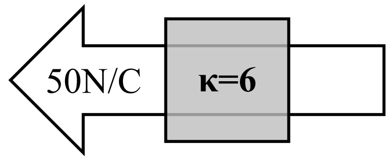
Physics 2140 Sample Exam 3 Solutions

1. Suppose I place a piece of plastic ($\kappa = 6$) in an electric field which points to the left, with a strength of 50 N/C.

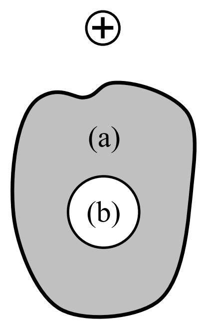


[3] (a) **A** In which direction does the net electric field inside the plastic point?
A) $\leftarrow$ **B)** $\rightarrow$

[3] (b) **B** What is the magnitude of the net electric field inside the plastic?
A) 0.12 N/C **B)** 8.3 N/C **C)** 300 N/C

$$E_{net} = \frac{1}{\kappa}E = \frac{1}{6}(50\,\mathrm{N/C}) = 8.3\,\mathrm{N/C}$$

2. Here is a lump of metal with a large air bubble inside (not visible from the outside). A positive charge is placed above the block as shown.

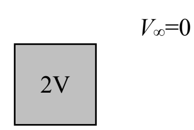


[3] (a) **B** The electric field inside the *metal*
A) points $\uparrow$ **B)** is zero **C)** points $\downarrow$

[3] (b) **B** The electric field inside the *bubble*
A) points $\uparrow$ **B)** is zero **C)** points $\downarrow$

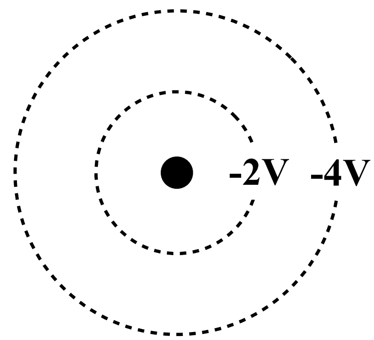
[2] (c) **A** The positive charge is . . . the metal lump.
A) attracted to **B)** repelled by

[3] 3. **A** The potential of a particular metal block is 2 V, if the potential at infinity is $V_\infty = 0$ V. The block is
A) positively charged **B)** neutral **C)** negatively charged
D) the block *can't* have a potential of 2 V



[3] 4. **B** Which is the *higher* potential?
A) -4V **B)** -2V

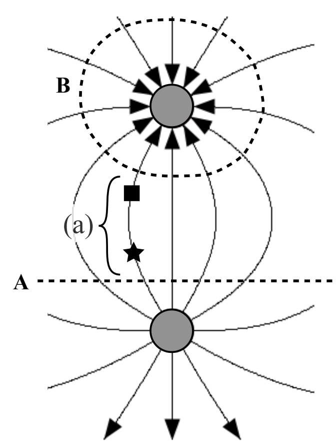
5. The figure shows a charge (the black dot) surrounded by a couple of equipotential surfaces it creates.



3 (a) **A** This charge is
A) positive **B)** neutral **C)** negative

3 (b) **C** If there are no other charges in the universe, then the potential at infinity is
A) positive **B)** zero **C)** negative
D) our choice

6. The figure shows the field lines of a dipole. Two locations are marked with a star and a square.

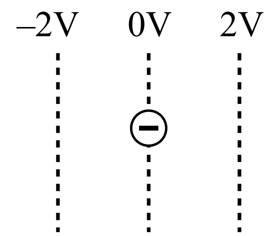


3 (a) **A** At which point is the electric potential V higher?
A) the star **B)** the square
C) both have the same potential

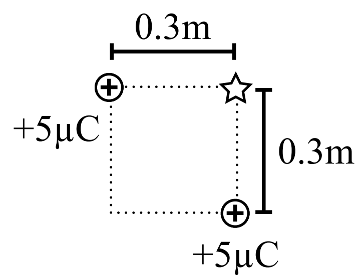
Electric field points downhill

3 (b) **B** Which of the dashed lines is an equipotential line?
A) A (the vertical line) **B)** B (the ovalish line)
C) Both are equipotential lines.

3 7. **B** If I place a negative charge on the zero equipotential line in the figure, what happens next?
A) it starts moving to the left
B) it starts moving to the right
C) it doesn't move at all



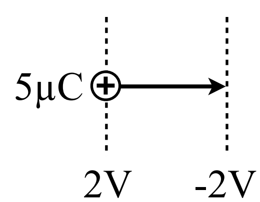
3 8. Two 5×10^{-6} C charges lay on opposite corners of a square with side 0.3 m. If $V_\infty = 0$, what is the electric potential at the star?



$$\begin{aligned} V &= k\frac{q_1}{d_1} + k\frac{q_2}{d_2} + V_\infty \\ &= (9 \times 10^9)\frac{5 \times 10^{-6}}{0.3} + (9 \times 10^9)\frac{5 \times 10^{-6}}{0.3} + 0 \\ &= \boxed{300,000\,\text{V}} \end{aligned}$$

9. A $+5 \times 10^{-6}$ C charge is moved from a 2 V line to a −2 V line.

3 (a) **B** The potential energy of the charge
A) increases **B)** decreases

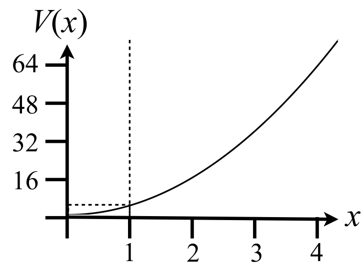


3 (b) **E** What is the magnitude of the change of potential energy, $|\Delta PE|$?
A) 0.4 μJ **B)** 1.25 μJ **C)** 2.5 μJ **D)** 10 μJ **E)** 20 μJ

$$\Delta PE = q\Delta V = (5\,\mu\text{C})((-2\,\text{V}) - 2\,\text{V}) = (5\,\mu\text{C})(-4\,\text{V}) = -20\,\mu\text{J}$$

$$\implies |\Delta PE| = 20\,\mu\text{J}$$

10. The electric potential in a particular region has the functional form $V(x) = 4x^2$. (This would be weird, but go with it.)



3 (a) **B** What direction does the electric field point at $x = 1$?

A) In the $+\hat{x}$ direction **B)** In the $-\hat{x}$ direction
C) The field is zero there

3 (b) **C** What is the magnitude of the electric field at $x = 1$?

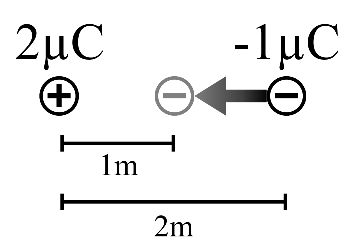
A) 2 N/C **B)** 4 N/C **C)** 8 N/C

$$E_x = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}(4x^2) = -8x|_{x=1} = -8\,\mathrm{N/C}$$

11. A -1×10^{-6} C charge is initially 2 meters from a 2×10^{-6} C charge. It is then moved closer, so that it is 1 meter from the positive charge.

3 (a) **B** The potential energy of the system

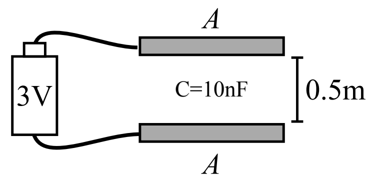
A) increases **B)** decreases



3 (b) Find the change in potential energy ΔPE, including the correct sign.

$$\begin{aligned}
\Delta PE &= PE_f - PE_i \\
&= k\frac{q_s q_t}{d_f} - k\frac{q_s q_t}{d_i} \\
&= (9 \times 10^9)\frac{(2 \times 10^{-6})(-1 \times 10^{-6})}{1} - (9 \times 10^9)\frac{(2 \times 10^{-6})(-1 \times 10^{-6})}{2} \\
&= (-0.018\,\mathrm{J}) - (-0.009\,\mathrm{J}) \\
&= \boxed{-0.009\,\mathrm{J}}
\end{aligned}$$

12. A parallel-plate capacitor has a capacitance of 10 nF, and the plates are 0.05 m apart. The capacitor is connected to a 3 V battery.



3 (a) What is the area of the top plate?

The capacitance is $C = \epsilon_0 \frac{A}{d}$ so the area of the top plate is

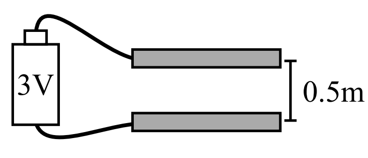
$$A = \frac{Cd}{\epsilon_0} = \frac{(10 \times 10^{-9})(0.05)}{8.85 \times 10^{-12}} = 56.5\,\mathrm{m}^2$$

3 (b) How much charge is on the top plate?

The charge on a capacitor is

$$Q = C\Delta V = (10 \times 10^{-9})(3) = 3 \times 10^{-8}\,\mathrm{V}$$

13. A battery is connected to a parallel-plate capacitor, whose plates are 0.5 m apart. When the voltage supply is set to $\Delta V = 3\,\mathrm{V}$, the top plate has a charge of $6\,\mu\mathrm{C}$.



3 (a) What is the capacitance of the plates?

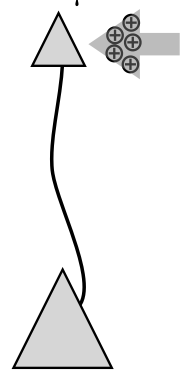
$$C = \frac{Q}{\Delta V} = \frac{6\,\mu\mathrm{C}}{3\,\mathrm{V}} = 2\,\mu\mathrm{F}$$

3 (b) If I move the plates together, so that they're only 0.25 m apart, what is the capacitance?

The capacitance of parallel plates is $C = \epsilon_0 A/d$, so halving the distance between the plates will double the capacitance: $\boxed{4\,\mu\mathrm{F}}$

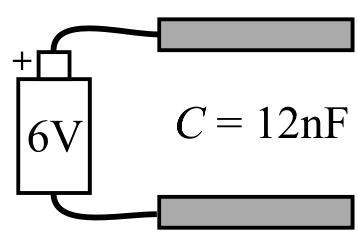
3 14. **C** A metal cone with capacitance $C = 2\,\mu$F is connected by a long metal wire to a metal cone with capacitance $C = 6\,\mu$F. If some positive charge is placed on the smaller cone, charge flows along the wire until

A) all the charge ends up in the large cone.
B) both cones have the same charge Q.
C) both have the same potential V.
D) both have the same surface charge density σ.
E) both have the same volume charge density ρ.
F) None of these: all the charge stays on the small cone.



15. A two-piece capacitor with $C = 12\,$nF is made up of two metal plates, each with area $A = 0.02\,\text{m}^2$. The plates are connected to a 6 V battery as shown.

3 (a) How far apart are the plates?



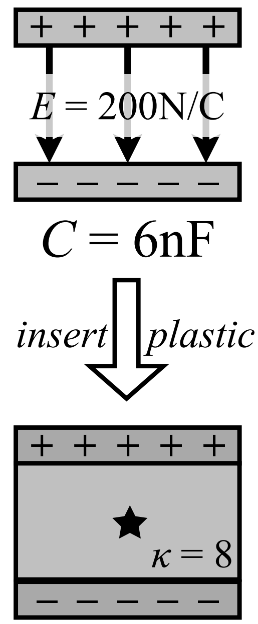
$$C = \epsilon_0 \frac{A}{d} \implies d = \epsilon_0 \frac{A}{C}$$

$$= (8.85 \times 10^{-12}) \frac{0.02}{12 \times 10^{-9}} = \boxed{1.47 \times 10^{-5}\,\text{m}}$$

3 (b) What is the charge on the top plate?

$$Q = C(\Delta V) = (12\,\text{nF})(6\,\text{V}) = \boxed{72\,\text{nC}}$$

16. Consider a parallel-plate capacitor with capacitance 6 nF which holds a charge, so that the electric field between the plates is 200 N/C pointing downward. (Notice: there is no battery connected to the plates.) Then, a piece of plastic with dielectric constant $\kappa = 8$ is slid between the plates. Once the plastic is fully inserted,



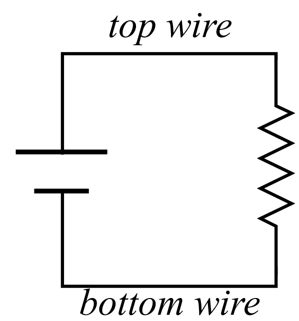
3 (a) **C** the capacitance of the plates is now
A) 0.75 nF **B)** 6 nF **C)** 48 nF **D)** 8 F

3 (b) **D** & the net electric field in the plastic (at the star) is
A) 25 N/C ↑ **B)** 192 N/C ↑ **C)** 200 N/C ↑
D) 25 N/C ↓ **E)** 200 N/C ↓ **F)** 1600 N/C ↓

2 (c) **C** When the plastic is slid between the plates, the potential energy stored in the capacitor
A) increases **B)** stays the same **C)** decreases

Q is constant and $PE = \frac{1}{2}Q^2/C$. C increases by a factor of 8, so the energy decreases by a factor of 8.

17. The figure shows a resistor attached to a battery.



2 (a) **B** The current I through the *resistor*, as usually defined, flows

A) up **B)** down

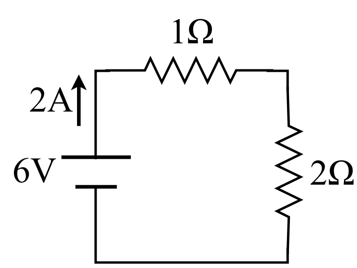
2 (b) **A** The electrons in the resistor are moving

A) up **B)** down

3 (c) **C** Which wire has more current?

A) the top wire **B)** the bottom wire **C)** both wires have the same current

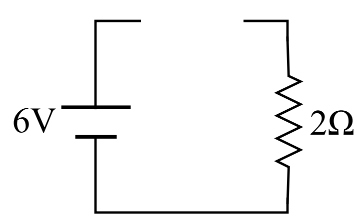
18. In this circuit, the current through the battery is 2 A.



3 (a) **B** What is the potential difference ΔV across the $2\,\Omega$ resistor?

A) 2 V **B)** 4 V **C)** 6 V

$$\Delta V = IR = (2\,\text{A})(2\,\Omega) = 4\,\text{V}$$



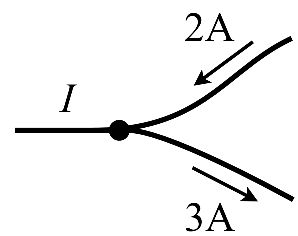
3 (b) **A** Suppose I remove the $1\,\Omega$ resistor, leaving a gap in the circuit. What is the potential difference across the $2\,\Omega$ resistor now?

A) 0 V **B)** 2 V **C)** 4 V **D)** 6 V **E)** ∞ V

$$\Delta V = IR = (0\,\text{A})(2\,\Omega) = 0\,\text{V}$$

3 19. **C** What is the current I in the leftmost wire?

A) 5 A to the left **B)** 1 A to the left
C) 1 A to the right **D)** 5 A to the right



3 20. **C** Compared to a certain wire, which of the following wires has *less* resistance?

A) Wire A, which is made of a material with less conductivity
B) Wire B, which is longer
C) Wire C, which has a larger radius

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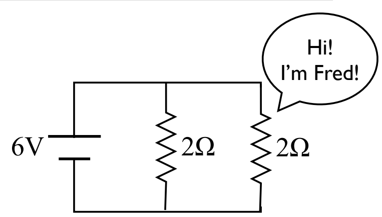
21. In this circuit, the resistor on the right is named "Fred".



3 (a) **C** What is the potential difference across Fred?

A) 1.5 V **B)** 3 V **C)** 6 V **D)** 12 V

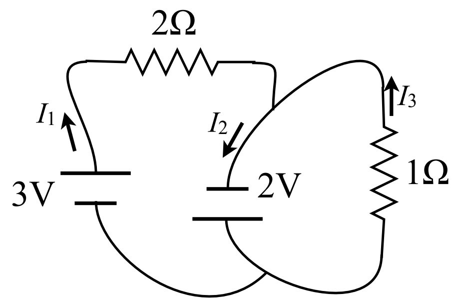
3 (b) What is the current through Fred?

$$\Delta V = IR \implies I = \frac{\Delta V}{R} = \frac{6\,\text{V}}{2\,\Omega} = \boxed{3\,\text{A}}$$

3 (c) How much power is output by Fred?

$$P = \frac{(\Delta V)^2}{R} = \frac{(6\,\text{V})^2}{2\,\Omega} = \boxed{18\,\text{W}}$$

22. In this circuit,



3 (a) **B** Which of the following is true?

A) $I_1 = I_2 + I_3$
B) $I_2 = I_1 + I_3$
C) $I_3 = I_1 + I_2$
D) $I_1 + I_2 + I_3 = 0$

3 (b) Write a loop rule equation. (There are three options.)

$$0 = 3 - 2I_1 + 2$$
$$0 = 2 - 1I_3$$
$$0 = 3 - 2I_1 + 1I_3$$

3 (c) Find the current I_2 through the 2 V battery.

The second loop rule above is

$$0 = 2 - 1I_3 \implies I_3 = 2\,\mathrm{A}$$

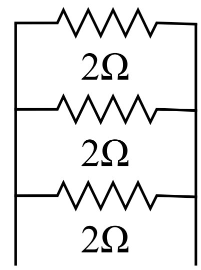
The first loop rule above is

$$0 = 3 - 2I_1 + 2 \implies 2I_1 = 5 \implies I_1 = 2.5\,\mathrm{A}$$

According to (a),

$$I_2 = I_1 + I_3 = 2.5\,\mathrm{A} + 2\,\mathrm{A} = \boxed{4.5\,\mathrm{A}}$$

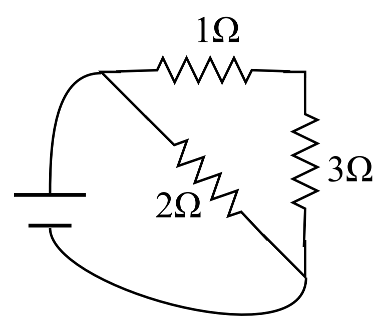
3 23. **B** The effective resistance of three $2\,\Omega$ resistors in parallel is
A) $\frac{1}{3}\,\Omega$ **B)** $\frac{2}{3}\,\Omega$ **C)** $1\,\Omega$ **D)** $\frac{3}{2}\,\Omega$ **E)** $2\,\Omega$ **F)** $6\,\Omega$



The total conductance is $\frac{1}{2}\mho + \frac{1}{2}\mho + \frac{1}{2}\mho = \frac{3}{2}\mho$, for an effective resistance of $\frac{2}{3}\,\Omega$.

24. For the following combinations of resistors,

3 (a) **E** Which of the following is true?
A) The $2\,\Omega$ and $3\,\Omega$ resistors are in parallel.
B) The $1\,\Omega$ and $2\,\Omega$ resistors are in parallel.
C) The $1\,\Omega$ and $3\,\Omega$ resistors are in parallel.
D) All three resistors are in parallel.
E) The $1\,\Omega$ and $3\,\Omega$ resistors are in series.
F) All three resistors are in series.



3 (b) Find the effective resistance of all three resistors via resistance reduction.

Replace the $1\,\Omega$ and $3\,\Omega$ resistors with a $4\,\Omega$ resistor, which is in parallel with the $2\,\Omega$ resistor. The total conductance is then $\frac{1}{4}\mho + \frac{1}{2}\mho = \frac{3}{4}\mho$, for an effective resistance of $\boxed{\frac{4}{3}\,\Omega}$.