2018-2019 Term 2

PHYS1001 Essential Physics

Assignment 6

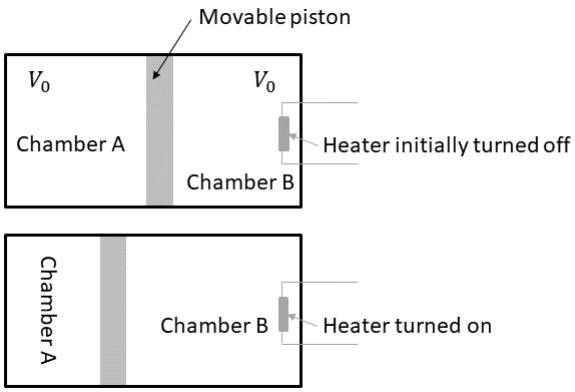
Due date: 19th March, 2019 by 6:00 pm

(Please leave your homework in the box with the label "PHYS 1001" outside room 213 in Science Centre North Block)

Please answer **all** six questions

1. Initially, an ideal gas has a pressure of 1.5×10^6 Pa, a volume of 2000 cm^3 and a temperature of 40 ℃. The gas expands until it reaches the standard temperature and pressure [Note: Standard temperature is 0℃ while standard pressure is 101325 Pa.].
   (a) Calculate the number of gas molecules present.
   (b) Calculate the final volume of the gas.
   Answers:
   (a)
   $$PV = nRT$$
   $$(1.5 \times 10^6)(2000 \times 10^{-6}) = n(8.314)(273 + 40)$$
   $$n = 1.15 \text{ moles}$$
   $$n = 6.94 \times 10^{24} \text{ molecules}$$
   (b) By the ideal gas law:
   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$
   $$\frac{(1.5 \times 10^6)(2000 \times 10^{-6})}{273 + 40} = \frac{(101.325 \times 10^3)V_2}{273 + 0}$$
   $$V_2 = 25.8 \times 10^{-3}\text{m}^3$$

2. A sealed cylinder is divided into two equal chambers by a piston as shown in the figure below. The initial temperature, pressure and volume of each chamber are T_0, P_0 and V_0 respectively. The wall of the cylinder and the piston are thermal insulators. Also, there is no friction between the piston and the cylinder. Now chamber B is heated by an electric heater for a short period of time. The gas in chamber B expands and pushes the piston to the left. After reaching equilibrium, the final volume and pressure of chamber A are 0.75 $V_0$and P_1 respectively. In addition, the final temperature of the gas in chamber A is 300 K.



(a) By applying the ideal gas law on the gas in chamber A, write down an expression relating T_0, P_0 and P_1.
(b) Express the final pressure of the gas chamber B in terms of P_1.
(c) Express the final volume of the gas in chamber B in terms of V_0.
(d) Using the results from (a) to (b), calculate the final temperature of gas in chamber B.

Answer:

(a)

$$\frac{P_0V_0}{T_0} = \frac{P_1V_1}{T_1}$$

$$\frac{P_0V_0}{T_0} = \frac{P_1(0.75\,V_0)}{300}$$

$$\frac{P_0}{T_0} = \frac{P_1}{400}$$

(b) At equilibrium, the final pressure of the gas in chamber B is also equal to P_1

(c) Since the total volume of the cylinder is $2V_0$ and the final volume of the gas in chamber A is $0.75\,V_0$, the final volume of the gas in chamber B is $2V_0 - 0.75\,V_0 = 1.25\,V_0$.

(c) Denoting the final pressure, volume and temperature of the gas in chamber B by $P_{B,final}$, $V_{B,final}$ and $T_{B,final}$ respectively

$$\frac{P_0V_0}{T_0} = \frac{P_{B,final}V_{B,final}}{T_{B,final}}$$

$$\frac{P_0V_0}{T_0} = \frac{P_1 1.25\,V_0}{T_{B,final}}$$

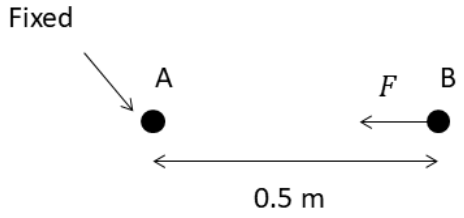
$$\frac{P_0}{T_0} = \frac{P_1 1.25}{T_{B,final}}$$

$$T_{B,final} = \frac{P_1T_0}{P_0}1.25$$

$$T_{B,final} = (400)1.25$$

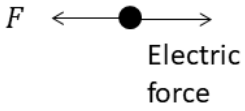
$$T_{B,final} = 500 \text{ K}$$

3. In the following diagram, charge A ($3\,\mu C$) is fixed at a location. Charge B (also carrying charges of $3\,\mu C$) is brought close to charge A. The separation between charge A and B is 0.5 m. A force is applied on charge B so that the charge stays at rest.



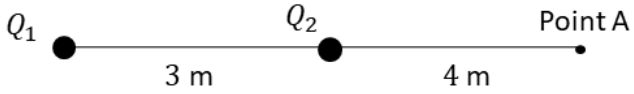
(a) Draw a force diagram for charge B.
(b) Calculate the magnitude of the applied force

Answer:
(a)



(b) The electrical force between A and B= $\frac{1}{4\pi\varepsilon_0}\frac{(3\times10^{-6})(3\times10^{-6})}{(0.5)^2} = 0.32$ N

4. Two point charges $Q_1 = 3e$ and $Q_2 = -5e$ are fixed and the separation between the two charges is 3 m as shown in the figure below.



(a) Calculate the electric field at point A due to charge Q_1. Indicate the direction of the electric field at point A due to charge Q_1
(b) Calculate the electric field at point A due to charge Q_2. Indicate the direction of the electric field at point A due to charge Q_2.
(c) For an electron placed at point A, what is the magnitude of the electric force acting on the electron due to the two charges? What is the direction of the electric force acting on the electron?

Answer:
(a) $|E_1| = \left|\frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r^2}\right| = \left|(8.988\times10^9)\frac{(3\times1.6\times10^{-19})}{(3+4)^2}\right| = 8.80\times10^{-11}$N/C
The electric field at point A due to charge Q_2 points to the right.

(b) $|E_2| = \left|\frac{1}{4\pi\varepsilon_0}\frac{Q_2}{r^2}\right| = \left|(8.988\times10^9)\frac{-5\times1.6\times10^{-19}}{(4)^2}\right| = 4.49\times10^{-10}$ N/C

The electric field at point A due to charge Q_2 points to the left.

(c) $E_{total} = 4.49\times10^{-10} - 8.80\times10^{-11} = 3.61\times10^{-10}$ N/C

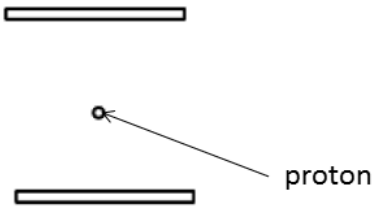
(The total electric field points to the left at point A)

Force on an electron at point A:

$|F| = |qE_{total}| = |(-1.6\times10^{-19})(3.61\times10^{-10})| = 5.78\times10^{-29}$ N

For a negatively charged electron, the direction of electric force is opposite to the direction of the electric field. The electric force points to the right.

5. A proton is suspended at rest between two horizontal parallel plates consisting of opposite charges as shown in the figure below.



(a) Draw a force diagram for the proton

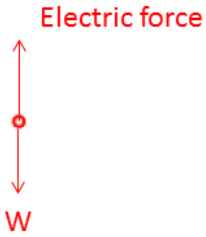
(b) Calculate the electric force and the electric field between the two plates (The mass of a proton is $m_p = 1.67\times10^{-27}$kg, $e = 1.6\times10^{-19}$C).

(c) Draw the appropriate charges on the two plates. Also indicate the direction of the electric field in your diagram.

(d) If the charge densities on the two plates are tripled, the electric field in the space between the two plates is tripled. Calculate the acceleration of the proton.

Answer:

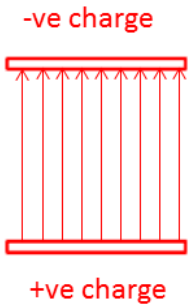
(a)



(b) $F_{electric} = mg = 1.67\times10^{-27}\times9.8 = 1.63\times10^{-26}$ N

$$E = \frac{F_{electric}}{q} = \frac{1.63\times10^{-26}}{1.6\times10^{-19}} = 1.02\times10^{-7}\ \text{N/C}$$

(c)

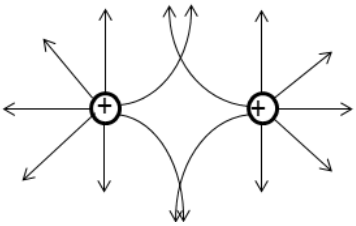


(d) $E = 3 \times 1.02 \times 10^{-7} = \frac{3mg}{q}$

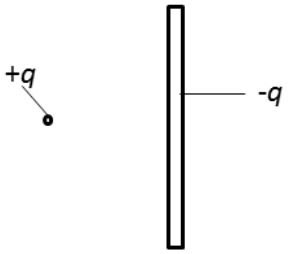
$$F_{electric} = 3mg$$

$$F_{electric} - W = ma$$
$$3mg - mg = ma$$
$$a = 2g \text{ (upwards)}$$

6. (a) Explain what is incorrect in the following field line diagram.



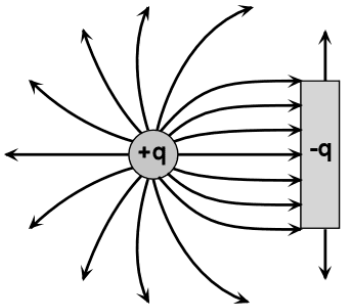
(b) A positive point charge $+q$ is placed at a distance from a negatively charged plate. Negative charges $-q$ are uniformly distributed on the plate. Draw the electric field pattern for this charge distribution.



Answer:

(a) Field lines should not cross over each other. The direction of the electric force is indicated by the tangent of the field line. If a test charge is placed at the position where field lines cross over each other, there will be two forces on the test charge, each pointing in a different direction. This contradicts our definition of electric field.

(b)



(Figure from http://physicslearning2.colorado.edu/pira/images/ResourceCD/ResourceImages/PhysicsDrawings/E_Field_Attraction_Charge_Plate.gif)