would be the electric flux through the cylinder if its radius were doubled while keeping its length the same?

8. Two opposite charges are placed on the $x$ axis. One charge of $-1.67 \times 10^{-9}$ C is placed at $x = -0.10$ m, and one charge of $+1.67 \times 10^{-9}$ C is placed at $x = +0.10$ m.

A. What is the electric potential on the $x$ axis at $x = +0.20$ m?

B. What is the electric potential on the $x$ axis at $x = -0.20$ m?

C. What is the electric potential on the $x$ axis at $x = 0$?

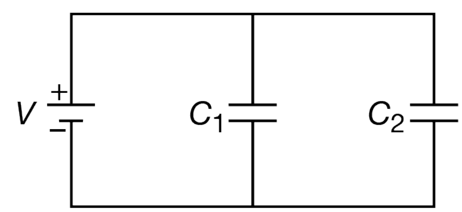
9. A 330-nF capacitor is charged to 50.0 volts.

A. What is the magnitude of charge on the plates of the capacitor?

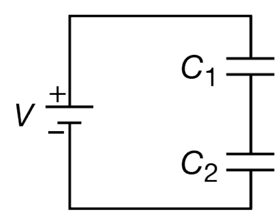
B. How much energy is needed to charge the capacitor to 50.0 volts?

10. A $C_1$ = 330-nF capacitor and a $C_2$ = 110-nF are wired together in circuits with a $V$ = 50.0-volt voltage source.

A. When the capacitors are wired in parallel, what is the charge on the 330-nF capacitor?




B. When the capacitors are wired in series, what is the charge on the 330-nF capacitor?



11. Suppose two parallel-plate capacitors carry the same charge $Q$, but the area of capacitor 1 is $A$ and the area of capacitor 2 is $2A$.

A. Suppose $d$, the spacing between the plates, is the same in both capacitors, and the voltage across capacitor 1 is $V$. What is the voltage across capacitor 2?

○ a. $V/2$ ○ b. $V$ ○ c. $2V$ ○ d. $4V$

B. Suppose the spacing between the plates in capacitor 1 is $d$. What should the spacing between the plates in capacitor 2 be to make the capacitance of the two capacitors equal?

○ a. $d/2$ ○ b. $d$ ○ c. $2d$ ○ d. $4d$

C. Suppose the spacing between the plates in both capacitors is $d$, and the gap between the plates of capacitor 2 is occupied by a vacuum while the gap between the pates of capacitor 1 is occupied by a dielectric material of thickness $d$. What should its dielectric constant be to make the capacitance of the two capacitors equal?

○ a. 1/4 ○ b. 1/2 ○ c. 2 ○ d. 4

12. Mica has a dielectric constant of 4.0 and a dielectric strength of 110 kV/mm.

A. To make a parallel-plate capacitor with a breakdown voltage of 600 volts, how thick would a mica dielectric need to be?

B. What would be the plate area of a 5.00-μF parallel-plate capacitor with a mica dielectric of the thickness of calculated in part A?

C. What would be the magnitude of the electric field inside the dielectric layer of this capacitor when at a voltage of 300 volts?