Question 2

8.1 4 equations for the rate of changes of 4 species

$$\frac{d[E]}{dt} = (k_2 + k_3)[\mathrm{ES}] - k_1[E][S]$$

$$\frac{d[S]}{dt} = k_2[\mathrm{ES}] - k_1[E][S]$$

$$\frac{d[\mathrm{ES}]}{dt} = k_1[E][S] - (k_2 + k_3)[\mathrm{ES}]$$

$$\frac{d[P]}{dt} = k_3[\mathrm{ES}]$$

8.2 solution of ODEs above

```
E_0 = 1;
S_0 = 10;
ES_0 = 0;
P_0 = 0;
k1 = 100;
k2 = 600;
k3 = 150;
h = 0.001;
span = 3;
N = ceil(span/h);
for i = 1 : N-1

    K11 = fun_E(E_0(i), ES_0(i), S_0(i)); % k1 of E
    K12 = fun_S(E_0(i), ES_0(i), S_0(i));
    K13 = fun_ES(E_0(i), ES_0(i), S_0(i));
    K14 = fun_P(ES_0(i));


    K21 = fun_E(E_0(i) + h * (1/2) * K11, ES_0(i) + h * (1/2) * K11,
S_0(i) + h * (1/2) * K11); % k2 of E
    K22 = fun_S(E_0(i) + h * (1/2) * K12, ES_0(i) + h * (1/2) * K12,
S_0(i) + h * (1/2) * K12);
    K23 = fun_ES(E_0(i) + h * (1/2) * K13, ES_0(i) + h * (1/2) * K13,
S_0(i) + h * (1/2) * K13);
    K24 = fun_P(ES_0(i) + h * (1/2) * K14);
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    K31 = fun_E(E_0(i) + h * (1/2) * K21, ES_0(i) + h * (1/2) * K21,
S_0(i) + h * (1/2) * K21);
    K32 = fun_S(E_0(i) + h * (1/2) * K22, ES_0(i) + h * (1/2) * K22,
S_0(i) + h * (1/2) * K22);
    K33 = fun_ES(E_0(i) + h * (1/2) * K23, ES_0(i) + h * (1/2) * K23,
S_0(i) + h * (1/2) * K23);
    K34 = fun_P(ES_0(i) + h * (1/2) * K24);


    K41 = fun_E(E_0(i) + h * K31, ES_0(i) + h * K31, S_0(i) + h * K31);
    K42 = fun_S(E_0(i) + h * K32, ES_0(i) + h * K32, S_0(i) + h * K32);
    K43 = fun_ES(E_0(i) + h * K33, ES_0(i) + h * K33, S_0(i) + h * K33);
    K44 = fun_P(ES_0(i) + h * K43);


    E_0 = [E_0, E_0(i) + h * (K11 + 2 * K21 + 2 * K31 + K41)/6];
    S_0 = [S_0, S_0(i) + h * (K12 + 2 * K22 + 2 * K32 + K42)/6];
    ES_0 = [ES_0, ES_0(i) + h * (K13 + 2 * K23 + 2 * K33 + K43)/6];
    P_0 = [P_0, P_0(i) + h * (K14 + 2 * K24 + 2 * K34 + K44)/6];
end


figure;
plot(E_0, 'LineWidth', 2, 'Color', [79, 129, 189]/255);
hold on;
plot(S_0, 'LineWidth', 2, 'Color', [192, 80, 77]/255);
hold on;
plot(ES_0, 'LineWidth', 2, 'Color', [155, 187, 89]/255);
hold on;
plot(P_0, 'LineWidth', 2, 'Color', [128, 100, 162]/255);
legend('E', 'S', 'ES', 'P');


function f_E = fun_E(E, ES, S)
    k1 = 100;
    k2 = 600;
    k3 = 150;
    f_E = (k2 + k3) * ES - k1 * E * S;
end


function f_S = fun_S(E, ES, S)
    k1 = 100;
    k2 = 600;
    k3 = 150;
```
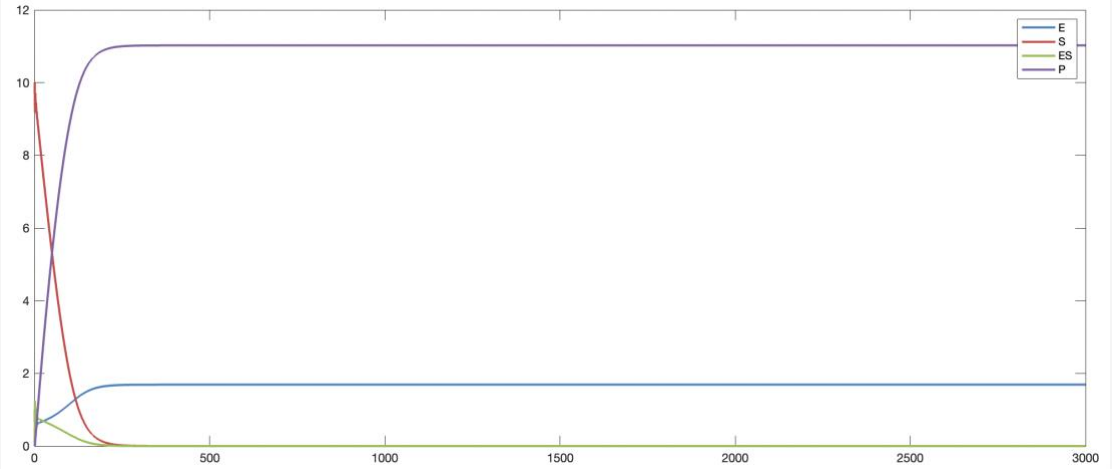

```
    f_S = k2 * ES - k1 * E * S;
end


function f_ES = fun_ES(E, ES, S)
    k1 = 100;
    k2 = 600;
    k3 = 150;
    f_ES = k1 * E * S - (k2 + k3) * ES;
end


function f_P = fun_P(ES)
    k1 = 100;
    k2 = 600;
    k3 = 150;
    f_P = k3 * ES;
end
```



8.3 plot V as f([S])