

**PHY2054 Summer 2006 Exam 1 06 June 2006 Solutions**

*Unless otherwise indicated, (1) is the correct answer.  
Solutions are, of necessity (due to the writer's self-taught & primitive word-processing skills), brief but should be comprehensible if you studied the material.....email me if you spot errors!*

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1. Two particles, X and Y, are 4 m apart. X has a charge of  $2Q$  and Y has a charge of  $Q$ . The electrostatic force exerted by X on Y :
- (1) has the same magnitude as the force of Y on X.
  - (2) has half the magnitude of the force of Y on X.
  - (3) has four times the magnitude of the force of Y on X.
  - (4) has one-fourth the magnitude of the force of Y on X.
  - (5) has twice the magnitude of the force of Y on X.

*$F = K (q_1 q_2)/r^2$  . Existence of the force requires both charges, so it is the same on both charges, regardless of their individual magnitudes!*

2. Two particles have charges  $+Q$  and  $-Q$  equal magnitude and opposite sign). For a net force of zero to be exerted on a third charge it must be placed:
- (1) at none of the places listed there's no such location).
  - (2) on the perpendicular bisector of the line joining  $Q$  and  $-Q$ , but not on that line itself.
  - (3) on the line joining  $Q$  and  $-Q$ , to the side of  $Q$  opposite  $-Q$ .
  - (4) on the line joining  $Q$  and  $-Q$ , to the side of  $-Q$  opposite  $Q$ .
  - (5) midway between  $Q$  and  $-Q$ .

.....(+Q).....(-Q).....

*Try it! For this kind of charge configuration, there's no place for a third charge along the dotted line, above it, or below it , where the force is zero!*

3. A particle with charge  $2\mu\text{C}$  charge is placed at the origin. An identical particle, with the same charge, is placed 2 m from the origin on the x axis, and a third identical particle, with the same charge, is placed 2 m from the origin on the y axis. The magnitude of the force on the particle at the origin is:

- (1)  $1.3 \times 10^{-2}$  N
- (2)  $6.4 \times 10^{-3}$  N
- (3)  $9.0 \times 10^{-3}$  N
- (4)  $1.8 \times 10^{-2}$  N
- (5)  $3.6 \times 10^{-2}$  N

*Sketch the configuration. The charged particles on the x- and y-axes, respectively, exert repulsive forces on the particle at the origin. The forces are equal, so regardless of where we place the off-origin particles ( $\pm x, \pm y$ ) the*

resultant force must be at  $45^\circ$ .  $\therefore$  the net force is  $2 [K (2 \times 10^{-6} \text{ C})^2 / 4\text{m}^2] \sin 45^\circ$ .

4. An isolated charged point particle produces an electric field with magnitude  $E$  at a point 2 m away. At a point 1 m from the particle the magnitude of the field is:

- (1)  $4E$    (2)  $2E$    (3)  $E$    (4)  $E/2$    (5)  $E/4$   
 $E = Kq/r^2$  so if  $r$  is halved  $E = Kq/(r/2)^2 = 4Kq/r^2 = 4E$

5. A 200-N/C electric field is in the positive  $x$  direction. The force on an electron in this field is:

- (1)  $3.2 \times 10^{-17}$  N, in the negative  $x$  direction  
(2) 200 N in the positive  $x$  direction  
(3)  $3.2 \times 10^{-17}$  N, in the positive  $x$  direction  
(4) 200 N in the negative  $x$  direction  
(5) 0

$F = eE$  where  $e =$  electron charge. Since the direction of  $E$  is always the direction of the force on a + charge and  $e$  is negative, the force here is toward ( $-x$ ).

6. A tiny charged sphere with a mass of  $2 \times 10^{-4}$  kg is held suspended by a downward electric field of 300 N/C. The charge on the sphere is:

- (1)  $-6.5 \times 10^{-6}$  C  
(2)  $-1.5 \times 10^{-6}$  C  
(3)  $+6.5 \times 10^{-6}$  C  
(4)  $+1.5 \times 10^{-6}$  C  
(5) 0

For suspension, the upward & downward forces are in equilibrium; hence  $mg = qE \Rightarrow q = mg/E$ . Substituting the given quantities yields answer (1).  $E$  is downward but the electrostatic force must be upward to counteract the gravitational force, so  $q$  must be negative.

7. A conducting sphere of radius 0.01 m has a charge of  $1.0 \times 10^{-9}$  C deposited on it. The magnitude of the electric field in N/C just outside the surface of the sphere is:

- (1) 90,000   (2) 450   (3) 900   (4) zero   (5) 4500  
 $E = Kq/r^2 = 90,000 \text{ N/C}$

8. A particle with a charge of  $5.5 \times 10^{-8}$  C charge is fixed at the origin. A particle with a charge of  $-2.3 \times 10^{-8}$  C charge is moved from  $x = 3.5$  cm on the  $x$  axis to  $y = 3.5$  cm on the  $y$  axis. The change in the potential energy of the two-charge system is:

- (1) zero   (2)  $-3.2 \times 10^{-4}$  J   (3)  $9.3 \times 10^{-3}$  J   (4)  $-9.3 \times 10^{-3}$  J   (5)  $3.2 \times 10^{-4}$  J  
The moving particle starts and ends at the same distance from the origin. Thus it remains at the same potential with respect to the charge at the origin; hence there's no change in  $V$ .

9. During a lightning discharge, 30 C of charge moves through a potential difference of  $1.0 \times 10^8$  V in  $2.0 \times 10^{-2}$  s. The energy released by this lightning bolt is

- (1)  $3.0 \times 10^9$  J
- (2)  $1.5 \times 10^{11}$  J
- (3)  $6.0 \times 10^7$  J
- (4)  $3.3 \times 10^6$  J

(5) 1500 J

$U = \text{work done} = qV = \text{answer (1)}$

10. A conducting sphere with radius R is charged until the magnitude of the electric field just outside its surface is E. The electric potential of the sphere, relative to the potential far away, is:

- (1) ER
  - (2) E/R
  - (3) E/R<sup>2</sup>
  - (4) zero
  - (5) ER<sup>2</sup>
- $E = kq/R^2$ ;  $V = kq/R \Rightarrow V = ER$

11. A metal sphere of radius 20 cm. carries a charge of  $5 \times 10^{-9}$  C and is at a potential of 400 V, relative to the potential far away. The potential 10 cm from the center of the sphere is:

- (1) 400 V
  - (2) -400 V
  - (3)  $2 \times 10^{-6}$  V
  - (4) 0
  - (5) none of these
- $V$  anywhere inside a conductor is the same as  $V$  at the surface !

12. The work required to carry a particle with a charge of 6.0-C from a 5.0-V equipotential surface to a 6.0-V equipotential surface and back again to the 5.0-V surface is:

- (1) zero
  - (2)  $1.2 \times 10^{-5}$  J
  - (3)  $3.0 \times 10^{-5}$  J
  - (4)  $6.0 \times 10^{-5}$  J
  - (5)  $6.0 \times 10^{-6}$  J
- $E$  is conservative  $\Rightarrow$  work is independent of path taken. Since the round trip path here involves no net change in potential, no work is done!

13. Pulling the plates of an isolated charged capacitor apart:

- (1) increases the potential difference
- (2) increases the capacitance
- (3) does not affect the potential difference
- (4) decreases the potential difference
- (5) does not affect the capacitance

$C = \epsilon_0 A/d$  and  $Q = CV$ , hence  $\epsilon_0 A/d = Q/V$ . In an isolated capacitor,  $Q$  doesn't change, so if  $d$  increases  $V$  must increase. [Another way to think of it: work is required to pull the (oppositely charged) plates apart, implying an increase in potential]

14. A parallel-plate capacitor has a plate area of  $0.2 \text{ m}^2$  and a plate separation of 0.1 mm. To obtain an electric field of  $2.0 \times 10^6$  V/m between the plates, the magnitude of the charge on each plate should be:

- (1)  $7.1 \times 10^{-6}$  C
- (2)  $1.8 \times 10^{-6}$  C
- (3)  $3.5 \times 10^{-6}$  C
- (4)  $8.9 \times 10^{-7}$  C
- (5)  $1.4 \times 10^{-5}$  C

$\epsilon_0 A/d = Q/V \Rightarrow Q = \epsilon_0 AV/d = \epsilon_0 AE$ . Work it out!

15. Capacitors A and B are identical. Capacitor A is charged so it stores 10 J of energy and capacitor B is uncharged. The capacitors are then connected in parallel. The total stored energy in the capacitors is now:

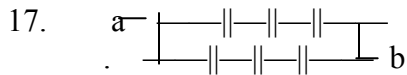
(1) 5 J (2) 10 J (3) 7.5 J (4) 15 J (5) 20 J

$U = Q^2/2C$ . When the second capacitor is connected in parallel, the total capacitance becomes  $2C$ . The charge  $Q$  remains the same, so now  $U = Q^2/2(2C) = Q^2/4C = U/2 = 10J/2 = 5J$

16. Copper contains  $8.4 \times 10^{28}$  free electrons/m<sup>3</sup>. A copper wire of cross-sectional area  $7.4 \times 10^{-7}$  m<sup>2</sup> carries a current of 1 A. The electron drift speed is approximately:

(1)  $10^{-4}$  m/s (2)  $10^{-3}$  m/s (3) 1 m/s (4)  $3 \times 10^8$  m/s (5)  $10^{-23}$  m/s

$I = nqvA \Rightarrow v = I/(nqA) = I/(neA)$



The diagram shows six  $6\text{-}\mu\text{F}$  capacitors. The capacitance between points a and b is:

- (1)  $4\mu\text{F}$  (2)  $6\mu\text{F}$  (3)  $3\mu\text{F}$  (4)  $9\mu\text{F}$  (5)  $1\mu\text{F}$

*Three identical capacitors  $C$  in series gives  $C' = C/3 = 6\mu\text{F}/3 = 2\mu\text{F}$ . Connecting a second identical set in parallel gives  $C = 2\mu\text{F} + 2\mu\text{F} = 4\mu\text{F}$*

18. A certain wire has resistance  $R$ . Another wire, of the same material, has half the length and half the diameter of the first wire. The resistance of the second wire is:

- (1)  $2R$  (2)  $R/2$  (3)  $R$  (4)  $R/4$  (5)  $4R$

*$R = \rho l/A$ . If the diameter is halved, the area becomes  $A/4$  and if  $l$  is also halved the resistance becomes  $R' = \rho (l/2)/(A/4) = 2R$*

19. A certain resistor dissipates  $0.5\text{ W}$  when connected to a  $3\text{ V}$  potential difference.

When connected to a  $1\text{ V}$  potential difference, this resistor will dissipate:

- (1)  $0.056\text{ W}$  (2)  $0.167\text{ W}$  (3)  $1.5\text{ W}$  (4)  $0.5\text{ W}$  (5) none of these

*$P = V^2/R \Rightarrow R = V^2/P = 9V^2/0.5\text{ W} = 18W$ . Hence  $P' = 1/18 = 0.056W$*

20. An ordinary light bulb is marked “60 watt, 120 volt”. Its resistance (when lit) is:

- (1)  $240\Omega$  (2)  $120\Omega$  (3)  $180\Omega$  (4)  $60\Omega$  (5)  $15\Omega$

*$P = V^2/R \Rightarrow R = V^2/P = 240\text{ W}$*