**Homework 1**

**P1.1.2** In a one-dimensional flow of current through a semiconductor, positively-charged holes move in the positive *x*-direction at a steady rate of , and electrons move in the negative *x*-direction at a steady rate of Determine the total current in mA in: (a) the positive *x*-direction, (b) the negative *x*-direction. (c) What would be the current if the holes and electrons move in the same direction? Note that the positive charge of a hole has the same magnitude as the charge on an electron.

**Solution:** (a) The current due to positive charges moving in the positive *x*-direction adds to the current due to negative charges moving in the negative *x*-direction. The total current is: += 0.02 A ≡ 20 mA..

(b) The sign of the current is reversed to –20 mA.

(c) The currents due to holes and electrons are in opposition. The total current is: + in the direction of movement.

**P1.1.4** In electroplating an object with silver, the object is made the cathode and a silver plate the anode. Silver ions in solution are attracted to the cathode, gain electrons from the cathode, and are deposited on the object as silver ions (Figure P1.1.4). (a) How many silver ions are deposited by a current of 10 A flowing for 1 hr? Note that a silver ion carries a single electronic unit of positive charge (+1.6×10-19 C); (b) If a gram-molecular weight of silver is 0.1079 kg and contains 6.025×1023 atoms (Avogadros’s number), what is the mass of silver deposited?



**Solution:** (a) The number of deposited silver atoms is .

(b) The mass of silver deposited is  kg ≡ 40 g.

**P1.2.2** Given an electric field *ξ* V/m that is constant in the *x*-direction and a charge +*q* C located at the origin and free to move in the *x*-direction (Figure 1.2.2). (a) What is the magnitude and direction of the force *F* acting on *q*? (b) If *q* moves under the influence of *F* a distance *d* m, how much work is done by *F*? (c) Assuming the voltage at the origin to be zero, what is the voltage *Vd* at *x* = *d* m, bearing in mind that *ξ = -dv/dx*? (d) How is the loss in electric potential energy related to the work done by *F*? (e) Assuming the charge has a mass m kg and zero velocity at the origin, show that the KE of the charge at *x* = *d* is equal to the loss in electric potential energy.



**Solution:** (a) From basic electrostatics, *F* = *q*ξ, in the direction of the electric field, where in SI units, q is in coulombs, *ξ* is in volts/meter, and F is in newtons.

(b) Since *F* is independent of *x*, work done by *F* is *W* = *Fd*.

(c)  V, the minus sign indicating that *v* decreases in the *x*-direction.

(d) The loss in electric PE is *qVd* = *qξd*, which is equal to *Fd*.

(e) The acceleration is *a* = *F*/*m* = *qξ*/*m* m/s2, which is constant. Hence, velocity is *at*. The distance travelled during the interval *t* is  . This gives: . The KE is , which is the loss in electric PE.

**P1.2.3** Consider the system of Figure P1.2.3, where the voltage *VAB* V between the two metal plates is maintained constant. Let there be a mechanism for moving positive charge from the lower plate to the upper plate. (a) How much work is done in moving an amount of charge +*q* C? What is the graph of *W* vs. *q*?



**Solution:** (a) In moving a charge *q* through a voltage rise *VAB*, the increase in electric PE is *qVAB*, which is equal to the work done in moving the charge.

(b) Since *W* = *qVAB*, with *VAB* constant, the graph of *W* vs. *q* is straight line of slope *VAB* passing through the origin.

**P1.2.4** Suppose that the voltage supply in Figure P1.2.3 is removed (Figure P1.2.4), but that positive charge is still moved from the lower plate to the upper plate. Assume that when the charge on the upper plate is +*q* C, with an equal and opposite charge -*q* C on the lower plate, the voltage between the plates is *v* = *Kq* V, where *K* is a constant. It is required to determine the work done in moving the amount of charge *qf* that establishes the voltage *VAB* = *Kqf*. To do this, consider an intermediate state when the charge is *q* C and the voltage is *v* V. Let an infinitesimal charge *dq* be moved, where *dq* is small enough to keep *v* constant while *dq* is moved. (a) What is the work *dW* that is done in moving the charge *dq*? (b) Substitute *Kq* for *v* and determine *W* by integrating between 0 and *qf*. (c) Express *W* as a function of *VAB*. (d) What is the graph of *W* vs. *q* in this case?



**P1.2.4** (a) The work done in moving *dq* through a voltage rise *v* is *dW* = *vdq*.

(b) Substituting *v* = *Kq*, *dW* = *Kqdq*, and  J.

(c) Substituting *qf* = *VAB*/*K*, .



(d) The graph of *W* vs. *q* is parabola centered at the origin.

**P1.3.2** The voltage *v* across an element A is a rectangular waveform of 5 V amplitude and 4 s duration (Figure P1.3.2).The current *i* through A in the direction of the voltage drop *v* is a biphasic pulse that



has an amplitude of +2 A, 0 < *t* < 2 s, and an amplitude of -2 A, 2 < *t* < 4 s. Determine the power delivered or absorbed by A during each 2 s interval. What is the total charge that has passed through A at *t* = 4 s?

**Solution:** During the interval 0 < *t* < 2 s, *i* is in the direction of a voltage drop *v*. Hence, A absorbs power equal to (5 V)×(2 A) = 10 W. During the interval 2 < *t* < 4 s, *i* reverses sign and becomes a current in the direction of a voltage rise *v*. Hence, A delivers power equal to (5 V)×(2 A) = 10 W. The charge is the area under the *i* vs. *t* graph. This charge is 4 C in one direction during the first 2 s and 4 C in the opposite direction during the next 2 s. The total charge though A is therefore zero at *t* = 4 s.



**P1.3.5** The voltage drop across a certain device, and the current through it, in the direction of voltage drop, are shown in Figure P1.3.5. Determine: (a) the charge *q* through the device at the end of each 1s interval from  to  (b) the instantaneous power  during the aforementioned intervals; and (c) the total energy consumed by the device.



**Solution:** (a) 0 < *t* < 1: *q* = ;

*t* = 2: *q* =  

*=* 2.5 mC;

*t* = 3: *q* = 2.5 +2.5

+5.5 mC;

*t* = 4: *q* = 5.5 +5.5

+8.5 mC;

*t* = 5: *q =* 8.5 +8.5 +8.5 += 11 mC;

*t* = 6: *q* = 11 + 11 mC.

(b) ;

mW;

mW;

mW;

mW;

.

(c) + +=  136/3 = 45.3 μJ.

**P1.3.7** The voltage drop  across a certain device, and the current  through it, in the direction of voltage drop, are related by:

 

  and

(a) Determine the power absorbed by the load when  and when  V; (b) at what value of  is the instantaneous power a maximum? (c) If V,  what is the total charge that passes through the device from *t* = 0 to ?

**Solution:** (a) ; *p = vi* = *v*(8 – 2*v*2) = –2*v*3 + 8*v*, and *p* = 0, .

At *v* = 1 V; *p* = 6 W; at *v* = 2 V, *p* = 0.

(b) , ; *pmax* V.

(c) ;C.