

Show equations, substitutions, units, and vector directions. Explain your reasoning. Use sensible rounding.

Answers appear below each question beside a vertical bar. Equivalent correct reasoning is acceptable.

Constants	$e = 1.60 \times 10^{-19} \text{ C}$ $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$ $1 \mu\text{C} = 10^{-6} \text{ C}$ $1 \text{ nC} = 10^{-9} \text{ C}$
Equations	$ q = Ne$ $F_e = k q_1q_2 /r^2$ $E = F/ q $ $ F_e = q E$ $F_g = Gm_1m_2/r^2$ $g = F_g/m = GM/r^2$ $v_{\text{orbit}} = \sqrt{GM/r}$

Use center-to-center distance. Orbital-speed equation applies to circular orbits.

6.1 Electric Charge

1. An object gains 2.0×10^{12} electrons. Find its net charge. A different object has charge $+4.8 \times 10^{-9} \text{ C}$. How many electrons did it lose?

First object: $q = -Ne = -(2.0 \times 10^{12})(1.60 \times 10^{-19}) = -3.2 \times 10^{-7} \text{ C}$. Second: $N = q/e = (4.8 \times 10^{-9})/(1.60 \times 10^{-19}) = 3.0 \times 10^{10}$ electrons lost.

2. Two identical conducting spheres initially carry $+8.0 \text{ nC}$ and -2.0 nC . They touch, then separate. Find each final charge. Explain the difference between charging by contact and polarization without contact.

Total charge = $+6.0 \text{ nC}$, shared equally: $+3.0 \text{ nC}$ each. Contact allows electron transfer. A nearby charge can redistribute charges in a neutral conductor without changing its net charge. Net charging by induction requires an additional transfer step, such as grounding.

6.2 Coulomb's Law

3. Charges $+2.0 \mu\text{C}$ and $-5.0 \mu\text{C}$ are 0.30 m apart. Find the electric-force magnitude and state whether the force is attractive or repulsive. Compare the forces on the two charges.

$F = (9.0 \times 10^9)(2.0 \times 10^{-6})(5.0 \times 10^{-6})/(0.30)^2 = 1.0 \text{ N}$. The force is attractive. Both charges experience equal-magnitude forces in opposite directions.

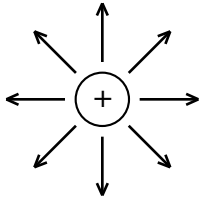
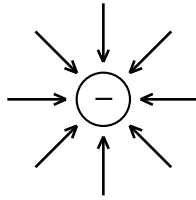
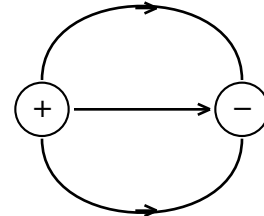
4. The force between two charges is F . Find the new force in terms of F if (a) distance doubles, (b) both charge magnitudes double, and (c) one charge doubles while distance triples.

(a) $F/4$. (b) $4F$. (c) $2F/9$. Coulomb force is proportional to the product of charge magnitudes and inversely proportional to distance squared.

ANSWER KEY

6.3 Electric Fields

5. Draw electric field lines for (a) one positive charge, (b) one negative charge, and (c) a positive-negative pair. Show arrow directions and identify where closer line spacing indicates stronger field.



(a) Radial arrows outward. (b) Radial arrows inward. (c) Lines leave the positive charge and enter the negative charge. Lines never cross. Greater line density indicates stronger field.

6. A $+3.0 \mu\text{C}$ test charge experiences 0.060 N east. Find the electric field. What force would act on an electron placed at the same point?

$E = F/q = 0.060/(3.0 \times 10^{-6}) = 2.0 \times 10^4 \text{ N/C}$ east. Electron force magnitude $= (1.60 \times 10^{-19})(2.0 \times 10^4) = 3.2 \times 10^{-15} \text{ N}$, directed west because its charge is negative.

6.4 Universal Gravitation

7. Two spherical masses of 1000 kg and 2000 kg have centers 5.0 m apart. Find the gravitational-force magnitude on each.

$F = Gm_1m_2/r^2 = (6.67 \times 10^{-11})(1000)(2000)/(5.0)^2 = 5.34 \times 10^{-6} \text{ N} \approx 5.3 \times 10^{-6} \text{ N}$. Each force points toward the other mass, with equal magnitude.

8. A satellite moves from distance R to distance $3R$ from a planet's center. How does the gravitational force change? If its altitude is $2R$ above a planet of radius R , what distance belongs in the gravity equation?

The force becomes $1/9$ of its original value. For altitude $2R$ above a surface of radius R , center-to-center distance is $R + 2R = 3R$, not $2R$.

ANSWER KEY

6.5 Gravitational Fields and Orbits

9. A planet has mass 6.0×10^{24} kg and radius 6.0×10^6 m. Calculate gravitational field strength at the surface and at an altitude equal to one planet radius.

Surface: $g = GM/R^2 = (6.67 \times 10^{-11})(6.0 \times 10^{24})/(6.0 \times 10^6)^2 = 11$ N/kg. At altitude R , $r = 2R$ and $g = 11.12/4 = 2.8$ N/kg.

10. A satellite has a circular orbit of radius 8.0×10^6 m around a planet of mass 6.0×10^{24} kg. Find orbital speed. Explain why orbiting astronauts can feel weightless even when gravity is substantial.

$v = \sqrt{GM/r} = \sqrt{[(6.67 \times 10^{-11})(6.0 \times 10^{24})]/(8.0 \times 10^6)} = 7.1 \times 10^3$ m/s. Astronauts and spacecraft are in shared free fall, so there is little or no supporting normal force on them.

6.6 Comparing Gravity and Electric Forces

11. Complete the comparison table. Use mass, charge, attraction, repulsion, and inverse-square behavior in your responses.

Property	Gravitational force	Electric force
Source property	Mass	Charge
Attract or repel?	Attracts	Either
Dependence on r	$1/r^2$	$1/r^2$

Gravity depends on mass and only attracts in these situations. Electric force depends on charge and can attract or repel. Both act across distance and decrease as $1/r^2$.

12. For an electron-proton pair, the electric force is 8.2×10^{-8} N and gravity is 3.6×10^{-47} N. Calculate their ratio. Explain why gravity can still dominate planetary motion.

$F_e/F_g = (8.2 \times 10^{-8})/(3.6 \times 10^{-47}) = 2.3 \times 10^{39}$. Large astronomical objects are usually nearly electrically neutral, so positive and negative charges largely cancel. Their masses add, making gravity important.

ANSWER KEY**Unit 6 Review**

13. A charge in a uniform field of $5.0 \times 10^3 \text{ N/C}$ upward experiences a force of 0.020 N downward. Find the charge, including its sign.

| The force is opposite the field, so the charge is negative. $|q| = F/E = 0.020/(5.0 \times 10^3) = 4.0 \times 10^{-6} \text{ C}$. $q = -4.0 \mu\text{C}$.

14. Two identical positive charges, each $+3.0 \mu\text{C}$, repel with a force of 0.90 N . Find the distance between them.

| $r = \sqrt{(kq^2/F)} = \sqrt{[(9.0 \times 10^9)(3.0 \times 10^{-6})^2/0.90]} = 0.30 \text{ m}$.

15. Two equal positive charges sit at equal distances left and right of point P. Find the net electric field direction at P. Would your answer remain true if the right-hand charge doubled? Explain.

| Equal charges create equal and opposite fields at the midpoint, so $E_{\text{net}} = 0$. If the right charge doubles, its leftward field is stronger, leaving a net field to the left.

16. Explain how pushing two positive charges closer together can store energy. How is this similar to lifting an object near Earth's surface?

| An external force does positive work against electric repulsion, increasing the system's electric potential energy. Lifting does work against gravity and increases gravitational potential energy. On release, either system can convert stored energy to kinetic energy.