GNG 1106
Fundamentals of Engineering Computation

Computer Lab 1: Electrical Engineering Case Study – Lead Acid Batteries

Prof: Gilbert Arbez
Student Name: Vlad Serb
Student Number: 7360143

February 9th 2014

Step 1: Problem Identification and Statement

Evaluate one of two possible discharge rate tables depending on the user input, based on ampere-hour capacity ratings and the reserve capacity with the use of Peukert's Law and Peukert's equation.

Step 2: Gathering Information and Input/Output Description

Peukert's Equation: $\mathbf{T=C_p/I^n}$ where

T= time for battery to completely discharge in hours
C_p= the Peukert battery capacity in ampere-hour, when the battery is completely discharged at a current of 1 ampere.
I= the electrical current drawn from the battery in amperes.
n= the Peukert exponent that can vary from 1.1 to 1.4

Ampere-hour rating = RC*0.4 (estimate)
Discharge time = Ampere-hour ratings/25 amps

1. a) Two ampere-hour capacity ratings (in which one ampere-hour capacity rating consists of an ampere-hour value for a given electrical current value)

   b) One Ampere-hour rating and the reserve capacity rating (in which the reserve capacity is the time it takes for the battery to discharge when 25 amp current is drawn from it, in minutes).

2. Based on the user input in the previous sub step, the program will generate one of two rate tables. The user will be allowed to choose the step size of the tables and which of the two will be shown.

a) The user will input an initial electrical current value with a step size (for varying electrical current) to generate a discharge table of 10 entries with this format:

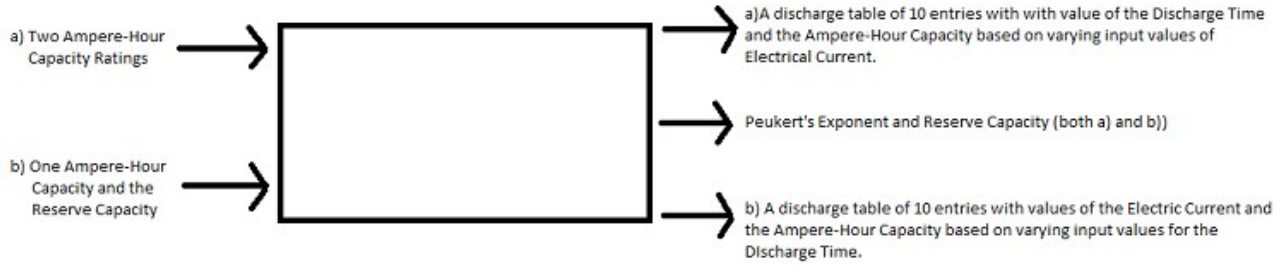
Electric Current	Discharge Time	Ah Capacity
User Input 1	Calculated Value	Calculated Value
User Input 1 + Step Size	Calculated Value	Calculated Value

The program will include the reserve capacity and the Peukert exponent.

b) The user will input an initial discharge time value with a step size (for varying the discharge time) to generate a discharge table of 10 entries with this formal format:

Discharge Time	Electric Current	Ah Capacity
User Input 1	Calculated Value	Calculated Value
User Input 1 + Step Size	Calculated Value	Calculated Value

The program will include the reserve capacity and the Peukert exponent.



The *inputs* are a and b.
The *outputs* a, b, and the Peukert Exponent and the Reserve Capacity.

Step 3: Test Cases and Algorithm Design

Lead-acid batteries discharge at a much faster when larger currents are drawn. Therefore, the amount of ampere-hour capacity is reduced with larger currents. For example, discharging at 20 amperes removes less energy than discharging at 10 amperes. Peukert's Equation is:

$$\mathbf{T=C_p/I^n}$$

T= time for battery to completely discharge in hours
C_p= the Peukert battery capacity in ampere-hour, when the battery is completely discharged at a current of 1 ampere.
I= the electrical current drawn from the battery in amperes.
n= the Peukert exponent that can vary from 1.1 to 1.4
When the battery discharges faster, the current drawn increases so the term $\mathbf{I^n}$ increases exponentially. The equation can be reworked and the current drawn from the battery as a function of the discharge time can be derived. The resulting equation is:

$$\mathbf{I=(T/C_p)^{1/n}}$$

Because the battery specifications rarely provide the Peukert capacity (CP) or the Peukert exponent n, we can use the following equation:

$$\mathbf{n = \log (R_2/R_1) / [\log (C_1/R_1) - \log (C_2/R_2)]}$$

to figure out the Peukert exponent, n given two Ampere-hour ratings, C1, R1 and C2, R2, where C1 and C2 are Ampere-hour ratings for the given discharge times.

It is possible to obtain Peukert's Capacity using one of the Ampere-hour ratings, say C1, R1 using the calculated Peukert exponent by the following equation:

$$\mathbf{C_p = TI^n = R_1(C_1/R_1)^n \text{ where } T = R_1 \text{ and } I = C_1/R_1}$$

The following table provides a set of test cases that can be used to test the algorithm and the program.

For a discharge table as a function of current, we have the following data:
First Ampere-hour rating: 48
Discharge Time: 5 hours
Second Ampere-hour rating: 60
Discharge Time: 20 hours

Initial current is 10 amps, with a step size of 10 amps. By inputting these values into our program, we get the following table:

Current	Discharge Time	Ah Capacity
10	4.76	47.63
20	2.08	41.7
30	1.29	38.58
40	0.91	36.5
50	0.7	34.97
60	0.56	33.77
70	0.47	32.79
80	0.4	31.96
90	0.35	31.24
100	0.31	30.62

Peukert Exponent: 1.191844041 Reserve Capacity (minutes): 99.870610

Similarly, if the user decided to choose the discharge table as a function of the discharge time with the following data:

First Ampere-hour rating: 150
Discharge Time: 20 hours
Second Ampere-hour rating: 117.6
Discharge Time: 4.704 hours

Initial discharge time is one hour, with a step size of one hour. By inputting the information in the program, we get this table:

Discharge Time	Electrical Current	Ah Capacity
1	90.64	90.64
2	50.92	101.85
3	36.34	109.03
4	28.61	114.44
5	23.76	118.81
6	20.42	122.51
7	17.96	125.73
8	16.07	128.58
9	14.57	131.15
10	13.35	133.5

Peukert Exponent: 1.202119 Reserve Capacity (minutes): 293.999965

Algorithm:

Define var1 as 1 or 2
Define var2 as 1 or 2
print "Enter 1 for 2 Ah ratings or 1 for 1 Ah rating and reserve capacity"
If var1=1
    Assign values to Ah1 and DT1
    Assign values to Ah2 and DT2
    Assign n to n = log (DT_2/DT_1) / [log (Ah_1/DT_1) – log (Ah_2/DT_2)]
    Print "Enter 1 for table with current as a function of discharge time or 2 for discharge time as a function of current"
    If var2=1
        print a table with current as a function of discharge time
    If var2=1
        print a table with discharge time as a function of current
If var1=2
    Assign values to Ah1 and DT1
    Assign value to RC(Reserve Capacity)
    *Assign Ah2=0.4*RC*
    Assign DT2=Ah2/25
    Print "Enter 1 for table with current as a function of discharge time or 2 for discharge time as a function of current"
If var2=1
        print a table with current as a function of discharge time
    If var2=1
        print a table with discharge time as a function of current

Step 4: Implementation

```
/*-------------------------------------------------*/
 /* Name: yournamehere, Student Number: 7360143 */
 /* Date: Feb 09, 2014. */
 /* Program: main.c */
 /* Description: This program computes various data for lead-acid batteries. */
/*-------------------------------------------------*/
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <float.h>


int main()
{
/* Declaration of variables*/
float   AH1,    /*Ampere-hours value 1*/
        DT1,    /*Discharge Time 1 in hours*/
        AH2,    /*Ampere-hours value 2*/
        DT2,    /*Discharge Time 2 in hours*/
        RC,     /*Reserve Capacity*/
        n,      /*Peukert's exponent*/
        I,      /*Electrical Current*/
        Cp,     /*Peukert's Capacity in Ampere-hours*/
        T,      /*Time*/
        Ah,     /*Ampere-hour value for present-iteration current*/
        Istart, /*Current Start value for Discharge Time values table*/
        Istep,  /*Current Step value for Discharge Time values table*/
        Tstart, /*Time Start value for Current values table*/
        Tstep;  /*Time Step value for Current values table*/
int      TwoAH,  /*selects between Two Ampere-Hour Capacities vs One Ampere-Hour Capacity
plus Reserve Capacity*/
        DT_I;   /*selects between Discharge Time vs Current table printout*/

/*User selects whether they want to use two Ampere-Hour Capacity ratings or one Ampere-Hour
Capacity rating plus Reserve Capacity*/
printf("Type 1 to use two Ampere-Hour Capacity  ratings, type 2 to use one Ampere-Hour
Capacity rating plus Reserve Capacity\n");
scanf("%d", &TwoAH);
if (TwoAH == 1)
    {
        printf("First Ampere-hour value\n");
        scanf("%f", &AH1);
        printf("First Discharge Time value (hours)\n");
        scanf("%f", &DT1);
        printf("Second Ampere-hour value\n");
        scanf("%f", &AH2);
        printf("Second Discharge Time value (hours)\n");
        scanf("%f", &DT2);
        n = log(DT2/DT1)/((log(AH1/DT1)- log(AH2/DT2)));
        Cp = DT1*(pow(AH1/DT1, n));
          /*User selects whether to table the Discharge Time as a function of Current or
Current as a function of Discharge Time*/
        printf("Type 1 for Discharge Time table and 2 for Electrical Current table\n");
        scanf("%d", &DT_I);
        if (DT_I == 1)
            {
                printf("Enter the Starting Electrical Current Value\n");
                scanf("%f", &Istart);
                printf("Enter the Electrical Current Step Size\n");
                scanf("%f", &Istep);
                printf("Electrical \t Discharge \t Ah\n");
                printf("Current \t Time \t\t Capacity\n");
                for(I=Istart; I<=Istart+9*Istep; I=I+Istep)
```

```
                    {
                        T = Cp/(pow(I, n));
                        Ah = I*T;
                        printf("%f\t %f\t %f\n", I, T, Ah);
                    }
                printf("Peukert Exponent: %f\nReserve Capacity (minutes): %f\n", n, (25*(Cp/
(pow(25,n))))/0.4);
            }
        else if (DT_I == 2)
            {
                printf("Enter the Starting Discharge Time (hours)\n");
                scanf("%f", &Tstart);
                printf("Enter the Discharge Time Step (hours)\n");
                scanf("%f", &Tstep);
                printf("Discharge \t Electrical \t Ah\n");
                printf("Time \t\t Current \t Capacity\n");
                for(T=Tstart; T<=Tstart+9*Tstep; T=T+Tstep)
                    {
                        I = pow((Cp/T), 1/n);
                        Ah = I*T;
                        printf("%f\t %f\t %f\n", T, I, Ah);
                    }
                printf("Peukert Exponent: %f\nReserve Capacity (minutes): %f\n", n, (25*(Cp/
(pow(25,n))))/0.4);
            }
        else
                printf("\nInvalid selection\n");
    }
else if (TwoAH == 2)
    {
        printf("First Ampere-Hour value\n");
        scanf("%f", &AH1);
        printf("First Discharge Time (hours)\n");
        scanf("%f", &DT1);
        printf("Reserve Capacity\n");
        scanf("%f", &RC);
        AH2 = RC * 0.4;
        DT2 = AH2 / 25;
        n = log(DT2/DT1)/((log(AH1/DT1)- log(AH2/DT2)));
        Cp = DT1*(pow(AH1/DT1, n));
          /*User selects whether to table the Discharge Time as a function of Current or
Current as a function of Discharge Time*/
        printf("Type 1 for Discharge Time table and 2 for Current table\n");
        scanf("%d", &DT_I);
        if (DT_I == 1)
            {
                printf("Enter the Starting Current Value\n");
                scanf("%f", &Istart);
                printf("Enter the Current Value Step\n");
                scanf("%f", &Istep);
                printf("Electrical \t Discharge \t Ah\n");
                printf("Current \t Time \t\t Capacity\n");
                for(I=Istart; I<=Istart+9*Istep; I=I+Istep)
                    {
                        T = Cp/(pow(I, n));
                        Ah = I*T;
                        printf("%f\t %f\t %f\n", I, T, Ah);
                    }
                printf("Peukert Exponent: %f\nReserve Capacity (minutes): %f\n", n, (25*(Cp/
(pow(25,n))))/0.4);
            }
        else if (DT_I == 2)
            {
                printf("Enter the Starting Discharge Time\n");
                scanf("%f", &Tstart);
                printf("Enter the Discharge Time Step\n");
```

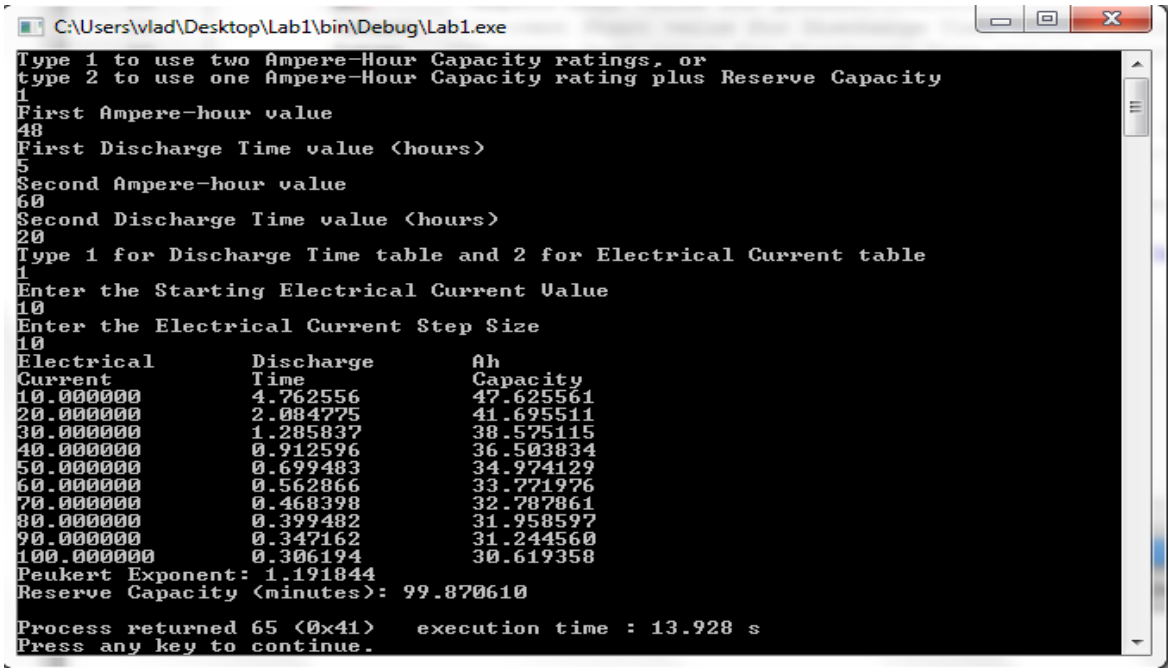
```
                scanf("%f", &Tstep);
                printf("Discharge \t Electrical \t Ah\n");
                printf("Time \t\t Current \t Capacity\n");
                for(T=Tstart; T<=Tstart+9*Tstep; T=T+Tstep)
                    {
                        I = pow((Cp/T), 1/n);
                        Ah = I*T;
                        printf("%f\t %f\t %f\n", T, I, Ah);
                    }
                printf("Peukert Exponent: %f\nReserve Capacity (minutes): %f\n", n, (25*(Cp/
(pow(25,n))))/0.4);
            }
        else
                printf("\nInvalid selection\n");
    }
else
    printf("\nInvalid selection\n");
}
```

Step 5: Tests and Verification (and Debugging)

In the first test case, for a discharge table as a function of current, we have the following data:

First Ampere-hour rating: 48
Discharge Time: 5 hours
Second Ampere-hour rating: 60
Discharge Time: 20 hours

Initial current is 10 amps, with a step size of 10 amps. By inputting these values into our program, we get the following results:

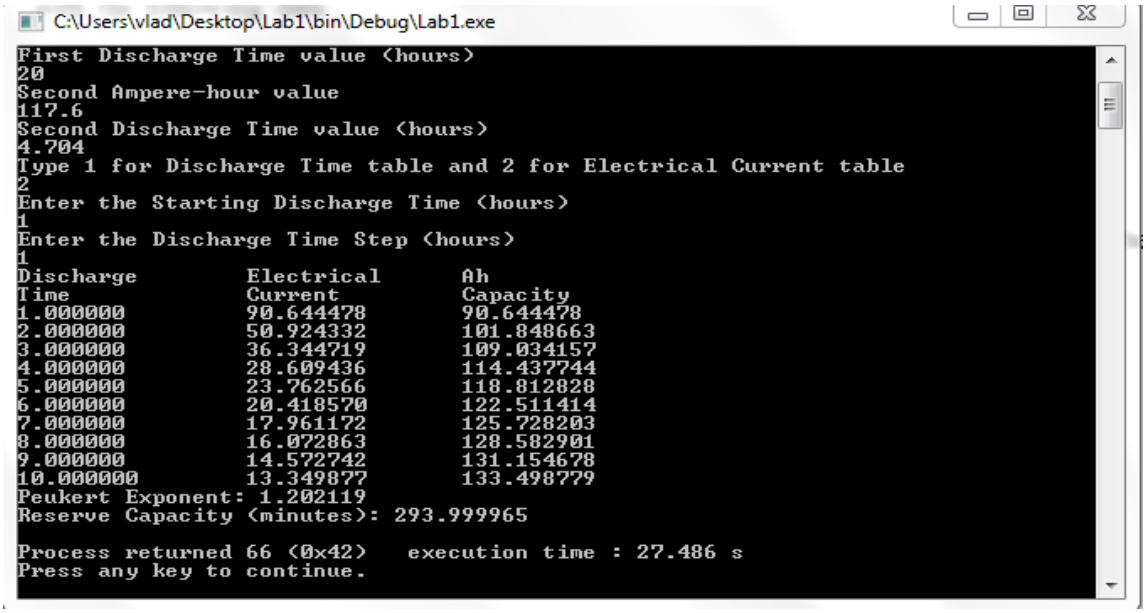


Peukert Exponent: 1.191844041
Reserve Capacity (minutes): 99.870610

Similarly, if we decided to choose the discharge table as a function of the discharge time with the following data:

First Ampere-hour rating: 150
Discharge Time: 20 hours
Second Ampere-hour rating: 117.6
Discharge Time: 4.704 hours

Initial discharge time is one hour, with a step size of one hour. By inputting the information in the program, we get the following results:



Peukert Exponent: 1.202119
Reserve Capacity (minutes): 293.999965

User Guide

To execute the program, compile and run the code found in the file Lab1.c

The user will be prompted to choose between two inputs, either two ampere-hour capacity ratings or one ampere-hour capacity rating and the reserve capacity.

If the user chooses two ampere-hour capacity ratings, he/she will be asked to input the two ampere-hour capacities along with their discharge time.

At this point, the user can choose between two rate tables, either a discharge time as a function of current table or an electrical current as a function of the discharge time table.

After choosing the desired table, the program will ask the user to input an initial value for the discharge time or electrical current, depending on the choice in the previous step. The user will also choose a desired step size.

If the one ampere-hour capacity rating and the reserve capacity input is chosen, the user will be prompted to type in an ampere-hour value along with its discharge time, as well as the reserve capacity value.

Again, the user will have to type in the initial value and step size, as well as to choose between the two rate tables.

The Peukert exponent and the reserve capacity will be shown at the bottom of any rate table the users chooses.