Part A – Knowledge and Understanding [20 marks]

Multiple Choice – ***Use a CAPITAL letter that best completes the statement or answers the question***

_____ 1. The gravitational force between two spherical masses is $F_!$. Which of the following would decrease the gravitational force between the objects to $0.25F_!$?

a) decreasing the mass of one object to half its original value.
b) increasing the distance by a factor of 2.
c) decreasing the distance to 0.5 the original value.
d) increasing the mass of both objects by a factor of 2.

_____ 2. For a given mass, m, and a given distance, d, separating you and the object, which of the following would exert a stronger gravitational force on you?

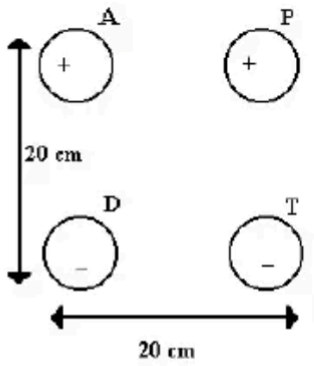
a) an object of mass 7m a distance 15d away.
b) an object of mass 9m a distance 5d away.
c) an object of mass 8m a distance 3d away.
d) an object of mass 12m a distance 4d away.

_____ 3. A small object has an excess of 4.7×10^{11} electrons. The magnitude of the electric potential at a distance of 0.200 m from the object would be: ($e = 1.6 \times 10^{-19}$ C)

a) 2.7×10^{6}V
b) 3.4×10^{3}V
c) 2.1×10^{22}V
d) 2.6×10^{4}V
e) 1.2×10^{-27}V

_____ 4. A satellite is in a circular orbit around the Earth at an altitude of 650 km. What orbital speed must the satellite maintain to stay in orbit at this altitude?

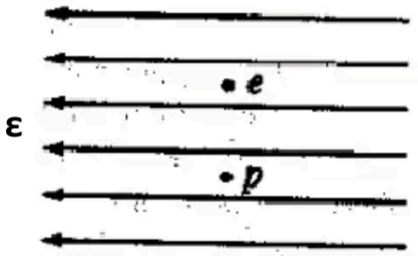
a) 5.7×10^{3} m/s
b) 7.5×10^{3} m/s
c) 2.5×10^{4} m/s
d) 7.9×10^{4} m/s



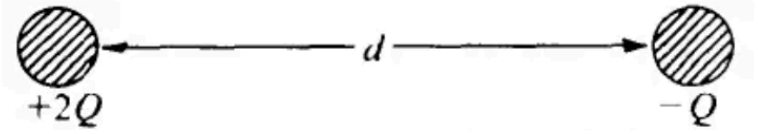
5. Four charged spheres, A, D, P, and T are arranged as shown above. Sphere A has a charge of +q, sphere D has a charge of -q, sphere P has a charge of +0.5q, and sphere T has a charge of -2q. Which two spheres exert the *largest* force on each other (magnitude only)?

a. A and D
b. D and T
c. A and P
d. P and D
e. P and T

6. An electron *e* and a proton *p* are simultaneously released from rest in a uniform electric field ε, as shown. Assume that the particles are sufficiently far apart so that the only force acting on each particle after it is released is that due to the electric field. At a later time when the particles are still in the field, the electron and the proton will have the same



a. direction of motion
b. speed
c. displacement
d. magnitude of acceleration
e. magnitude of force acting on them



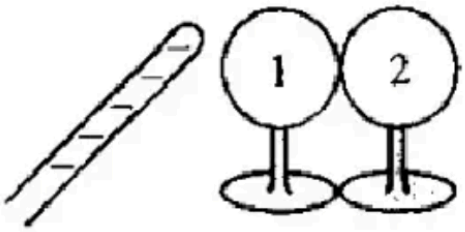
7. Two identical conducting spheres are charged to +2Q and –Q, respectively, and are separated by a distance d (much greater than the radii of the spheres) as shown above. The magnitude of the force of attraction on the left sphere is F_1. After the two spheres are made to touch and then are separated by distance d, the magnitude of the force on the left sphere is F_2. Which of the following relationships is correct?

a. $2F_1 = F_2$
b. $F_1 = F_2$
c. $F_1 = 2F_2$
d. $F_1 = 4F_2$
e. $F_1 = 8F_2$

_____ 8. The electric field at a distance of 1.0 m from a charged sphere is 100 N/C. At what distance from the sphere will the electric field be 50 N/C?

a) 1.1 m.
c) 2.0 m.
b) 1.4 m
d) 4.0 m.

_____ 9. Two metal spheres that are initially uncharged are mounted on insulating stands, as shown. A negatively charged rubber rod is brought close to, but does not make contact with, sphere 1. Sphere 2 is then brought close to 1 on the side opposite to the rubber rod. Sphere 2 is allowed to touch 1 and then is removed some distance away. The rubber rod is then moved far away from 1 and 2 What are the final charges on the spheres?



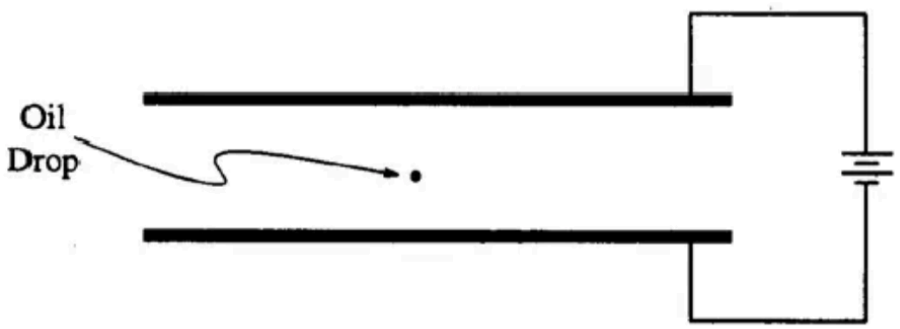
	Sphere 1	**Sphere 2**
a)	Negative	Negative
b)	Negative	Positive
c)	Positive	Negative
d)	Positive	Positive

_____ 10. The electric potential due to a point charge at a point depends on

a) the direction of the electric field.
c) the velocity of the point charge.
b) the distance from the point charge
d) the mass of the point charge.

12. When considering the forces acting between two charged objects, explain why we would typically only consider the Coulomb's force and not the force of gravity. [3 marks]

13. A student rubs a balloon against her hair. She then places the side of the balloon against a wall and the balloon sticks to the wall. Explain why the balloon sticks to the wall. [2 marks]



14. Robert Millikan received a Nobel Prize for determining the charge on the electron. To do this, he set up a potential difference between two horizontal parallel metal plates. He then sprayed drops of oil between the plates and adjusted the potential difference until drops of a certain size remained suspended at rest between the plates, as shown above. Suppose that when the potential difference between the plates is adjusted until the electric field is 1.00×10^4 N/C downward, a certain drop with a mass of 3.27×10^{-16} kg remains suspended.

a. What is the charge on this drop? (4 marks)

b. If the distance between the plates is 0.010 m, what is the battery's potential? (3 marks)

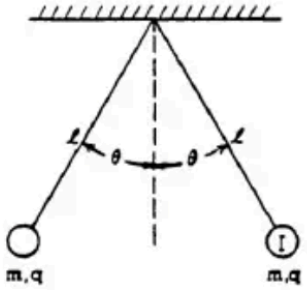
c. The oil in the drop slowly evaporates while the drop is being observed, but the charge on the drop remains the same. Indicate whether the drop remains at rest, moves upward, or moves downward. Explain briefly, using equations to support your answer. (3 marks)

Part D – Application (Full Solutions are Required) [20 marks]

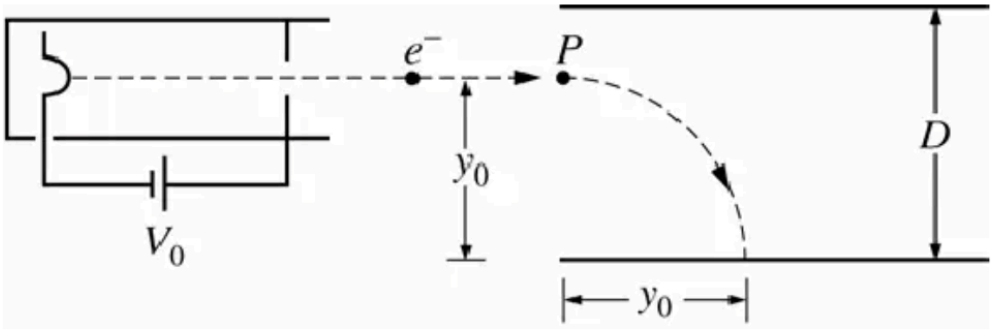
14. An electron is released from rest at the negative plate in a parallel plate apparatus kept under vacuum and maintained a potential difference of 5.0×10^{1} V. With what speed does the electron collide with the positive plate? ($m = 9.11 \times 10^{-31}$kg, $q = -1.6 \times 10^{-19}$C) [2 marks]

15. A 1500-kg satellite is moved from an orbit of 2 Earth radii to an orbit of 2.5 Earth radii. How much energy is required to accomplish this? ($M_E = 5.98 \times 10^{24}$ kg, $R_E = 6.38 \times 10^{6}$m) (4 marks)

16. Two masses of 5.0 g each are suspended from thin strings and a charge q is placed on each. The result is shown in the diagram below. If the angle between each string and the vertical is 15° and the length of the string is 35 cm, determine the charge q. (4 marks)



17. Electrons are accelerated through a potential difference, $V_0 = 120$ V, before exiting and being subjected to a new set of parallel plates. The electrons enter this region 5.0 cm from the bottom plate, and hit this bottom plate a distance of 5.0 cm in. If the total plate separation of this second set of plates is 8.0 cm, determine the voltage of the second source AND draw this source in, clearly showing the positive vs negative terminals of the battery. ($m = 9.11 \times 10^{-31}$kg, $q = -1.6 \times 10^{-19}$C) (10 marks)



1. The gravitational force between two spherical masses is F_1. Which of the following would decrease the gravitational force between the objects to $0.25F_1$?

$\frac{GmM}{r^2}$

a) decreasing the mass of one object to half its original value.
b) increasing the distance by a factor of 2.
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2. For a given mass, m, and a given distance, d, separating you and the object, which of the following would exert a stronger gravitational force on you?

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a) 2.7×10^{6} V
b) 3.4×10^{3} V
c) 2.1×10^{22} V
d) 2.6×10^{4} V
e) 1.2×10^{-27} V

$(4.7 \times 10^{11}\ \text{ele})(1.6 \times 10^{-19}\ \text{C}) = 7.52 \times 10^{-8}$ C

$V = \frac{(8.99 \times 10^{9})(7.52 \times 10^{-8})}{0.2\text{m}} = 3.38 \times 10^{3}$ V

4. A satellite is in a circular orbit around the Earth at an altitude of 650 km. What orbital speed must the satellite maintain to stay in orbit at this altitude?

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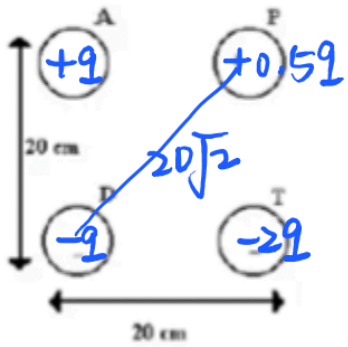
$\sqrt{\frac{Gm}{r}} = \sqrt{\frac{(6.67 \times 10^{-11})(5.98 \times 10^{24}\ \text{kg})}{650 \times 10^{3} + 6.4 \times 10^{6}}} = 7.52 \times 10^{3}$



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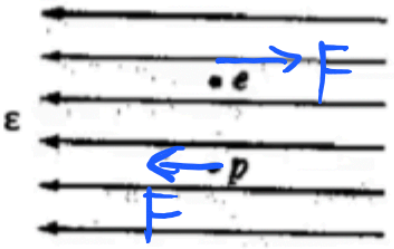

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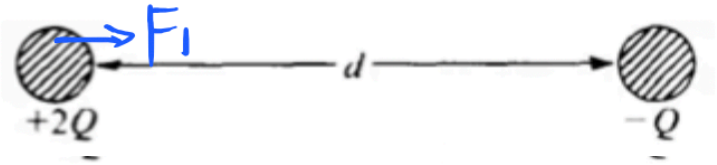

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$$F_1 = \frac{k(2Q)(Q)}{d^2} = 2$$

$$F_2 = \frac{k\left(\frac{Q}{2}\right)\left(\frac{Q}{2}\right)}{d^2} = \frac{1}{4}$$

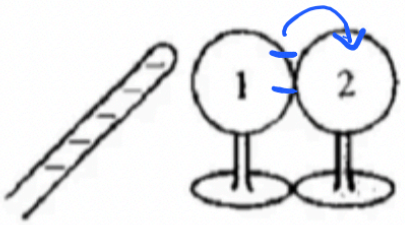
$E = \frac{kq}{r^2}$ and $\frac{kq}{(\sqrt{2}r)}$

8. The electric field at a distance of 1.0 m from a charged sphere is 100 N/C. At what distance from the sphere will the electric field be 50 N/C?

a) 1.1 m.
c) 2.0 m.
b) 1.4 m
d) 4.0 m.

$\frac{1m}{x} \quad \frac{100N/C}{50N/C}$

9. Two metal spheres that are initially uncharged are mounted on insulating stands, as shown. A negatively charged rubber rod is brought close to, but does not make contact with, sphere 1. Sphere 2 is then brought close to 1 on the side opposite to the rubber rod. Sphere 2 is allowed to touch 1 and then is removed some distance away. The rubber rod is then moved far away from 1 and 2 What are the final charges on the spheres?



	Sphere 1	Sphere 2
a)	Negative	Negative
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10. The electric potential due to a point charge at a point depends on $V = \frac{kq}{r}$

a) the direction of the electric field.
c) the velocity of the point charge.
b) the distance from the point charge
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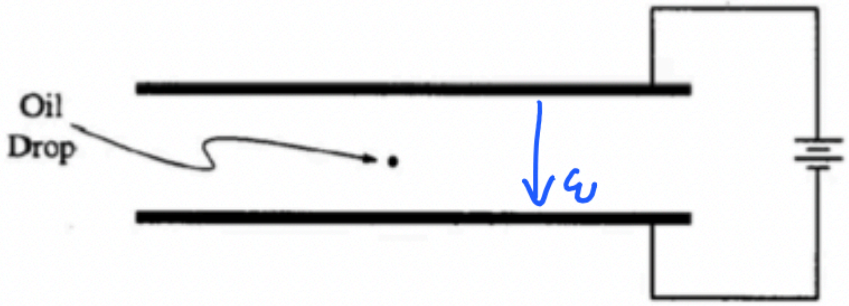
12. When considering the forces acting between two charged objects, explain why we would typically only consider the Coulomb's force and not the force of gravity. [3 marks]

$F_e \gg F_g$

$k = 8.99 \times 10^9$ but the mass of an electron is 10^{-31}

13. A student rubs a balloon against her hair. She then places the side of the balloon against a wall and the balloon sticks to the wall. Explain why the balloon sticks to the wall. [2 marks]

When a student **rubs a balloon on their hair**, **charge by friction** occurs, transferring **electrons** from the hair to the balloon. This makes the **balloon negatively charged**. When the balloon is brought near a **neutral wall**, it **polarizes** the wall's surface by repelling its electrons, leaving the closer side **slightly positive**. This creates an **electrostatic attraction**, causing the balloon to stick to the wall.



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a. What is the charge on this drop? (4 marks)

$$\mathcal{E}q = mg$$

$$q = \frac{(3.27 \times 10^{-16})(9.8)}{1.00 \times 10^4} = 3.2046 \times 10^{-19}\ C$$

b. If the distance between the plates is 0.010 m, what is the battery's potential? (3 marks)

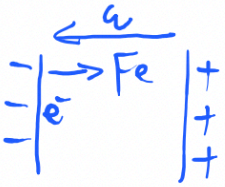
$$V = \mathcal{E}d = (1.00 \times 10^4\ N/C)(0.010m) = 100\ V$$

c. The oil in the drop slowly evaporates while the drop is being observed, but the charge on the drop remains the same. Indicate whether the drop remains at rest, moves upward, or moves downward. Explain briefly, using equations to support your answer. (3 marks)

As the oil droplet's mass decreases due to evaporation, the electric force remains constant, resulting in a greater net upward force. This causes the droplet to move upward.

Part D – Application (Full Solutions are Required) [20 marks]

14. An electron is released from rest at the negative plate in a parallel plate apparatus kept under vacuum and maintained a potential difference of 5.0×10^{1} V. With what speed does the electron collide with the positive plate? ($m = 9.11 \times 10^{-31}$ kg, $q = -1.6 \times 10^{-19}$ C) [2 marks]

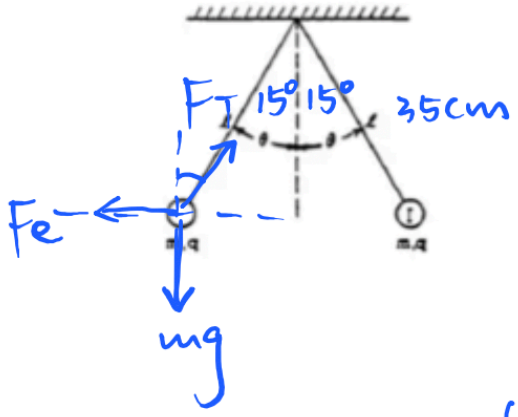


$$\frac{1}{2}mv_f^2 = -Vq$$

$$\frac{1}{2}(9.11 \times 10^{-31}\,kg)\,v_f^2 = -(5.0 \times 10\,V)(-1.6 \times 10^{-19})$$

$$v_f = 4.19 \times 10^{6}\ m/s$$

16. Two masses of 5.0 g each are suspended from thin strings and a charge q is placed on each. The result is shown in the diagram below. If the angle between each string and the vertical is 15° and the length of the string is 35 cm, determine the charge q. (4 marks)



$$mg = F_T \cos 15°$$

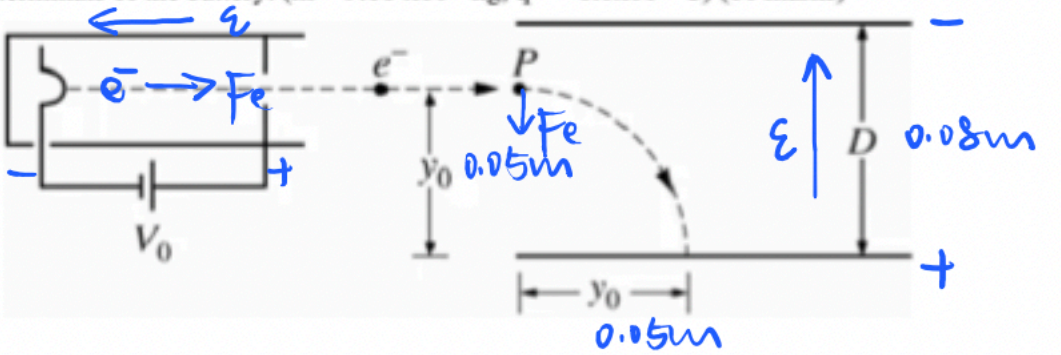
$$F_T = \frac{mg}{\cos 15°} = 0.0507\ N$$

$$\frac{kq^2}{(0.35 \times 2 \times \sin 15°)^2} = 0.0507 \sin 15°$$

$$\frac{x}{0.35} = \sin 15°$$

$$q = 2.189 \times 10^{-7}\ C$$

17. Electrons are accelerated through a potential difference, $V_0 = 120$ V, before exiting and being subjected to a new set of parallel plates. The electrons enter this region 5.0 cm from the bottom plate, and hit this bottom plate a distance of 5.0 cm in. If the total plate separation of this second set of plates is 8.0 cm, determine the voltage of the second source AND draw this source in, clearly showing the positive vs negative terminals of the battery. ($m = 9.11 \times 10^{-31}$kg, $q = -1.6 \times 10^{-19}$C) (10 marks)



$\frac{1}{2}mv^2 = -qV$

$\frac{1}{2}(9.11\times10^{-31}\text{kg})\, v_f^2 = -(-1.6\times10^{-19})(120\text{V})$

$v_f = 6.492\times10^{6}$ m/s

$t = \frac{0.05\text{m}}{6.492\times10^{6}} = 7.701\times10^{-9}$ sec

$\frac{Fe}{m} = \frac{qE}{m} = \frac{qV}{md}$

y-comp: $d = \frac{1}{2}at^2$

$d = \frac{1}{2}\cdot\frac{qV}{md}\cdot t^2$

$0.05 = \frac{1}{2}\cdot\frac{(1.6\times10^{-19})V(7.701\times10^{-9})^2}{(9.11\times10^{-31})(0.08)}$

$0.05 = 6.51\times10^{-5}V$

$V = 768\text{V}$