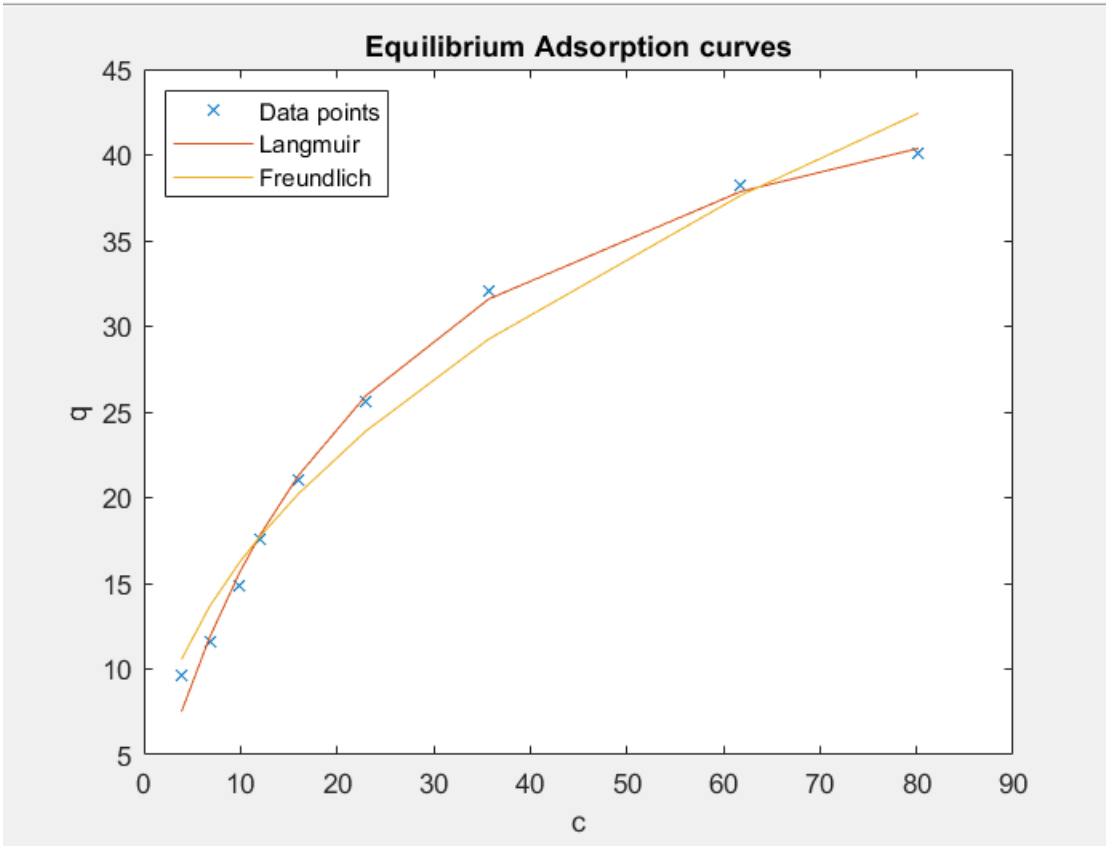
Question 1 MATLAB CODE AND PLOT

```
clear;close all; clc;
c = [3.9;6.8;9.9;12;16;23;35.7;61.8;80.2];
q= [9.6;11.6;14.9;17.6;21.0;25.6;32.1;38.2;40.1];
options = statset('MaxIter',500);
[beta,R,J,COVB,MSE] = nlinfit(c,q,@Freund,[1,1]);
[beta1,R1,J1,COVB1,MSE1] =
nlinfit(c,q,@Lang,[0.00001,2*10000],options);
qlang = Lang(beta1,c);
qfreund = Freund(beta,c);
plot(c,q,'x',c,qlang,c,qfreund);
title('Equilibrium Adsorption curves');
legend('Data points','Langmuir', 'Freundlich');
xlabel('c');
ylabel('q');
function y = Freund(parms,c)
    k = parms(1);
    n = parms(2);
    y = k.*(c.^(1./n));
end
function y= Lang(parms,c)
    k = parms(1);
    qm = parms(2);
    y = qm.*(k.*c./(1+k.*c));
end
```



Question 2 MATLAB CODE

```
clear; close all;
kl = 2.25*10^-5;%m/s
L = 10;%Litres
wmin = (3.5-0.1)/(50*0.1^(0.32))*L;%g
w = 2*wmin;%g
ci = 3.5;%mg/L
K = 50;%q should be in mg/g, c in mg/L
a = 5;%m^2/kg
time = integral(@dtbydc,3.5,0.1);
t_inhours = time/3600;
function val = dtbydc(c)
    kl = 2.25*10^-5;%m/s
    L = 10;%Litres
    wmin = (3.5-0.1)/(50*0.1^(0.32))*L;%g
    w = 2*wmin;%g
    ci = 3.5;%mg/L
    K = 50;%q should be in mg/g, c in mg/L
    a = 5;%m^2/kg
    %units of val
    %c is the conc in solution, second term is the ideal
c in soln
    val = -1./(kl*(a*w/L).*(c-((ci-
c)*L/(w*K)).^(1/0.32)));
end
```

Question 3 MATLAB CODE AND PLOT

```
clear; close all;
%% Given data
u_superficial = 0.29;
t =
[9.5,19,21,25.7,34.3,39,42,46.7,51.4,56.2,64.7,68.6,72.4,
77.1,84.8,97.1,104.7,108.6];
te = 108.6;
c =
[0,0.018,0.037,0.083,0.287,0.435,0.491,0.62,0.713,0.768,0
.852,0.935,0.952,0.963,0.97,0.987,0.991,1];
L = 0.2;
ci = 0.11;
plot(t,c);
title('c/ci vs t');
ylabel('c/ci');
xlabel('time');

%% Part a
t_break = spline(c,t,0.03);
pp = spline(t,c);
n = 40;
time = linspace(9.5,108.6,n*(10));
ts = te - trapz(time,ppval(pp,time));
% Following code evaluates both the integrals numerically
and minimises it.
% No need to run this part because we have already
simplified it into a simple linear eqn in ts.
% min = trapz(time,ppval(pp,time));
% ts = 230;
% ar_diff = zeros(n*10-1,1);
% l = length(time);
% for i = 2:l-1
%     ar_diff(i) = trapz(time(1:l),ppval(pp,time(1:l)))-
(108.6-time(i));
%     if min > abs(ar_diff(i))
%         min = abs(ar_diff(i));
%         ts = time(i);
%     end
% end
us = L/ts*60; %m/h
LUB = L*(1-t_break/ts);
MTZ = (te-t_break)/te*L;%Since curve is NOT symmetric

%% Part b
V = 3000/60/60;%m^3/s
D = sqrt(4*V/(u_superficial*pi));
```

```
t_cycle = 8;
bed_density = 700;
L_used = 8*us;
L_scaleup = LUB + L_used;
sol_adsorbed = V*ci*t_cycle*3600;
avg_loading =
sol_adsorbed/(L_scaleup*bed_density*pi*D^2/4);
max_loading = sol_adsorbed/(L_used*bed_density*pi*D^2/4);
```