If the charge on a given capacitor is doubled, then
   (a) the capacitance doubles.
   (b) the potential difference across the capacitor doubles.
   (c) the permeability of free space doubles.
   (d) the energy stored in the capacitor doubles.
   (e) all of the above.

The **dielectric constant** for a material is
   (a) the factor by which the capacitance decreases when the material is inserted between the plates of a parallel plate capacitor.
   (b) the factor by which the magnitude of the electric field decreases when the material is inserted between the plates of a parallel plate capacitor.
   (c) the factor by which the potential increases when the material is inserted between the plates of a parallel plate capacitor.
   (d) the minimum electric field the material can withstand before dielectric breakdown.
   (e) (a) through (c) the above.

The **dielectric constant** for a material is
   (a) the factor by which the capacitance increases when the material is inserted between the plates of a parallel plate capacitor.
   (b) the factor by which the magnitude of the electric field decreases when the material is inserted between the plates of a parallel plate capacitor.
   (c) the factor by which the potential increases when the material is inserted between the plates of a parallel plate capacitor.
   (d) the maximum electric field the material can withstand before dielectric breakdown.
   (e) (a) through (c) the above.

The **dielectric strength** for a material is
   (a) the factor by which the capacitance increases when the material is inserted between the plates of a parallel plate capacitor.
   (b) the factor by which the magnitude of the electric field decreases when the material is inserted between the plates of a parallel plate capacitor.
   (c) the factor by which the potential decreases when the material is inserted between the plates of a parallel plate capacitor.
   (d) the maximum electric field the material can withstand before dielectric breakdown.
   (e) (a) through (c) the above.

A parallel plate capacitor is charged by being connected to a battery and is then disconnected from the battery. The separation between the plates is then doubled. The electric field strength between the plates
   (a) doubles.
   (b) stays the same.
   (c) is reduced by a factor of one-half.
   (d) is reduced by a factor of one-quarter.
   (e) becomes zero as soon as the capacitor is disconnected from the battery.
A parallel plate capacitor is charged by being connected to a battery. It remains connected to the battery as the separation between the plates is then doubled. The charge on the capacitor
(a) doubles.
(b) stays the same.
(c) is reduced by a factor of one-half.
(d) is reduced by a factor of one-quarter.
(e) becomes zero as soon as the capacitor is disconnected from the battery.

A parallel plate capacitor is charged by being connected to a battery, and while remaining connected to the battery a dielectric ($K = 3$) insulating material is placed between the plates of the capacitor. As a result of inserting the dielectric, the charge on the capacitor
(a) increases.
(b) decreases.
(c) stays the same.
(d) reverses sign.
(e) becomes zero as soon as the dielectric is inserted.

The effective capacitance of two capacitors connected in series is
(a) always less than the individual capacitance of either of the two capacitors.
(b) always greater than the individual capacitance of either of the two capacitors.
(c) always between than the individual capacitances of the two capacitors.
(d) none of the above always holds.

The effective capacitance of two capacitors connected in parallel is
(a) always less than the individual capacitance of either of the two capacitors.
(b) always greater than the individual capacitance of either of the two capacitors.
(c) always between than the individual capacitances of the two capacitors.
(d) none of the above always holds.

A solid slab of conductor is placed between the plates of a parallel plate capacitor (without touching either plate) as shown. The slab has the same area as the capacitor plates. The effective capacitance of the device
(a) increases.
(b) decreases.
(c) stays the same.
(d) changes unpredictably.

The principles used to derive the expressions for equivalent capacitances of series and parallel combinations of capacitors were
(a) conservation of energy and conservation of momentum.
(b) conservation of energy and conservation of charge.
(c) conservation of charge and conservation of momentum.
(d) symmetry and conservation of energy.
(e) no principles are required as the necessary equations can be found in the chapter summary.
The principles used to derive the expressions for equivalent resistance of series and parallel combinations of resistors were
(a) conservation of energy and conservation of momentum.
(b) conservation of energy and conservation of charge.
(c) conservation of charge and conservation of momentum.
(d) symmetry and conservation of energy.
(e) no principles are required as the necessary equations can be found in the chapter summary.

Two wires of different diameters but made of the same material are joined end to end. When the current flows in the wire, electrons move from the wire of larger diameter into the wire with smaller diameter. As the electrons pass through this junction, their drift speed
(a) increases.
(b) remains fixed.
(c) decreases.
(d) goes to zero.
(e) may change, but more information is required to determine the change.

Two wires of different metallic conductors with the same diameters are joined end to end. When the current flows through the wires electrons move from the wire with lower resistivity into the wire with higher resistivity. As the electrons pass through this junction,
(a) the electron drift speed increases.
(b) the electron drift speed decreases.
(c) the electron number density increases.
(d) the electron number density decreases.
(e) either (b) or (d) or both.

Kirchhoff’s loop rule is essentially a statement of
(a) conservation of charge.
(b) conservation of momentum
(c) conservation of energy
(d) conservation of angular momentum
(e) none of the above.

Kirchhoff’s junction rule (or point rule) is essentially a statement of
(a) conservation of charge.
(b) conservation of momentum
(c) conservation of energy
(d) conservation of angular momentum
(e) none of the above.

Since the resistance of a human body can be as low as 1000Ω and a current of .1A can be fatal, a safety mechanism can be designed into a high-voltage power supply by
(a) having a low internal resistance which will maximize the current delivered.
(b) having a 1000Ω to maximize the power delivered.
(c) having a high internal resistance to limit the maximum current which could be delivered.
(d) having a low EMF to limit the maximum current which could be delivered.
A physics professor with a body resistance of 10kΩ accidentally grips the terminals of a 10kV power supply which has an internal resistance of 10kΩ. If a potentially lethal shock occurs when the current exceeds 100mA, then the professor
(a) is in need of a call to 911, since the current is well in excess of 100 mA.
(b) may be in need of a call to 911, since the current is about 100 mA.
(c) is swearing loudly but is largely unharmed because the current was well below 100 mA.
(d) is vaporized since 10kV exceeds his dielectric strength.
(e) trick question, my physics professor would never do such thing (do not pick this answer, it is for humor purposes only!).

A physics professor with a body resistance of 10kΩ accidentally grips the terminals of a 10kV power supply which has an internal resistance of 10MΩ. If a potentially lethal shock occurs when the current exceeds 100mA, then the professor
(a) is in need of a call to 911, since the current is well in excess of 100 mA.
(b) may be in need of a call to 911, since the current is about 100 mA.
(c) is swearing loudly but is largely unharmed because the current was well below 100 mA.
(d) is vaporized since 10kV exceeds his dielectric strength.
(e) trick question, my physics professor would never do such thing (do not pick this answer, it is for humor purposes only!).

The potential difference between the terminals of a real battery (emf $E$, internal resistance $r$) can be exactly the same as the emf in magnitude and polarity if
(a) the battery is shorted out (zero load resistance).
(b) there is an infinite load resistance (open circuit).
(c) the battery is being charged by an external source.
(d) an external source helps drive a large current through the battery in the direction it would naturally discharge.
(e) never.

The potential difference between the terminals of a real battery (emf $E$ internal resistance $r$) can have the opposite polarity (direction) of the emf if
(a) the battery is shorted out (zero load resistance).
(b) there is an infinite load resistance.
(c) the battery is being charged by an external source.
(d) an external source helps drive a large current through the battery in the direction it would naturally discharge.
(e) never.

The current-voltage characteristics at right indicate a device whose resistance is
(a) increasing with increasing current.
(b) remaining constant.
(c) decreasing with increasing current.
(d) changing uncontrollable with increasing current.
(e) none of the above.
Physics 212 Sample Question Bank II

The current-voltage characteristics at right indicate a device whose resistance is
(a) increasing with increasing current.
(b) remaining constant.
(c) decreasing with increasing current.
(d) changing uncontrollable with increasing current.
(e) none of the above.

A real battery delivers maximum power when
(a) the load resistance is zero.
(b) the load resistance matches the internal resistance of the battery.
(c) the load resistance is infinite.
(d) the power is the same regardless of the load resistance.
(e) none of the above.

A real battery delivers maximum current when
(a) the load resistance is zero.
(b) the load resistance matches the internal resistance of the battery.
(c) the load resistance is infinite.
(d) the current is the same regardless of the load resistance.
(e) none of the above.

A real battery has a maximum terminal voltage when
(a) the load resistance is zero.
(b) the load resistance matches the internal resistance of the battery.
(c) the load resistance is infinite.
(d) the terminal voltage is the same regardless of the load resistance.
(e) none of the above.

Two wires of different metallic conductors with the same diameters are joined end to end. As the current from the wire with lower resistivity into the wire with higher resistivity,
(a) the current decreases.
(b) the current density decreases.
(c) the electric field decreases.
(d) the electric field increases.
(e) the electrons stop moving.

The effective resistance of two resistors connected in parallel is
(a) always less than the individual resistance of either of the two resistors.
(b) always greater than the individual resistance of either of the two resistors.
(c) always between the individual resistance of the two resistors.
(d) always less than the individual resistance of either of the two resistors.
(e) none of the above always holds.
The effective resistance of two resistors connected in series is
(a) always less than the individual resistance of either of the two resistors .
(b) always greater than the individual resistance of either of the two resistors .
(c) always between than the individual resistance of the two resistors .
(d) always less than the individual resistance of either of the two resistors .
(e) none of the above always holds.

Two identical light bulbs are connected in series to an ideal battery as shown. In this configuration
(a) Bulb A will glow brighter than Bulb B.
(b) Bulb B will glow brighter than Bulb A.
(c) Only Bulb A will glow.
(d) Only Bulb B will glow.
(e) both bulbs will glow equally bright.

The principles used to to analyze electrical circuits in the last three chapters were
(a) conservation of energy and conservation of momentum.
(b) conservation of charge and conservation of momentum.
(c) symmetry and conservation of energy.
(d) conservation of energy and conservation of charge.
(e) all of the above.

Ideal voltmeters and ideal ammeters have resistances which are
(a) both zero.
(b) both infinite.
(c) zero and infinite, respectively.
(d) infinite and zero, respectively.
(e) none of the above.

An ammeter is a measurement apparatus which
(a) is used to measure the voltage across a device by placing the meter in series with the device. Ideally it has infinite resistance.
(b) is used to measure the current through a device by placing the meter in parallel with the device. Ideally it has infinite resistance.
(c) is used to measure the current through a device by placing the meter in series with the device. Ideally it has zero resistance.
(d) is used to measure the voltage across a device by placing the meter in parallel with the device. Ideally it has infinite resistance.
(e) is used to measure the resistance of a device by placing the meter in parallel with the device. Ideally it has matching resistance.
An **voltmeter** is a measurement apparatus which

(a) is used to measure the voltage across a device by placing the meter in series with the device. Ideally it has infinite resistance.

(b) is used to measure the current through a device by placing the meter in parallel with the device. Ideally it has infinite resistance.

(c) is used to measure the current through a device by placing the meter in series with the device. Ideally it has zero resistance.

(d) is used to measure the voltage across a device by placing the meter in parallel with the device. Ideally it has infinite resistance.

(e) is used to measure the resistance of a device by placing the meter in parallel with the device. Ideally it has matching resistance.

The current versus voltage graph which best represents a device which obeys Ohm's Law:

(A) ![Graph A](image)

(B) ![Graph B](image)

(C) ![Graph C](image)

(D) ![Graph D](image)

(E) none of the above.
A series RC circuit with an initially uncharged capacitor is connected as shown. The switch is closed at \( t=0 \). Which graph below best describes current through the resistor as a function of time?
A series RC circuit with an initially charged capacitor is connected as shown. The switch is closed at \( t=0 \). Which graph below best describes the current as a function of time?

(A)  
(B)  
(C)  
(D)  
(E) none of the above.

A capacitor and a resistor are connected in series across the terminals of a battery. If the capacitance is increased, then

- (a) the final charge on the capacitor is increased.
- (b) the final charge on the capacitor is decreased.
- (c) the final charge on the capacitor is the same, but the capacitor charges more slowly.
- (d) both (a) and (c) above.
- (e) both (b) and (c) above.

A capacitor and a resistor are connected in series across the terminals of a battery. If the resistance is increased, then

- (a) the final charge on the capacitor is increased.
- (b) the final charge on the capacitor is decreased.
- (c) the final charge on the capacitor is the same, but the capacitor charges more slowly.
- (d) the final charge on the capacitor is the same, but the capacitor charges more quickly.
A 4 μF capacitor is connected in series with a 2.5 kΩ resistor. The time constant of this combination is
(a) 1. x 10^2 s.
(b) 1. x 10^-5 s.
(c) 1. x 10^-2 s.
(d) 1. x 10^1 s.
(e) none of the above.
**For the diagram shown below**

a) Calculate the equivalent capacitance of the capacitor network, and the energy stored in the equivalent capacitance.

b) Calculate the charge on each capacitor, the potential difference across each capacitor and the energy stored in each capacitor.

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**For the diagram shown below**

a) Calculate the equivalent capacitance of the capacitor network, and the energy stored in the equivalent capacitance.

b) Calculate the charge on each capacitor, the potential difference across each capacitor and the energy stored in each capacitor.

---

A capacitor with plates of area $A$ and separation $d$ is completely filled with a “leaky” dielectric with dielectric constant $K$ and resistivity $\rho$. When the capacitor has a charge $Q$, there is a leakage current $I$.

(a) Determine the resistance of the dielectric slab in terms of the parameters listed above.

(b) Determine the capacitance of the capacitor in terms of the parameters listed above.

(c) Determine the voltage across the capacitor in terms of the parameters listed above.

(d) The voltage across the capacitor drives the leakage current through the dielectric. Express the current in terms of the parameters listed above.

(e) What is the RC time constant of this combination of resistor and capacitor? (expressed in terms of the parameters listed above)
An air parallel plate capacitor is to be made using plates that are each 0.025 m² in area. Their initial separation is 0.050 cm. They are charged with a 12.0 V source which is then disconnected.

a) What is the original capacitance of the capacitor?
b) What is the charge on the capacitor?
c) What is the initial energy stored in the capacitor?

The separation between the plates is increased to 0.100 cm.

c) What is the new capacitance of the capacitor?
d) What is the new energy stored in the capacitor?
e) How much mechanical work went into increasing the separation between the plates?

A parallel plate capacitor is to be made using a material whose who dielectric constant is 4.7 and whose dielectric strength is $1 \times 10^7$ V/m. The capacitor is to have a capacitance of 500 nF, and must withstand a potential difference 1000 V with suffering dielectric breakdown.

a) What is the minimum separation between the plates of the capacitor?
b) Using this minimum separation, determine the area of each plate for the design capacitance.

If this capacitor has 500 V applied, determine

c) the charge on the capacitor,
d) the electric field between the plates, and
e) the energy stored in the capacitor.

A parallel-plate capacitor is to be constructed using a dielectric material which has a dielectric constant of 3.4 and a dielectric strength of $2.00 \times 10^7$ V/m. The capacitor is to have a capacitance of 2 nF and must withstand a potential differences up to 6000V.

(a) Determine the minimum separation (d) between the plates by taking the strength (E) of the uniform electric field between the plates to be equal to the dielectric strength of the material when the applied potential ($V_{ab}$) is equal to the design maximum (6000V).

(b) Determine the area of each plate if the capacitor has the design capacitance and a plate separation as determined in part (a). (Remember to account for the dielectric constant in your calculation).
Physics 212 Sample Question Bank II 2006

An air parallel plate capacitor is to be made using plates of area $A$. Their initial separation is given as $x$. The capacitor is charged with a charge $Q$ and then disconnected from its charging battery.

a) What is the capacitance of the capacitor in terms of the parameters given?
b) What is the energy stored in this capacitor in terms of the parameters given?
c) From mechanics we learned that the relationship between the force on an object and its potential energy was

$$F(x) = -\frac{dU(x)}{dx}.$$  

Use this relation to find an expression for the force between the plates of a charged parallel plate capacitor in terms of the parameters given.

Suppose a capacitor has plates each of area $.02 \text{ m}^2$ separated by a distance of $4.00 \text{ mm}$, which is charged by a $10 \text{ V}$ battery.

d) what is the capacitance of this capacitor?
e) what is the charge on this capacitor?
f) using your results (including your answer to part c) determine the force of attraction between the plates of this capacitor.

A resistor is made of a cylinder of graphite $2 \text{ cm}$ long and $.2 \text{ cm}$ in diameter. At $20^\circ \text{C}$ graphite has a resistivity of $3.5 \text{E-5 } \Omega \cdot \text{m}$ and a temperature coefficient of resistivity of $-.0005 (\text{C})^{-1}$.

(a) What is the resistance of the resistor at $20^\circ \text{C}$?
(b) What would be the resistance at $250^\circ \text{C}$?
(c) At what temperature would the resistance be $0.25\%$ higher than at $20^\circ \text{C}$?

For the diagram shown at right

a) Calculate the equivalent resistance of the resistor network, and the power dissipated in the equivalent resistance.
b) Calculate the current through each resistor, the power dissipated in each resistor, and the potential difference across each resistor.

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For the diagram at right, determine six currents indicated. Clearly indicates the loops and junctions you are using for your application of Kirchoff’s rules on the diagram. Clearly write the loop and junction equations you generate. Use your calculator to solve these simultaneous equations. Hint: to find the 6 unknown currents will require 6 equations. In this case, 3 loops and 3 junctions will likely work.

**Bonus** (3 points) what is the effective resistance of the network (look at the net current drawn by the network and the battery’s voltage). (must be correct value to get any points)

Warning: there are no serial or parallel combinations in this problem.

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For the diagram, determine the five currents indicated. Clearly indicates the loops and junctions you are using for your application of Kirchoff’s rules on the diagram. Clearly write the loop and junction equations you generate. Use your calculator to solve these simultaneous equations. Hint: to find the 5 unknown currents will require 5 equations. Each current must appear in at least one junction rule, and each branch must appear in at least one loop rule. 2 junction rules and 3 branch rules will most likely work.

Warning: there are no serial or parallel combinations of resistors in this problem.
For the diagram at right, determine six currents indicated. Clearly indicates the loops and junctions you are using for your application of Kirchoff’s rules on the diagram. Clearly write the loop and junction equations you generate. Use your calculator to solve these simultaneous equations. Hint: to find the 4 unknown currents will require 4 equations. In this case, 3 loops and 1 junction will likely work.

Warning: there are no serial or parallel combinations of resistors in this problem.

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A real battery has an EMF of $\varepsilon=15V$ and an internal resistance of $r=5\Omega$. A load resistance $R$ is placed across the terminals of the battery. The current in the circuit is 1A.

A) Find the load resistance.
B) Determine the power delivered to the load resistance.
C) Determine the power dissipated in the internal resistance.
D) Determine the total power delivered by the EMF.

The battery is now disconnected from the load, and is charged by a 1 A charging current.

E) Determine the power delivered to the EMF.
F) Determine the power dissipated in the internal resistance.
G) Determine the total power delivered by the 1A charging current.
H) Calculate the efficiency of the battery as a storage device by taking the ratio of the power delivered (answer B) to the power used in storage (answer G) x 100%.