Conceptual Physics NAME:

Homework 5a Electrostatics Homeworks are due usually a day after the corresponding textbook part/lecture is completed. Due dates will be announced in class. Multiple-choice problems will all be marked. **USE** the answer table for these problems. The rest of the homeworks will be marked for apparent completeness and some full-answer problems will/may be marked in detail. Make the full-answer solutions sufficiently detailed that the grader can follow your reasoning. Solutions will be posted eventually after the due dates. The solutions are intended to be (but not necessarily are) super-perfect and often go beyond full answers. For an argument or discussion problem, there really is no single right answer. The instructor's answer reflects his long experience in physics, but there could be objections to his arguments, assumptions, nuances, style, facts, etc.

NAME:

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	26.	O	O	O	O	O
2.	O	O	O	O	O	27.	O	O	O	O	O
3.	O	O	O	O	O	28.	O	O	O	O	O
4.	O	O	O	O	O	29.	O	O	O	O	O
5.	O	O	O	O	O	30.	O	O	O	O	O
6.	O	O	O	O	O	31.	O	O	O	O	O
7.	O	O	O	O	O	32.	O	O	O	O	O
8.	O	O	O	O	O	33.	O	O	O	O	O
9.	O	O	O	O	O	34.	O	O	O	O	O
10.	O	O	O	O	O	35.	O	O	O	O	O
11.	O	O	O	O	O	36.	O	O	O	O	O
12.	O	O	O	O	O	37.	O	O	O	O	O
13.	O	O	O	O	O	38.	O	O	O	O	O
14.	O	O	O	O	O	39.	O	O	O	O	O
15.	O	O	O	O	O	40.	O	O	O	O	O
16.	O	O	O	O	O	41.	O	O	O	O	O
17.	O	O	O	O	O	42.	O	O	O	O	O
18.	O	O	O	O	O	43.	O	O	O	O	O
19.	O	O	O	O	O	44.	O	O	O	O	O
20.	O	O	O	O	O	45.	O	O	O	O	O
21.	O	O	O	O	O	46.	O	O	O	O	O
22.	O	O	O	O	O	47.	O	O	O	O	O
23.	O	O	O	O	O	48.	O	O	O	O	O
24.	O	O	O	O	O	49.	O	O	O	O	O
25.	O	O	O	O	O	50.	O	O	O	O	O

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014 qmult 00100 1 4 5 easy deducto-memory: electromagnetism 1

1. "Let's play *Jeopardy*! For $100, the answer is: It is the realm of physics concerned with electrical and magnetic phenonema: i.e., electricity and magnetism. Electricity and magnetism are, in fact, two manifestations of the same underlying realm: i.e., the realm in question."

   What is _____, Alex?

   a) mechanics b) waves c) thermodynamics d) magnetoelectricity
   e) electromagnetism

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) As Lurch would say AAAARGH.

   Redaction: Jeffery, 2012jan01

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014 qmult 00150 1 1 5 easy memory: Ben Franklin named charges

Extra keywords: physci KB-137

2. Who named positive and negative electric charge?

   a) George Washington (1732–1799). b) John Adams (1735–1826).
   c) Benedict Arnold (1741–1801). d) Aaron Burr (1756–1836).
   e) Benjamin Franklin (1706–1790).

   SUGGESTED ANSWER: (e) KB-137 and WP-513 confirm it was old Ben.

   Wrong answers:
   c) Oh, c'mon.

   Redaction: Jeffery, 2001jan01

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014 qmult 00200 1 1 1 easy memory: electric charge definition, incomplete

Extra keywords: physci

3. Electric charge is:

   a) a fundamental property of matter: it comes in invariant quantized amounts of size $\pm e$.
   b) a derived property of matter: it comes in somewhat variable quantized amounts of size $\pm e$ more or less.
   c) a fundamental property of matter which comes in a continuum of quantities: there is no smallest bit of charge.
   d) a derived property of matter which comes in a continuum of quantities: there is no smallest bit of charge.
   e) amber.

   SUGGESTED ANSWER: (a)

   Wrong answers:
   e) Forever Amber. Where it all began since the Greek word for amber mutated into electricity and electron.

   Redaction: Jeffery, 2001jan01

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014 qmult 00210 1 1 3 easy memory: electric charge causes electric force

4. Electric charge is a cause (but not the only one in direct sense) of the electric field. The electric field is the direct cause of the electric force in the modern conception of electromagnetism. Thus, in a indirect sense, charge is a cause of:

   a) the Hooke's law force b) the gravitational force. c) the electric force.
   d) short circuits e) electric bills.

   SUGGESTED ANSWER: (c)

   Wrong answers:
   d) Not an answer at all. No quibbles.

Fortran-95 Code

Redaction: Jeffery, 2012jan01

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014 qmult 00220 1 1 3 easy memory: two kinds of electric charge

5. There are two kinds of electric charge:

   a) black and white. b) north and south. c) positive and negative. d) left and right.
   e) up and down.

   SUGGESTED ANSWER: (c)

   Wrong answers:
   a) Wouldn't have worked as well.

   Redaction: Jeffery, 2012jan01

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014 qmult 00222 1 1 1 easy memory: like repel, unlike attract

6. Like charges _____ and unlike charges _____.

   a) repel; attract b) attract; repel c) repel; repel d) attract; repel
   e) compel; detract

   SUGGESTED ANSWER: (a)

   Wrong answers:
   b) Exactly wrong.
   e) As Tas would say: #$&XX!!X%@@!!XX!!! .

   Redaction: Jeffery, 2012jan01

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014 qmult 00224 1 1 4 easy memory: net charge conserved

7. Net charge is _____. Positive are and negative charge are _____.

   a) not conserved; conserved b) not conserved; not conserved c) conserved; conserved
   d) conserved; not conserved e) sometimes conserved; not conserved

   SUGGESTED ANSWER: (d)

   Wrong answers:
   a) Exactly wrong.

   Redaction: Jeffery, 2012jan01

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014 qmult 00230 1 1 1 easy memory: elementary charge 1

Extra keywords: physci KB-169-1

8. The absolute value of the smallest nonzero physical amount of electric charge (not considering quarks) is:

   a) e or $1.602\ldots \times 10^{-19}$ C. b) 1 C. c) indefinitely small. d) indefinitely large.
   e) indeterminate.

   SUGGESTED ANSWER: (a)

   Wrong answers:
   e) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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014 qmult 00240 1 4 5 easy deducto-memory: ordinary matter neutral

Extra keywords: physci

9. "Let's play *Jeopardy*! For $100, the answer is: It is usually approximately electrically neutral."

   What is _____, Alex?

   a) an electron b) a proton c) highly charged matter
   d) highly negatively charged matter e) ordinary, terrestrial matter above the atomic scale

SUGGESTED ANSWER: (e)

Wrong answers:
a) C'mon.

Redaction: Jeffery, 2001jan01

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014 qmult 00242 1 4 5 easy memory: no microscopic charge neutralization
Extra keywords: physci

10. Why don't positive and negative charge largely neutralize each other at the microscopic level just like they mostly do at the macroscopic level? The short answer is it is forbidden in most circumstances by _____.

a) classical physics b) James Clerk Maxwell c) Michael Faraday d) Ben Franklin
e) quantum mechanics

SUGGESTED ANSWER: (e):

Quantum mechanics is formulated in terms of differential equations and a lot of other rules that have been found to work. When you have elementary positive and negative charges in proximity and they don't have the energy to escape each other and they don't annihilate each other (or undergo some other metamorphosis), they can form stable, charge-separated structures according to these quantum mechanical rules: e.g., atoms.

Wrong answers:
a) No it doesn't and the stability of atoms began to puzzle people at the end of the 19th century.

Redaction: Jeffery, 2001jan01

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014 qmult 00250 1 1 2 easy memory: electrons not permanently bound
Extra keywords: physci KB-169-7

11. Electrons in an atom are:

a) permanently bound to the atom. b) **NOT** permanently bound to the atom.
c) confined to the nucleus. d) more massive than the nuclues. e) green.

SUGGESTED ANSWER: (b)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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014 qmult 00260 2 3 3 moderate math: charge on 1 g of protons
Extra keywords: physci KB-173-1

12. Given the mass of a proton is 1.67×10^{-24} g and the elementary charge is 1.602×10^{-19} C, what approximately is the total charge of 1 g of protons?

a) 1.67×10^{-24} C. b) 1.602×10^{-19} C. c) 10^{5} C. d) 2.5×10^{-43} C. e) zero.

SUGGESTED ANSWER: (c)

Behold:

$$Q = Ne = \frac{M}{m_{\text{proton}}} e = \frac{1}{1.67 \times 10^{-24}} \times 1.602 \times 10^{-19} \approx 10^{5}\,\text{C} ,$$

where N is the number of protons, $M = 1$ g, and m_{proton} is the mass of a proton.

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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014 qmult 00300 1 4 5 easy deducto-memory: Coulomb's law

13. "Let's play *Jeopardy*! For $100, the answer is:

$$F = \frac{kq_1q_2}{r^2} ,$$

where $k = 8.987\ldots \times 10^9$ in MKS units is Coulomb's constant, q_1 is the charge on object 1, q_2 is the charge on object 2, r is the distance between the objects, and F is the magnitude of force between the objects. This formula holds for objects which are must smaller in size scale than r or are spherically symmetric and not overlapping."

What is _____, Alex?

a) Volta's law b) Ohm's law c) Ampere's law d) Franklin's law e) Coulomb's law

SUGGESTED ANSWER: (e)

Wrong answers:
b) Ohm, ohm on the range . . . .

Redaction: Jeffery, 2012jan01

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014 qmult 00304 1 1 5 easy memory: category of Coulomb's law
Extra keywords: physci KB-169-5
14. Coulomb's law is a:

a) societal law. b) law of thermodynamics. c) law of motion. d) conservation law. e) force law.

SUGGESTED ANSWER: (e)

Wrong answers:
a) Oh, c'mon.

Redaction: Jeffery, 2001jan01

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014 qmult 00306 1 1 2 easy memory: net charge and force
Extra keywords: physci KB-172-9 This is a simplified version.
15. For two **POINT** masses to exert a Coulomb force on each other:

a) both must be uncharged. b) both must be charged. c) one must charged and the other uncharged. d) their charges must both be greater than 1 C. e) their charges must both be less than 1 C.

SUGGESTED ANSWER: (b)

Bodies with structure that have no net charge can in many cases exert electric force and have electric net force exerted on them. The most obvious case is that of dipoles which have no net charge, but have positive and negative ends. More complex (i.e., higher) multipole structures can also interact via the electric force.

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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014 qmult 00310 1 1 5 easy memory: Coulomb's law is an inverse-square law
16. Coulomb's law is an:

a) cube law. b) square law. c) inverse-sine law. d) inverse-cube law. e) inverse-square law.

SUGGESTED ANSWER: (e)

Wrong answers:
b) Exactly wrong.

Redaction: Jeffery, 2012jan01

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014 qmult 00312 1 1 2 easy memory: Coulomb's law calculation 1
17. If you **DOUBLE** the distance between charged particles, the force between them:

a) increases by a factor of 4. b) decreases by a factor of 4. c) decreases by a factor of 2. d) increases by a factor of 2. e) decreases by a factor of 9.

SUGGESTED ANSWER: (b)

Wrong answers:
a) Exactly wrong.

Redaction: Jeffery, 2012jan01

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014 qmult 00320 1 1 2 easy memory: electric and gravity force inverse-square
Extra keywords: physci KB-140 sort of
18. The electrostatic force and gravity are both _____ force laws.

a) inverse-linear b) inverse-square c) inverse-cube d) linear e) quadratic

SUGGESTED ANSWER: (b)

Wrong answers:
d) This is the Hooke's law force or the linear restoring force: $F = -kx$.

Redaction: Jeffery, 2001jan01

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014 qmult 00322 3 3 3 hard math: Coulomb and gravitational force
Extra keywords: physci KB-171-5
19. Coulomb's law and the point-mass gravitational formula in scalar form are, respectively:

$$F_{\mathrm{C}} = \frac{kq_1q_2}{r^2} \qquad \text{and} \qquad F_{\mathrm{G}} = \frac{Gm_1m_2}{r^2} \ ,$$

where $k = 8.98755179 \times 10^9\,\mathrm{N\,m^2/C^2}$, $G = 6.67428(67) \times 10^{-11}$ in MKS units, q stands for charge, m for mass, 1 and 2 for particles 1 and 2, and r is the distance between the particles. The mass of electrons is $9.1093826 \times 10^{-31}\,\mathrm{kg}$ and their electric charge is $1.60217653 \times 10^{-19}\,\mathrm{C}$. Approximately, what is the ratio of the magnitude of gravitational force to the magnitude of the electrical force between two electrons (i.e., $F_{\mathrm{G}}/F_{\mathrm{C}}$) for any distance r?

a) 1. b) 10. c) 3×10^{-43}. d) 3×10^{43}. e) 10^{-19}.

SUGGESTED ANSWER: (c) The answer can actually be deduced with only a little math. Behold

$$\frac{F_{\mathrm{G}}}{F_{\mathrm{C}}} = \frac{Gm_1m_2}{kq_1q_2} \approx \frac{7 \times 10^{-11}(10^{-30})^2}{10^{10} \times (1.6 \times 10^{-19})^2} \approx 3 \times 10^{-43} \ .$$

This is pretty small. Clearly, the electrical force between elementary charges is very dominant over the gravitational force. The gravitational force is negligible, in fact.

Wrong answers:
e) Gauss's law is equivalent to Coulomb's law: each implies the other.

Redaction: Jeffery, 2001jan01

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014 qmult 00400 1 1 3 easy memory: electric field
20. The electric field is a vector field. At each point in space it has a magnitude and a direction. The direction is in real space. The extent of the electric field vector is in its own abstract space. The electric field is the direct cause of:

a) gravitational force. b) magnetic force. c) electric force. d) charge. e) pressure.

SUGGESTED ANSWER: (c)

Wrong answers:
a) A nonsense answer.

Redaction: Jeffery, 2012jan01

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014 qmult 00410 1 1 3 easy memory: electric field and force
21. The general formula for the electric force on a point charge q caused by an electric field $\vec{E}$ is:

a) $\vec{F} = q/\vec{E}$. b) $\vec{F} = \vec{E}/q$. c) $\vec{F} = q\vec{E}$. d) $\vec{F} = q^2\vec{E}$. e) $\vec{F} = \vec{E}/q^2$.

SUGGESTED ANSWER: (c)

Wrong answers:
a) As Lurch would say: AAAAaarrrgh.

Redaction: Jeffery, 2012jan01

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014 qmult 00420 1 4 4 easy deducto-memory: electric field lines

22. "Let's play *Jeopardy*! For $100, the answer is: These curves are tangent to the electric field vector at every point along then. They point in the direction of the electric field. On positive charge, they only start; on negative charge they only end. They can extend to infinity or, when caused by the Maxwell-Faraday law of induction, form closed loops. They can never cross since a vector cannot point two ways at once, except they can cross when the electric field goes to zero since a zero vector has an indeterminate direction."

    What are _____, Alex?

    a) zigzags. b) equipotential lines c) magnetic field lines d) electric field lines e) dipole field lines

SUGGESTED ANSWER: (d)

Wrong answers:
a) As Lurch would say AAAARGH.

Redaction: Jeffery, 2012jan01

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014 qmult 00450 1 1 4 easy memory: electric field lines at conductors

23. In electrostatic cases, the electric field lines at a conductor surface are always _____ to the surface.

    a) outward b) randomly oriented c) parallel d) normal e) inward

SUGGESTED ANSWER: (d)

Wrong answers:
c) Exactly wrong.

Redaction: Jeffery, 2012jan01

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014 qmult 00500 1 1 4 easy memory: conduction classes

Extra keywords: physci

24. There are four main charge conduction categories for material:

    a) insulator, conductor, demiconductor, orchestra conductor.
    b) insulator, conductor, semiconductor, infraconductor.
    c) insulator, conductor, semiconductor, Superman-conductor.
    d) insulator, conductor, semiconductor, superconductor.
    e) insulator, conductor, semiconductor, demisemiconductor.

SUGGESTED ANSWER: (d) We usually think only of metals as conductors. But ionic fluids and ionized gases can also conduct. Ionic fluids can be pure fluids, but the more strongly conducting ones have solutes in them.

Wrong answers:
a) Orchestra conductor?
c) The last one on trains is a very difficult man get away with fooling.

Redaction: Jeffery, 2001jan01

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014 qmult 00510 1 4 2 easy deducto-memory: conductors defined

Extra keywords: physci

25. "Let's play *Jeopardy*! For $100, the answer is: These materials allow an electric current to flow through them easily."

    What are _____, Alex?

a) insulators b) conductors c) vacuum states d) solids e) crystals

SUGGESTED ANSWER: (b)

Wrong answers:
a) Exactly wrong

Redaction: Jeffery, 2001jan01

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014 qmult 00512 1 4 1 easy deducto-memory: insulators defined
Extra keywords: physci

26. "Let's play *Jeopardy*! For $100, the answer is: These materials do **NOT** allow an electric current to flow through them easily."

What are _____, Alex?

a) insulators b) conductors c) vacuum states d) solids e) crystals

SUGGESTED ANSWER: (a)

Wrong answers:
b) Exactly wrong

Redaction: Jeffery, 2001jan01

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014 qmult 00600 1 4 5 easy deducto-memory: conductors in E-fields

27. "Let's play *Jeopardy*! For $100, the answer is: In electrostatic cases, these materials have no macroscopic electric field in their interiors, have electric field normal to their surfaces, have no macroscopic net charge in their interiors, and have any net charge on their surfaces. In the macroscopic picture we are using, the surface is an infinitely thin, inpenetrable barrier."

What are _____, Alex?

a) insulators b) superconductors c) gases d) liquids e) conductors

SUGGESTED ANSWER: (e)

Wrong answers:
a) As Lurch would say AAAARGH.

Redaction: Jeffery, 2012jan01

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014 qmult 00650 1 1 1 easy memory: Faraday cage

28. A good conductor in an electrostatic case will have no electric field in any cavity caused by charges in the conductor or by an external applied field. Thus, the conductor shields the cavity from external fields. Although perfect shielding is only guaranteed in exactly electrostatic cases with the cavity having no holes to the outside, in practice, the shielding is often pretty good for even pretty rapidly varying external electric fields and for cavities with quite a few holes. Thus, practical structures for very general shielding are easy to make and, in fact, are ubiquitous in technology. These structures are called:

a) Faraday cages. b) Faraday traps. c) Faraday shields. d) Ampere traps.
e) Coulomb traps.

SUGGESTED ANSWER: (a)

Wrong answers:
c) It would make sense, but that's not what they are called.

Redaction: Jeffery, 2012jan01

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014 qmult 00720 1 1 4 easy memory: two-ball induction charging 1

29. Two uncharged conducting balls A and B are mounted on insulating stands. The balls are touching. A positively charged rod is brought from infinity to near B, but **NOT** so near A. The balls are then separated and the rod is put back at infinity. The charges on A and B are, respectively:

a) positive and positive. b) negative and negative. c) negative and positive.
d) positive and negative. e) zero and zero.

SUGGESTED ANSWER: (d)

When the rod is brought up to B, negative charge is attracted to the rod and positive charge is repelled. So B becomes a bit negative and A a bit positive. When the balls are separated, they can no longer exchange charge and so A remains positive and B becomes negative.

If we specify that the conductors are metals (which implicitly we have since we have treated them like metals), then in a microscopic description B acquires an excess of electrons and A has a deficiency. In metals, electrons are the charge carriers and are mobile. The positive charge is the protons in the atomic nuclei and that is essentially immobile in metals. In fluids and gases, there can be positive and negative ions both of which are mobile.

If the rod were removed before the balls were separated, then the attractive force between positive and negative would have quickly neutralized both balls.

Wrong answers:

a) This violates the conservation of charge.

Redaction: Jeffery, 2008jan01

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014 qmult 00750 1 1 3 easy memory: polarization

30. Charge separation in a object is called:

a) rasterization. b) pasteurization. c) polarization. d) north polarization. e) miniaturization.

SUGGESTED ANSWER: (c) The object doesn't have to be neutral, but usually we think of neutral objects first when thinking of polarization.

Wrong answers:

a) Something computer system nerds go on about.
d) Only by Santa Claus.

Redaction: Jeffery, 2001jan01

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014 qmult 00770 3 5 4 hard thinking: neutral finite body attract-repel

Extra keywords: physci-172-9 This is the hard version

31. Can two finite bodies each electrically neutral overall ever attract or repel each other?

a) No.
b) Always.
c) Always and no.
d) **YES**. For example, consider two small, non-conducting balls attached by a non-conducting bar: give one ball a positive charge (uniformly spread) and the other ball a negative charge (uniformly spread) of the same magnitude. The structure is an electric dipole that is overall neutral. Now consider a second identical dipole. Align the two with unlike ends closest and then with like ends closest. The distance between the balls is a fixed distance a in both cases. The force between the two unlike ends is attractive and between the like ends is repulsive. What of the other forces between the balls? We can make the bars as long as we like. The other forces between the balls get smaller and smaller as we make the bars longer and longer. Eventually the other forces become negligible and the closest ball forces dominate.
e) They can **REPEL**, but never **ATTRACT**. That is the valid conclusion of answer (d).

SUGGESTED ANSWER: (d)

The longest-answer-is-right rule triumphs again.

Wrong answers:

a) The right answer proves this is not the case.
b) Not always. Two neutral non-polarized objects would not attract or repel. Such objects are an idealization strictly speaking, but are approximately realized to high accuracy by most macroscopic objects most of the time.
c) A logical impossibility.
e) C'mon, why wouldn't there be attraction.

Redaction: Jeffery, 2001jan01

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014 qmult 00800 1 1 3 easy memory: electric potential

32. Electric potential (AKA voltage) is the electric potential energy:

a) period. b) divided by the electric field magnitude. c) per unit point charge.
d) always negative. e) always positive.

SUGGESTED ANSWER: (c)

Wrong answers:
a) Nope.

Redaction: Jeffery, 2012jan01

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014 qmult 00810 1 1 5 easy memory: symbol and unit for potential

33. The standard symbol for electrical potential is _____ and the MKS unit is _____.

a) J; joule (J) b) V; joule (J) c) V; joule (J) d) V; volt (V) e) V; volt (V)

SUGGESTED ANSWER: (e)

Wrong answers:
d) In physics, constants and variables are in italic and units are in roman.

Redaction: Jeffery, 2012jan01