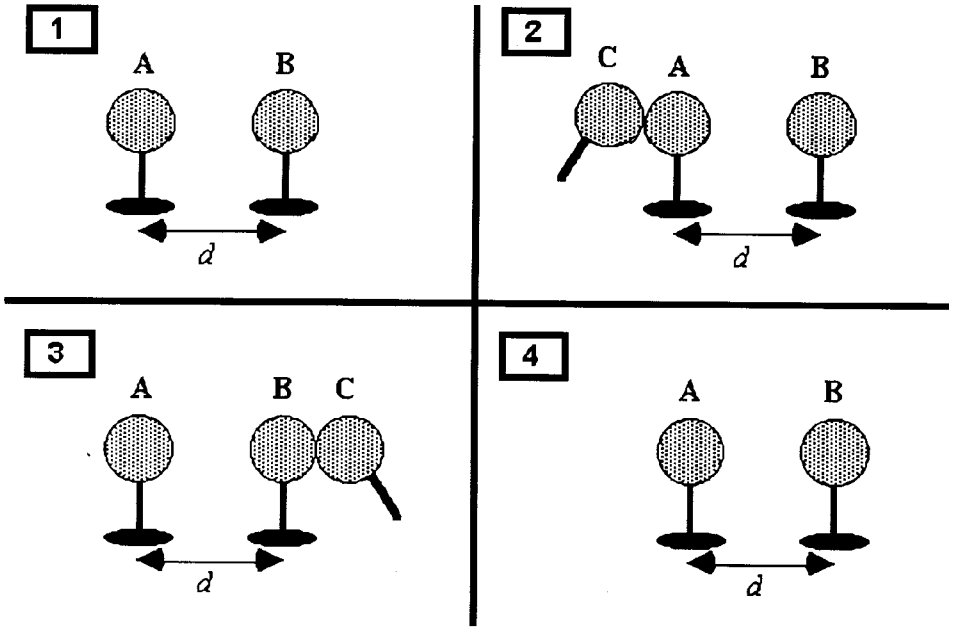
1. One mole of a substance contains 6.02×10^{23} protons and an equal number of electrons. If the protons could somehow be separated from the electrons and placed in separate containers separated by 1.00×10^{3} m, what would be the magnitude of the electrostatic force exerted by one box on the other?

__ A. 8.7×10^{8} N
__ B. 9.5×10^{9} N
__ C. 2.2×10^{10} N
X D. 8.3×10^{13} N
__ E. 1.6×10^{19} N

$q = 6.02 \times 10^{23} \times 1.6 \times 10^{-19} = 9.65 \times 10^{4}\ C$

$F = \frac{k_e q_1 q_2}{r^2} = \frac{8.99 \times 10^{9} \times (9.65 \times 10^{4})^2}{(10^3)^2} = 8.37 \times 10^{13}$

2. In Frame **1**, two identical conducting spheres, **A** and **B**, carry equal amounts of excess charge that have the same sign. The spheres are separated by a distance *d*; and sphere **A** exerts an electrostatic force on sphere B which has a magnitude *F*. A third sphere, **C**, which is handled only by an insulating rod, is introduced in Frame **2**. Sphere **C** is identical to **A** and **B** except that it is *initially uncharged*. Sphere **C** is touched first to sphere **A**, in Frame **2**, and then to sphere **B**, in Frame **3**, and is finally removed in Frame **4**.



Determine the magnitude of the electrostatic force that sphere **A** exerts on sphere **B** in Frame **4**.

__ A. *F*/2
__ B. *F*/3
__ C. 3*F*/4
X D. 3*F*/8
__ E. zero

A & B HAVE q (EACH) $\Rightarrow F = \frac{k_e q^2}{d^2}$

TOUCH C TO A, A & C HAVE $\frac{1}{2}q$ (EACH). TOUCH C TO B, C & B HAVE $(1+\frac{1}{2})q \times \frac{1}{2} = \frac{3}{4}q$ (EACH). NOW

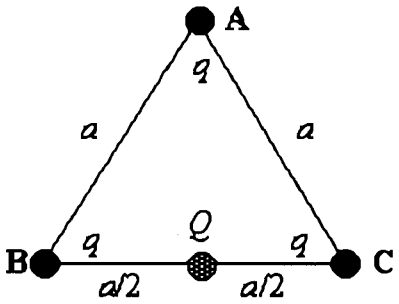
$F' = \frac{k_e (\frac{1}{2}q)(\frac{3}{4}q)}{d^2} = \frac{3}{8}F$

3. A conducting sphere has a net charge of -4.8×10^{-17} C. What is the approximate number of excess electrons on the sphere?

__ A. 100
__ B. 200
X C. 300
__ D. 400
__ E. 500

$$\frac{-4.8 \times 10^{-17}\ C}{-1.6 \times 10^{-19}\ C} = 300$$

The figure shows an equilateral triangle **ABC**. A positive point charge $+q$ is located at each of the three vertices **A**, **B**, and **C**. Each side of the triangle is of length a.



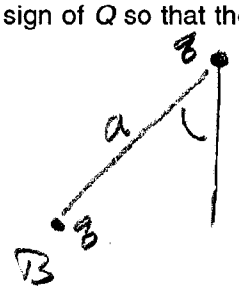
A point charge Q (that may be positive or negative) is placed at the mid-point between **B** and **C**.

4. Is it possible to choose the value of Q (*that is non-zero*) such that the force on Q is zero? Explain why or why not.

__ A. Yes, because the forces on Q are vectors and three vectors can add to zero.
__ B. No, because the forces on Q are vectors and three vectors can never add to zero.
__ C. Yes, because the electric force at the mid-point between **B** and **C** is zero whether a charge is placed there or not.
__ D. No, because the forces on Q due to the charges at **B** and **C** point in the same direction.
X E. No, because a fourth charge would be needed to cancel the force on Q due to the charge at **A**.

FORCES ON Q FROM B AND C CANCEL BUT THERE IS NOTHING TO CANCEL FORCE ON Q FROM A.

5. Determine an expression for the magnitude and sign of Q so that the net force on the charge at **A** is zero.

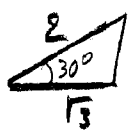


30° BECAUSE THIS IS AN EQUILATERAL TRIANGLE

__ A. $Q = +q\left(\frac{3\sqrt{3}}{4}\right)$

X B. $Q = -q\left(\frac{3\sqrt{3}}{4}\right)$

FORCE ON A FROM B HAS A VERTICAL AND A HORIZONTAL COMPONENT. THE HORIZONTAL COMPONENT IS CANCELED BY THE FORCE FROM C. THE VERTICAL COMPONENT IS $\frac{k_e q^2}{a^2}\cos 30°$ UPWARD.

$\cos 30° =$ 

$\frac{\sqrt{3}}{2}$

__ C. $Q = -q\left(\frac{4\sqrt{3}}{3}\right)$

__ D. $Q = +q\left(\frac{3}{4\sqrt{3}}\right)$

__ E. $Q = +q\left(\frac{4\sqrt{3}}{3}\right)$

THE VERTICAL COMPONENT FROM C IS THE SAME, SO WE NEED $2\frac{k_e q^2}{a^2}\frac{\sqrt{3}}{2}$

6. Determine the ratio of the electrostatic force to the gravitational force between a proton and an electron, F_E/F_G. **Note**: $k = 8.99 \times 10^9$ N•m²/C²; $G = 6.672 \times 10^{-11}$ N•m²/kg²; $m_e = 9.109 \times 10^{-31}$ kg; and $m_p = 1.672 \times 10^{-27}$ kg.

__ A. 1.24×10^{23}

__ B. 2.52×10^{29}

__ C. 1.15×10^{31}

X D. 2.27×10^{39}

__ E. 1.42×10^{58}

$F_E = \frac{k_e e^2}{r^2}$ $F_G = \frac{G m_e m_p}{r^2}$

$\frac{F_E}{F_G} = \frac{k_e e^2}{G m_e m_p} =$

$= \frac{8.99\times10^{9}\times(1.6\times10^{-19})^2}{6.67\times10^{-11}\times9.11\times10^{-31}\times1.67\times10^{-27}}$

$= 2.27\times10^{39}$

DOWNWARD, FROM Q.

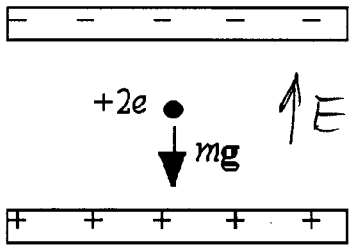
DISTANCE TO Q IS $a\cos 30° = a\frac{\sqrt{3}}{2}$ SO WE HAVE

$\sqrt{3}\frac{k_e q^2}{a^2} = -\frac{k_e Q}{(a\frac{\sqrt{3}}{2})^2}$

$Q = -\left(\frac{\sqrt{3}}{2}\right)^2\sqrt{3}\,q$

$Q = -\frac{3\sqrt{3}}{4}q$

7. A helium nucleus is located between the plates of a parallel-plate capacitor as shown. The nucleus has a charge of +2e and a mass of 6.6×10^{-27} kg. What is the magnitude of the electric field such that the electric force exactly balances the weight of the helium nucleus so that it remains stationary?



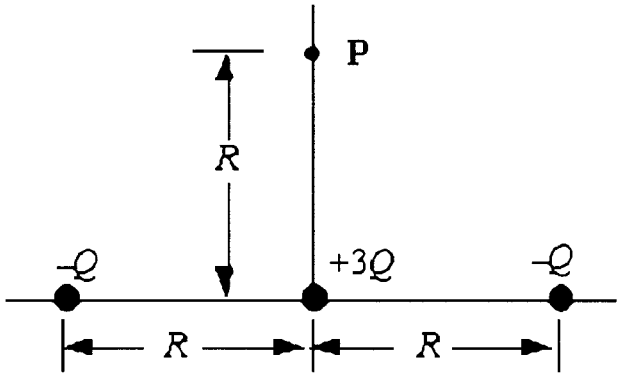
__ A. 4.0×10^{-7} N/C
__ B. 6.6×10^{-26} N/C
X C. 2.0×10^{-7} N/C
__ D. 5.0×10^{-3} N/C
__ E. 1.4×10^{8} N/C

WE NEED $qE = mg \Rightarrow E = \frac{mg}{q}$

$q = 2e$, SO $E = \frac{6.6\times10^{-27}\times9.8}{2\times1.6\times10^{-19}}$

$E = 2.0\times10^{-7}$

8. Three point charges $-Q$, $-Q$, and $+3Q$ are arranged along a line as shown in the sketch.



What is the electric potential at the point **P**?

__ A. $+kQ/R$
__ B. $-2kQ/R$
__ C. $-1.6kQ/R$
X D. $+1.6kQ/R$
__ E. $+4.4kQ/R$

ELECTRIC POTENTIAL IS $\frac{k_e q}{r}$ FOR EACH CHARGE. THE 2 $-Q$'s ARE $\sqrt{R^2+R^2} = \sqrt{2}R$ FROM P SO

$$V = k_e\left[\frac{-Q}{\sqrt{2}R} + \frac{-Q}{\sqrt{2}R} + \frac{3Q}{R}\right]$$

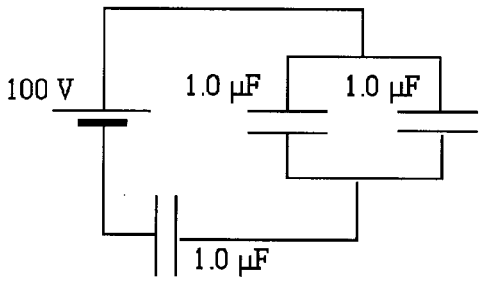
$$V = \frac{k_e Q}{R}\left[-\frac{2}{\sqrt{2}} + 3\right] = 1.6\,\frac{k_e Q}{R}$$

9. A capacitor has a very large capacitance of 10 F. The capacitor is charged by placing a potential difference of 2 V between its plates. How much energy is stored in the capacitor?

__ A. 2000 J
__ B. 500 J
__ C. 100 J
__ D. 40 J
X E. 20 J

$E = \frac{1}{2}CV^2 = \frac{1}{2} \cdot 10 \cdot 2^2 = 20\ J$

10. What is the equivalent capacitance of the combination of capacitors shown in the circuit?



1.0 μF IN PARALLEL WITH 1.0 μF IS 2.0 μF.
2.0 μF IN SERIES WITH 1.0 μF IS

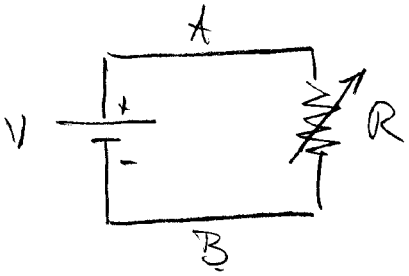
$\frac{1}{C} = \frac{1}{2} + \frac{1}{1} = \frac{3}{2}$

$C = \frac{2}{3}\ \mu F$

__ A. 0.37 μF
__ B. 3.3 μF
__ C. 4.6 μF
X D. 0.67 μF
__ E. 2.1 μF

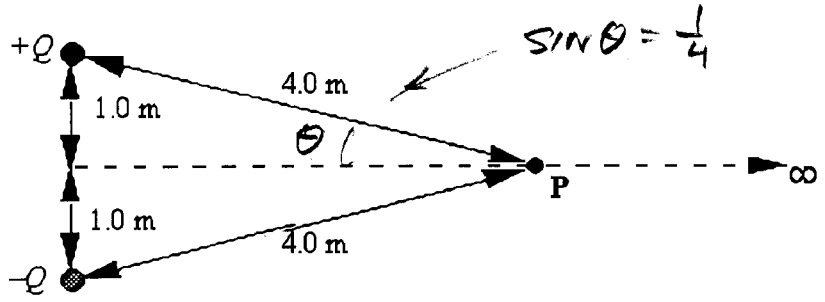
11. Two wires, **A** and **B**, and a variable resistor, **R**, are connected in series to a battery. Which one of the following results will occur if the resistance of **R** is increased?

__ A. The current through **A** and **B** will increase. → I ↓
__ B. The voltage across **A** and **B** will increase. → V = BATTERY, MAY ↓ A LITTLE. (DUE TO INTERNAL RESISTANCE)
__ C. The voltage across the entire circuit will increase.
__ D. The power used by the entire circuit will increase. → $P = I^2R$ ↓
X E. The current through the entire circuit will decrease.



THE ARROW MEANS R IS VARIABLE, A AND B HAVE VERY LITTLE RESISTANCE COMPARED TO A RESISTOR, AND SO DOES THE BATTERY. THUS $V = IR \Rightarrow I = V/R$
IF R↑ THEN I↓.

Two charges of opposite sign and equal magnitude $Q = 2.0$ C are held 2.0 m apart as shown in the figure.



SIN θ = 1/4

12. Determine the electric potential at the point **P**. DIDN'T WE JUST DO THIS?

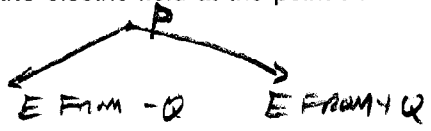
__ A. 1.1×10^9 V
__ B. 2.2×10^9 V
__ C. 4.5×10^9 V
__ D. 9.0×10^9 V
X E. zero

$V = \frac{k_e q}{r}$ AND ADD 'EM UP

$V = \frac{k_e(Q)}{4} + \frac{k_e(-Q)}{4} = 0$

13. Determine the magnitude of the electric field at the point **P**.

__ A. 2.2×10^9 V/m
X B. 5.6×10^8 V/m
__ C. 4.4×10^8 V/m
__ D. 2.8×10^8 V/m
__ E. zero ← WATCH OUT! NOT JUST BECAUSE V = 0.



HORIZONTAL PARTS CANCEL. VERTICAL PARTS ARE $\frac{k_e Q}{r^2} \sin\theta$ DOWNWARD, AND THERE ARE 2 OF THEM. $\sin\theta = \frac{1}{4}$, SO

$2 \cdot \frac{8.99 \times 10^9 \times 2.0}{(4.0)^2} \times \frac{1}{4}$

$= 5.6 \times 10^8$ V/m

WOW! BIG FIELD.

14. How many electrons flow through a battery that delivers a current of 3.0 A for 12 s?

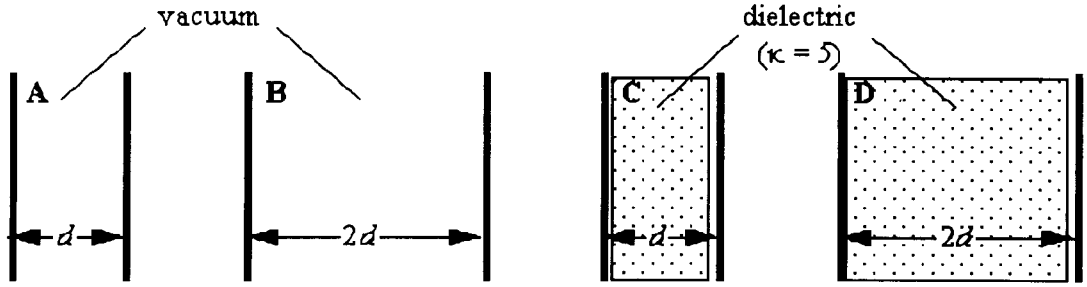
__ A. 4
__ B. 36
__ C. 4.8×10^{15}
__ D. 6.4×10^{18}
X E. 2.2×10^{20}

$3.0\text{ A} \times 12\text{ s} = 36$ COULOMBS

$\frac{36}{1.6 \times 10^{-19}} = 2.2 \times 10^{20}$

SURE ARE A LOT OF 'EM.

The figure below shows four parallel plate capacitors: **A**, **B**, **C**, and **D**. Each capacitor carries the same charge q and has the same plate area A. As suggested by the figure, the plates of capacitors **A** and **C** are separated by a distance d while those of **B** and **D** are separated by a distance $2d$. Capacitors **A** and **B** are maintained in vacuum while capacitors **C** and **D** contain dielectrics with constant $\kappa = 5$.



ASSUME PLATES HAVE AREA A.

15. Which list below places the capacitors in order of *increasing* capacitance?

__ A. **A**, **B**, **C**, **D**
__ B. **B**, **A**, **C**, **D**
__ C. **A**, **B**, **D**, **C**
X D. **B**, **A**, **D**, **C**
__ E. **D**, **C**, **B**, **A**

$C = \frac{\kappa \varepsilon_0 A}{d}$ $\kappa = 5$ SO

$C_A = \frac{\varepsilon_0 A}{d}$ $C_B = \frac{\varepsilon_0 A}{2d}$ $C_C = \frac{5\varepsilon_0 A}{d}$

$C_D = \frac{5\varepsilon_0 A}{2D}$

$\left(\frac{1}{2}, 1, \frac{5}{2}, 5\right) \times \varepsilon_0 A/d$

16. Which capacitor has the largest potential difference between its plates?

__ A. **A**
X B. **B**
__ C. **C**
__ D. **D**
__ E. **A** and **D** are the same and larger than **B** or **C.**

EACH HAS q AND $q = CV$ SO $V = q/C$

LARGEST $V \Rightarrow$ SMALLEST C

17. A resistor dissipates 1.5 W when it is connected to a battery with a potential difference of 12 V. What is the resistance of the resistor?

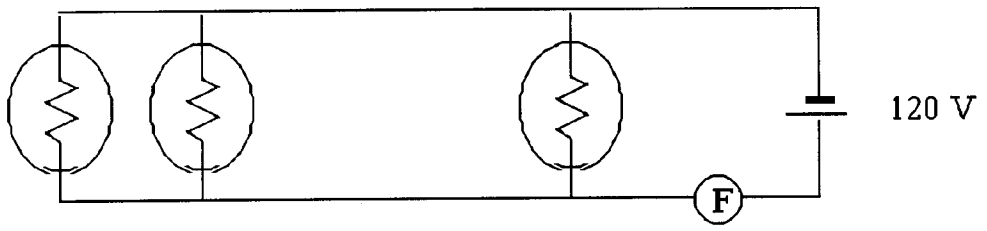
__ A. 0.13 Ω
__ B. 220 Ω
__ C. 18 Ω
__ D. 8.0 Ω
X E. 96 Ω

$P = I^2 R$ BUT $V = IR$ SO $I = V/R$

$P = \left(\frac{V}{R}\right)^2 R = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{12^2}{1.5}$

$R = \frac{2}{3} \cdot 144 = 96\ \Omega$

18. Some light bulbs are connected in parallel to a 120 V source as shown in the figure. Each bulb dissipates an average power of 60 W.

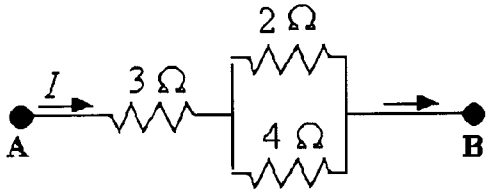


The circuit has a fuse **F** that burns out when the current in the circuit exceeds 9 A. Determine the largest number of bulbs, that can be used in this circuit without burning out the fuse.

__ A. 9
X B. 17
__ C. 25
__ D. 34
__ E. 36

$P = I^2R$ BUT $V = IR$ (HERE WE GO AGAIN)
SO $P = I(IR) = IV$, AT 9A, $P = 120 \times 9$
$P = 1080$; $1080/(60 \text{ PER BULB}) = 18$ BULBS
BLOW A FUSE. BETTER USE 17.

Three resistors are connected as shown in the figure. The potential difference between points **A** and **B** is 26 V.



19. What is the equivalent resistance between the points **A** and **B**?

__ A. 3.8 Ω
X B. 4.3 Ω
__ C. 5.1 Ω
__ D. 6.8 Ω
__ E. 9.0 Ω

2Ω PARALLEL WITH 4Ω : $\frac{1}{R_{11}} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$
$R_{11} = 4/3$, SERIES WITH 3, $R_{TOTAL} = 3 + \frac{4}{3}$
$R_{TOTAL} = 4.3\ \Omega$

20. How much current flows through the 3-Ω resistor?

__ A. 2.0 A
__ B. 4.0 A
X C. 6.0 A
__ D. 8.7 A
__ E. 10.0 A

FOR THE WHOLE CIRCUIT $V_{AB} = 26$ V.
$R_{TOTAL} = R_{AB} = 4.3\ \Omega$ AND $V_{AB} = I_{AB} R_{AB}$
SO $I_{AB} = \frac{V_{AB}}{R_{AB}} = \frac{26}{4.3} = 6.0$ A
AND ALL OF IT MUST GO THROUGH THE 3Ω