Problems – Part 1

1. A boat heading due to north crosses a wide river with a speed of 10 km/h relative to the water. The river has a uniform speed of 5 km/h. Determine the velocity of the boat with respect to a stationary ground observer.

2. Suppose that the displacement of a particle i given by the equation $x = a + bt + ct^2$ where *a*, *b* and *c* are the constants. Determine the expressions for the acceleration and velocity of this particle. Analyse this motion.

3. An electron in the picture tube of TV set, travelling in a straight line, accelerates uniformly from speed v_0=4.6x10^4 m/s to v=7.7x10^6 m/s in a region of length x=2 cm.
   a. How much time does the electron spend in this region?
   b. is the magnitude of the electron's acceleration?

4. The acceleration of the moving particle increases from rest at time t_o to the value of a_1 at time t_1 .
   a. Determine the velocity of this particle as a function of time *t*
   b. Express the trajectory of its motion as a function of time *t*

5. The angular displacement of a particle moving along the circle depends on the time as $\varphi = k_1 t^2 + k_2$
   where k_1 and k_2 are the constants. Determine the angular velocity and angular acceleration of the circular motion of this particle as the function of time *t* and analyse this motion.

6. A shaft rotating initially at 1725 revolutions per minute is brought to rest in 20 seconds. What is the average angular acceleration? How many times does the shaft turn during this period?

7. A wheel rotates with frequency f=1000 revolutions per minute. Its motion is retarded due to breaking during the time 2 minutes. Calculate the angular deacceleration and the number of revolutions performed during the stopping time.

8. A golfer wants to drive o golf ball a distance d=283 m. If the 4-wood launches the ball at 15^0 above the horizontal, what must be the initial speed of the ball to achieve the required distance? Ignore air resistance.

9. Find the initial angle if the range of a projectile is twice its maximum.

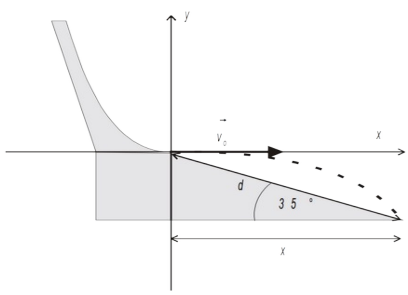

Fig. 10

10. A ski jumper travels down a slope and leaves the ski track moving in the horizontal direction with speed of v_0=25 m/s. The lauding incline below him falls off with a slope of 35^0.
   a. Where does he land on the incline?
   b. Determine how long the ski jumper is airborne.

11. A stone is thrown the top of a building upward at an angle of 30^0 to the horizontal and with an initial speed of 20 m/s. If the height of the building is 45m
    a. how long is stone “in flight”
    b. what is the speed of the stone just before it strikes the ground?

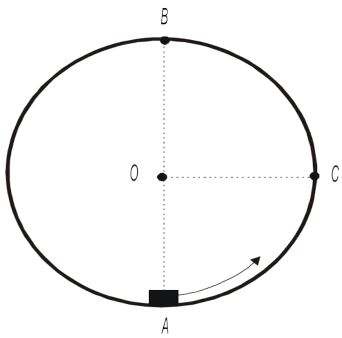

Fig. 13

12. A 3 kg mass undergoes an acceleration given by
    $a = (2i + 5j)$ m/s^2
    Find the resultant force, F , and its magnitude.

13. An object of mass 2 kg revolves in a vertical plane on the end of massless string 0.6 m long. At the bottom of its it has a speed of 6.0 m/s. Calculate:
    a. the speed of the body at the top of the loop
    b. centripetal force at the top

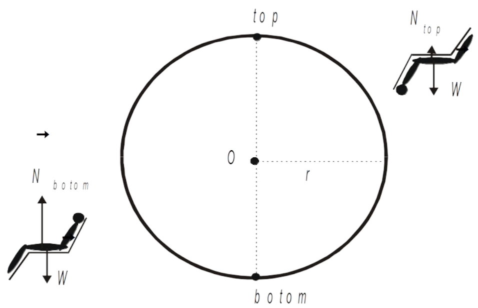

Fig. 14

    c. the net force on the body at point C Fig. 13
    d. the minimum speed at point A that will keep it moving in a circular path

14. A pilot of mass *m* in a jet aircraft executes a “loop the loop” maneuver. In this flying pattern, the aircraft moves in a vertical circle of radius 2.7 km at constant speed of 225 m/s. Determine the force of the seat on the pilot
    a. the bottom of the loop
    b. the top of the loop.

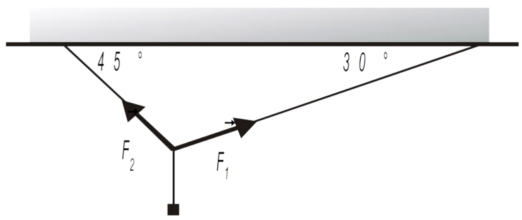

Fig. 15

15. Suppose a 1 kg mass is suspended from two cords as is shown in Fig.15. What is the tension in the cords?

16. A body of mass m=1 kg is hanging on the string of length l=0.3 m. The body revolves in a horizontal circle with constant speed. Since the sweeps out the surface of a come with the angle $\alpha = 60^0$, the system is known as a conical pendulum (see Fig.16). Find the speed of the body, tension and the period of revolution.

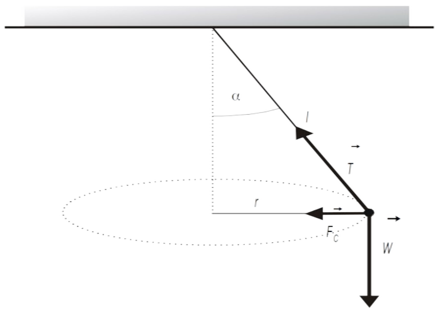

Fig. 16

17. A block of mass m is placed on a smooth, inclined plane of angle α.
    a. Determine the acceleration of a block after it is released
    b. Suppose the block is released from rest at the top and the distance from the block to the bottom is d. How long does it take the block to reach the bottom, and what is the speed just as it gets there?

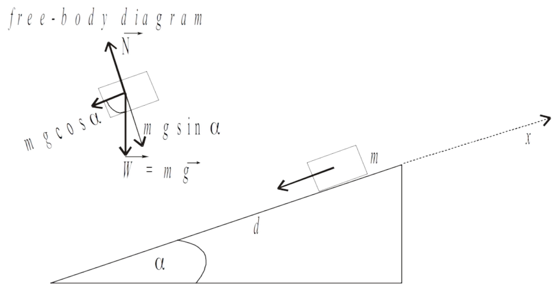

Fig. 17

18. A 3 kg block slides down a rough incline 1 m in length. The block starts from rest at the top and experiences a constant force of friction of magnitude 5 N. The angle of inclination is 30^0.
    a. Use energy method to determine the speed of the block when it reaches the bottom of the incline
    b. Check the answer to 'a.' using Newton's second law to first find the acceleration.

19. An elevator has a mass of 10^3 kg and carries a maximum load of 800 kg. A constant frictional force of $4x10^3$ N retards its motion upward. What must be the minimum power delivered by the motor to lift the elevator at constant speed of 3 m/s ?

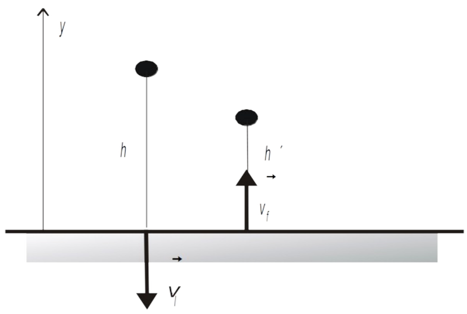

Fig. 20

20. A ball of mass 100 g is dropped from a height h=2 m above the floor. It rebounds vertically to a height h'=1.5 m after colliding with the floor.
    a. Find the momentum of the ball immediately before and after the ball collides with the floor

b. Determine the average force exerted by the floor of the ball. Assume the time of the collision is 10^{-2} s (this is typical value)

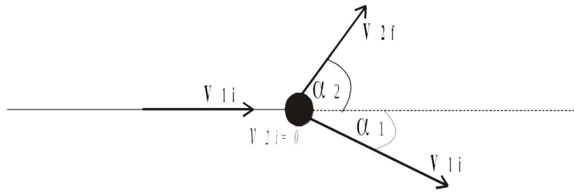

Fig. 21

21. A proton with an initial velocity of 10^6 m/s strikes another proton that is at rest initially. One proton (there is no way of knowing which one) is observed at an angle of 30^0 to the direction of the original beam as is in Fig.21. What is its velocity? With what velocity and in what direction will the other proton be observed?

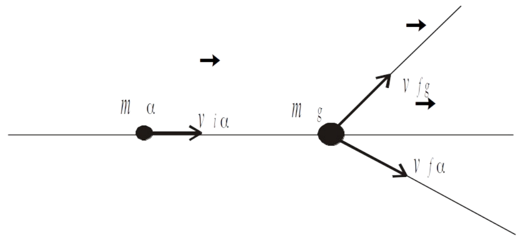

Fig. 22

22. In the experiment that first showed the nuclear character of atom, α particle were scattered from gold atom. The α particle is the nucleus of a helium atom and has a mass $m_\alpha = 6.64x10^{-27} kg$. The mass of the gold nucleus is $m_{Au} = 3.27x10^{-25} kg$. The α particles used were from decay of ^{226}Ra and have a kinetic energy of $7.64x10^{-13}$ J. What are the velocities of the α particles and the gold nucleus after collision? Note that the gold nucleus may be assumed to be at rest before being struck by the α particle. Situation is shown in Fig.32.

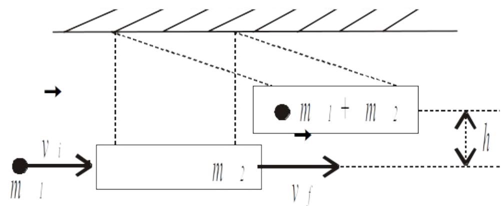

Fig. 23

23. Ballistic pendulum is a system used to measure the velocity of a fast-moving projectile. The projectile is fired into a large block of wood suspended from some light wires. The bullet is stopped by the block, and the entire system swings through a height *h* as is shown in Fig.23. Determine the initial velocity of the projectile.

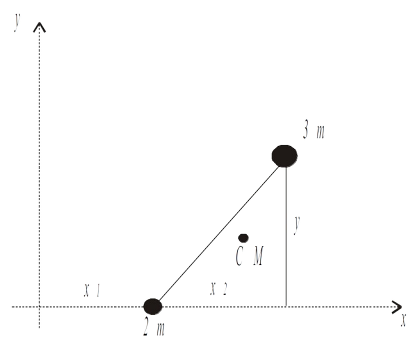

Fig. 24

24. A system consists of three particles located at the corners of a right triangle as is shown in Fig.24. Find the center of mass of the system.

25. Compute the location of the center of mass of a half of sphere of mass m and radius r.

26. An object of mass m is in the shape of a right triangle. Locate the coordinates of the center of mass, assuming the object has a uniform mass per unit area.

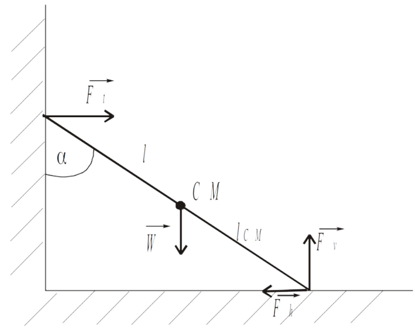

Fig. 27

27. Suppose a ladder 450 cm long a weighing 120 N with its center of mass 180 cm from the ground end is leaning against a wall as is shown in Fig.27. The angle α is assumed to be 30^0 and it is also assumed that the wall can exert only a normal force on the ladder. Determine the magnitude of horizontal components F_T and F_W if the ladder is at rest Fig.27

28. Calculate the moment of inertia of a uniform rigid rod of length l=1 m and mass m=0.5 kg about an axis perpendicular to the rod passing through

a. its center of mass

b. the end of the rod

29. Uniform solid cylinder has a radius R, mass m and length l. Calculate the moment of inertia about its axis.

30. Calculate the moment of inertia and the rotational kinetic energy of the oxygen molecule O_2 about z-axis. At room temperature the "average" separation between two oxygen atoms is $1.21x10^{-10}$ m and mass of oxygen atom is $2.66x10^{-26}$ kg. The distance of each atom from z-axis is $d/2$ and average angular velocity is $\varpi = 2.0x10^{12}$ rad/s.

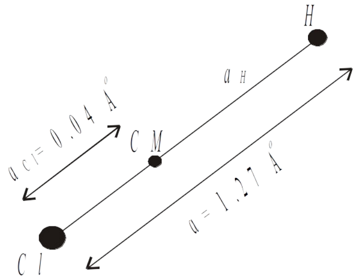

Fig. 31

31. The hydrogen chloride molecule consists of a hydrogen atom separated by $1.27\ x10^{-10}$ m from a chlorine atom that has a mass 35 times greater. The mass is concentrated in the nuclei and hence the molecule has essentially zero moment of inertia about an axis that consists of the line passing through the two atoms. An axis that passes through the molecule center of mass is not zero (see Fig.31). Calculate

a. the moment of inertia of the molecule HCl

b. frequency of rotation of this molecule.

32. A simple pendulum has a mass of 0.25 kg and a length of 1 m. It is displaced through the angle of 15^0 and then released .What is

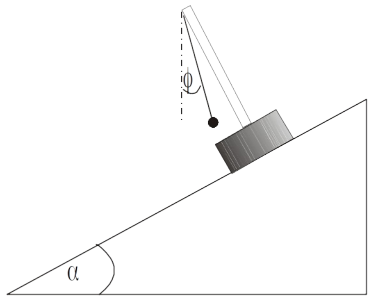

Fig. 36

a. the maximum velocity
b. maximum angular acceleration
c. the maximum restoring force

33. A physical pendulum in the form of planar body exhibits simple harmonic motion with a frequency of 0.45 Hz. If the pendulum has a mass of 2.2 kg and the pivot is located 0.35 m from the center of mass determine the moment of inertia of the pendulum.

34. Show by using a method of $\sin\phi = \phi$ that the equation of motion for a simple pendulum of length *l* is $\frac{d^2\phi}{dt^2} + \frac{g}{l} = 0$

35. A uniform rod of mass 0.5 kg and length 1 m is pivoted about one end and oscillates in a vertical plane. Find the period of oscillations *T*, if the amplitude of the motion is small.

36. A simple pendulum is attached to a support, which can slide down a frictionless incline, which makes an angle α with the horizontal. What angle ϕ does the pendulum make with the vertical?

37. A circular loop of radius *R* is hung over a knife edge. Show that its period of oscillation is equal to that of a simple pendulum.

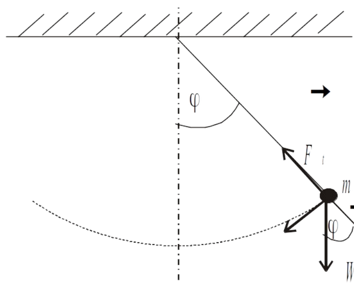

Fig. 38

38. The simple pendulum of mass is released at *t*=0 when the cord makes an angle $\phi = \phi_0$ to the vertical as is shown in Fig 38. The length of massless cord is *l*. Determine

a. speed as a function of position and at the lowest point
b. the tension in a cord Fig.36

Note ignore friction and air resistance.

39. A cylinder encloses 19.6 l of an ideal gas under a pressure of $1.4\text{x}10^{-4}$Pa at 27^0C. How many moles of gas does it contain?

40. A bubble of marsh gas rises from a bottom of a fresh-water lake at a depth of 4.2 m and a temperature of 5^0C to the surface where the temperature is 12^0C. What is the ratio of the bubble diameter at the two locations? (assume that the bubble gas is in thermal equilibrium with the water at each location).

41. A glass bottle containing air at atmospheric pressure p=101 kPa and having a volume of 30 cm^3 is at 23^0C. It is then tossed into an open fire. When the temperature of the air in the bottle reaches 200^0C what is the pressure inside the bottle?

42. Air in the cylinder of a diesel engine at 20^0C is compressed from an initial pressure of 1atm and volume of 800 cm^3 to a volume of 60 cm^3. Assuming the air behaves as an ideal gas ($\kappa = 1.4$) and that the compression is adiabatic, find the initial pressure and temperature.

43. The heat capacity, C, of a monoatomic gas measured at constant pressure is 62.3 J/K. Find
  a. the number of moles of gas
  b. the heat capacity at constant volume
  c. The internal energy of a gas at 350 K

44. Consider 2 moles of an ideal diatomic gas. Find the total heat capacity at constant volume and at constant pressure if
  a. the molecules rotate but not vibrate
  b. the molecules rotate and vibrate

45. Calculate the mean free path and collision frequency for a nitrogen molecules at a temperature of 20 ^{0}C and the pressure of 1 atm. Assume a molecular diameter of $2\text{x}10^{-10}$m

46. Gas in a container is at a pressure of 1.5 atm and volume of 4 m^3. What is the work done by the gas if
  a. it expands at constant pressure to twice its initial volume
  b. it is compressed at constant pressure to one quarter its initial volume ?

47. A gas is compressed at a constant pressure of 0.8 atm from volume of 9 liters to a volume of 2 liters.. In the process 400 J of heat energy flows out of the gas.
  a. What is the work done by the gas?
  b. What is the change in internal energy of the gas?

48. An ideal gas initially at 300 K undergoes an isobaric expansion at a pressure of 2.5 kPa. If the volume increases from 1 m^3 to 3 m^3 and 12500 J of heat is added to the gas, find
  a. the change in internal energy of the gas
  b. its final temperature

49. One gram of water occupies a volume of 1 cm^3 at atmospheric pressure. When this amount of water is boiled, it becomes 1671 cm^3 of steam. Calculate the change in internal energy for this process. Note that the heat of vaporization of water is $2.26\text{x}10^6$ J/kg at atmospheric pressure.

50. A thermodynamic system undergoes a process in which its internal energy decreases by 500 J. If at the same time, 220 J of work is done on the system, find the heat transferred to or from the system.

51. A cylinder contains 3 moles of helium gas at a temperature of 300K.
  a. How much heat must be transferred to the gas to increase its temperature to 500K if the gas is heated at constant volume?
  b. How much heat must be transferred to the gas at constant pressure to raise the temperature to 500K?
  c. What is the work done by the gas in this process? Note that for helium is C_V=12.5 J/mol.K and C_P=20.8 J/mol.K.

52. A steam engine has a boiler that operates at 500K. The heat changes water to steam, which drives the piston.The exhaust temperature is that of the outside air, about 300K. What is the maximum thermal efficiency of this steam engine?

53. A solid substance with a heat of fusion l_f melts at a temperature T_m. Calculate the change in entropy that occurs when m grams of this substance is melted.

54. Determine the amplitude of the acceleration of gravity at an altitude of 500 km. By what percentage is the weight of a body reduced at this altitude?

55. Locate the point between two fixed masses of m_3= 50 kg and m_2=80 kg, which are separated by 1m, where third mass of m_1=10kg feels no force.

56. A particle of mass m is displaced through a small vertical distance Δy near the earth's surface. Let us show that the general expression for the change in gravitational potential energy given by equation $\Delta U = \kappa M_E m \frac{r_f - r_i}{r_f r_i}$ reduces to relationship $\Delta U = mg\Delta y$.

57. Calculate the escape velocity from the earth for 5000kg spacecraft, and determine the kinetic energy it must have at the earth's surface in order to escape the earth's field.

58. A particle moves in a circular orbit of radius r under influence of the gravitational force due to a body of mass M. Calculate the total energy of the particle as a function of r.

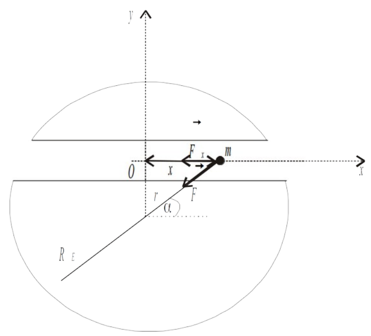

Fig. 60

59. Calculate the work required to move an earth satellite of mass m from circular orbit of radius $2R_E$ to one of radius $3R_E$.

60. An object moves in a smooth, straight tunnel dug between two points on the earth surface. Show that the object moves with simple harmonic motion and find the period of its motion. Assume that the earth's density is uniform throughout its volume (see Fig.60).

61. Halley's comet approaches the sun to within 8,55x10^{7}km, and its orbital period is 75.6 years. How far from the sun will Halley's comet travel before it starts its return journey? Situation is shown in Fig.61.

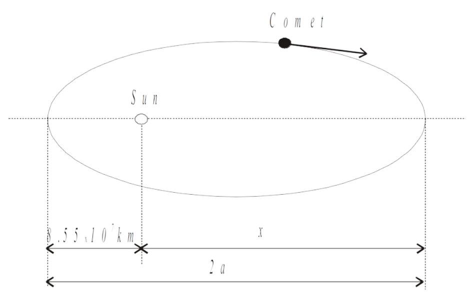

Fig. 61

62. A homogenous bar that has a length l and mass m is at a distance d from a point of mass m_0. Calculate the force on m_0 (see Fig.62)

63. A uniform solid sphere has a mass of 500kg and radius of 0.4m. Find the magnitude of the force on a particle of mass 50g located

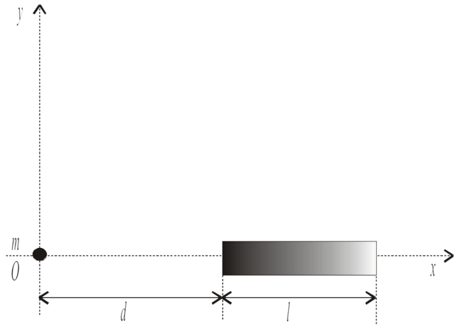

Fig. 62

a. 1.5m from the center of the sphere
b. at the surface of the sphere
c. inside the solid sphere

64. Three particles lie along the x-axis. The positive charge q_1=15 μC is at x=2m, and the positive charge q_2=6 μC is at origin. Where must a negative charge q_0 be placed on the x-axis such that the resultant force on it is zero?

65. The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately $5.3\text{x}10^{-11}$m. Find the magnitude of the electrical and the gravitational force between the two particles.

66. Two identical small charged spheres, each having a mass of $3\text{x}10^{-2}$kg, hang in equilibrium. If the length of each string is 0.15m and the angle $\alpha = 5^0$, find the magnitude of the charge on each sphere, assuming the spheres have identical charges.

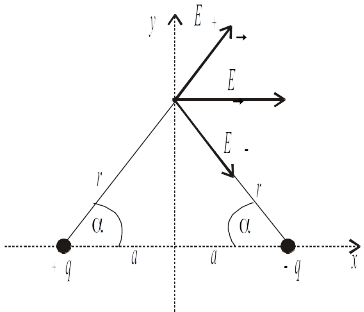

Fig. 67

67. An electric dipole consists of a positive charge q and negative charge $-q$ separated by a distance 2a. Find the electric field E due to these charges along the y-axis at the point P, which is a distance y from the origin. Assume that $y >> a$. (see Fig 67.)

68. Find a geometrical arrangement of one proton and two electrons such that the potential energy of the system is exactly zero. How many such arrangements are there with the three particles on the same straight line?

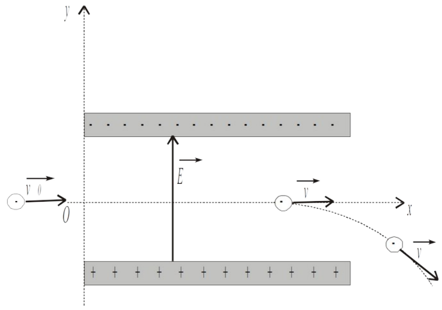

Fig. 69

69. An electron enters the region of a uniform electric field with velocity v_0=3x10^{6}m/s and E=200N/C. The width of the plates is l=0.1m. Find

a. the acceleration of the electron while in the electric field
b. the time it takes the electron to travel through the region of electric field
c. the vertical displacement y of the electron while it is in electric field

70. A proton moves in a region of a uniformly electric field. The proton experiences an increase in kinetic energy of 5x10^{-18}J after being displaced 2cm in a direction parallel to the field. What is the magnitude of the electric field E?

71. A positive point charge of 2x10^{-9}C, of a mass 10^{-3}kg is released from rest in a uniform electric field E=3x10^{4}N/C directed along the x-axis.

a. Describe its motion
b. Determine the value of acceleration of point charge due to the electric field
c. Calculate the velocity of point charge at time t=2s.

72. Find the electric potential and intensity of electric field along the x-axis of a uniformly charged disk of radius R and charge per unit area σ at the distance of a from the center of disk.

73. A rod of length l located along x-axis has a uniform charge per unit length λ and the total charge Q. Find the electric potential at a point P along the y-axis at the distance d from the origin.

74. Calculate the electric field of a uniformly charge sphere of radius R and the charge Q

a. outside the sphere
b. on the surface of the sphere
c. inside the sphere

Draw the graph of E versus the distance r from the center of the sphere.

75. The water molecule has a dipole momentum of 6.3x10^{-30}C.m. A sample contains 10^{21}such molecules, whose dipole moment are oriented in the direction of an electric field of 2.5x10^{5}N/C. How much work is required to rotate the dipoles from the orientation $\alpha = 0$ to one in which all moments are perpendicular to the field, i.e. $\alpha = 90^0$.?

76. A cylindrical conductor of radius a and charge q is concentric with a larger cylindrical shell of radius b and charge $-q$. Find the capacitance of this cylindrical capacitor if its length is l.