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```
function []=solution_hw4()
```

EE361 HW#4

NAME: *SOLUTION*

STUDENT NUMBER: 123456

PARAMETERS

```
%define the constant parameters
I = 15; % Amps
Nturn = 150; % turns
A = 10e-4; % m^2
lr = 1e-2; % m
m = 0.5; % kg
kspring = 20; % N/m
u0 = 4*pi*1e-7; % H/m

x = -0.1:0.0001:0.1; % meters
```

part a

RELUCTANCE

$$R = l/(u_0 A)$$

$$R = (0.1 - x + l_r)/(u_0 A)$$

```
R = (0.1-x+lr)/(u0*A);
```

INDUCTANCE

$$L = N^2/R$$

```
L = Nturn^2./R;
```

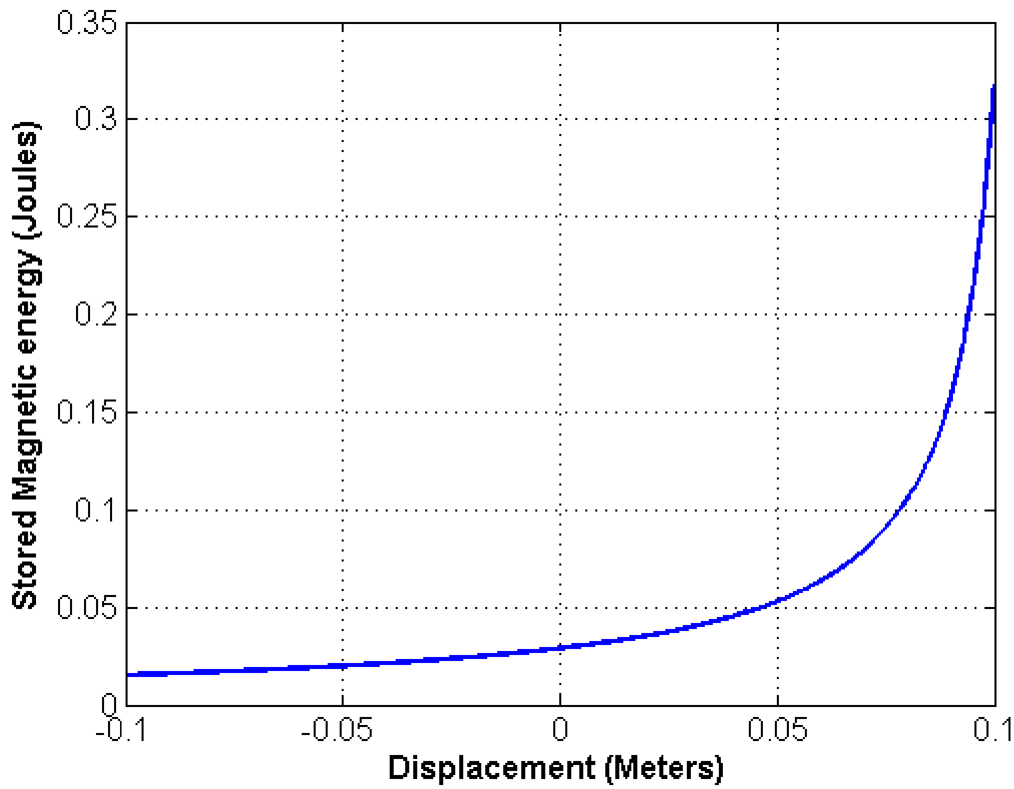
part b

STORED MAGNETIC ENERGY

$$W = (1/2)LI^2$$

```
W = (1/2)*L*I^2;

figure;
plot(x,W,'b -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Stored Magnetic energy (Joules)','FontSize',12,'FontWeight','Bold')
```



part c

part c-i

ELECTROMAGNETIC FORCE

$$W = (1/2)LI^2$$

$$W = (1/2)(N^2/R)I^2$$

$$W = (1/2)(N^2AI^2u_0)/(0.1 - x + l_r)$$

$$Fem = dW/dx$$

$$Fem = (1/2)(N^2 A I^2 u_0)/(0.1 - x + l_r)^2$$

```
Fem = (1/2)*(Nturn^2*A*I^2*u0)./(0.1-x+lr).^2;
```

part c-ii

MECHANICAL SPRING FORCE

$$Fms = kx$$

```
Fms = kspring*x;
```

the direction is to the right

part c-iii

NET FORCE

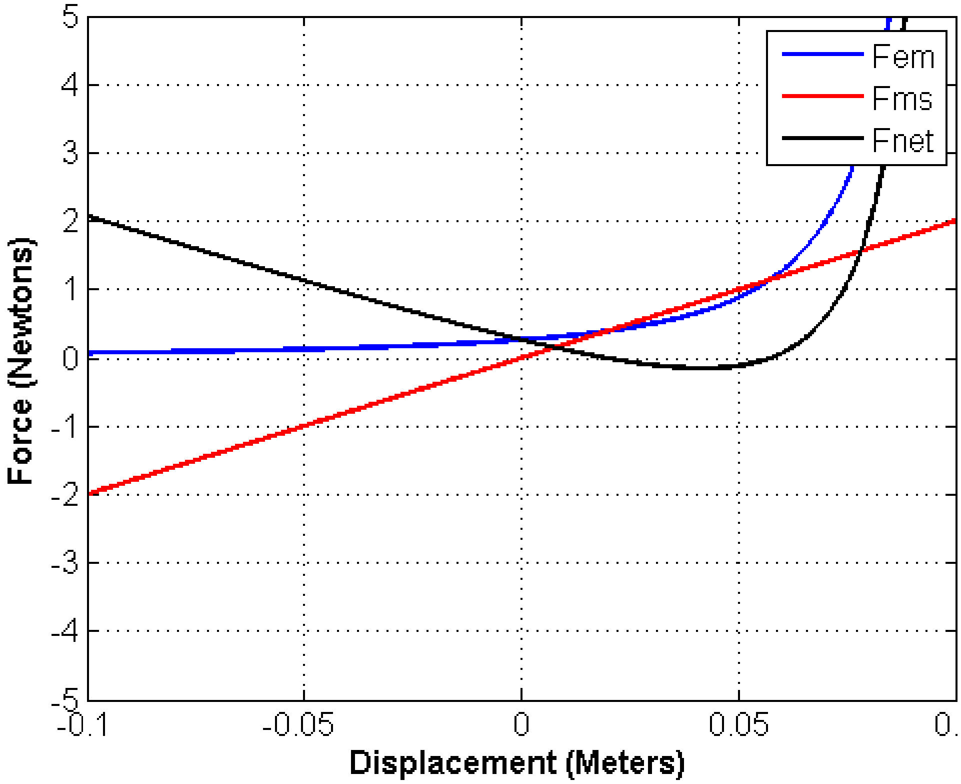
$$Fnet = Fem - Fms$$

```
Fnet = Fem-Fms;
```

net force is defined in the direction of displacement

part c-iv

```
figure;
plot(x,Fem,'b -','Linewidth',1.5);
hold on;
plot(x,Fms,'r -','Linewidth',1.5);
hold on;
plot(x,Fnet,'k -','Linewidth',1.5);
hold off;
grid on;
ylim([-5,5]);
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Force (Newtons)','FontSize',12,'FontWeight','Bold')
legend('Fem','Fms','Fnet');
```



part c-v

The net force is positive (in the direction of +x) in interval1: [-0.1 - 0.02] and interval2: [0.057 - 0.1] The net force is negative (in the direction of -x) in interval3: [0.02 - 0.057] In intervals 1 and 2, the electromagnetic device overcomes the the spring force. In interval 3, the spring force is stronger.

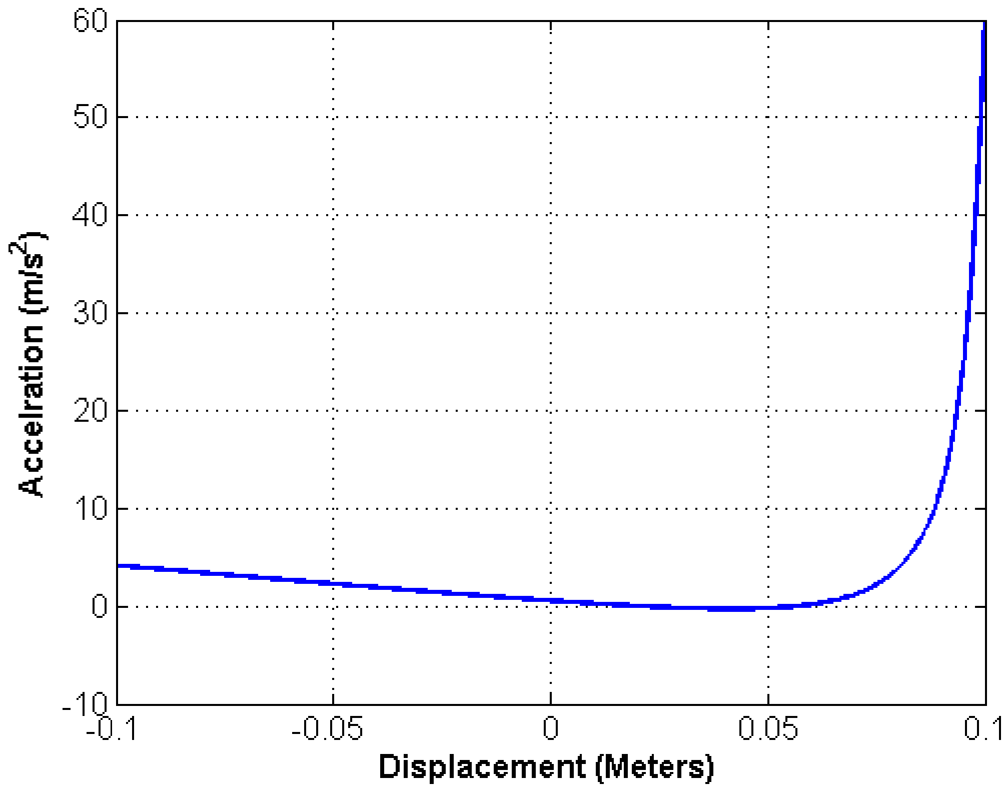
part d

ACCELERATION

$$a = [(1/2)(N^2 A I^2 u_0)/(0.1 - x + l_r)^2 - kx]/m$$

```
a = Fnet/m;

figure;
plot(x,a,'b -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')
ylabel('Accelration (m/s^2)','FontSize',12,'FontWeight','Bold')
```



part e

part e-i

AGAINST TIME

```
Ts = 1e-3; % time step (seconds)
t = 0:Ts:5; % time vector
N = numel(t); % number of elements
position = zeros(1,N);
velocity = zeros(1,N);
ivme = zeros(1,N);

for k = 2:N-1
    acceleration = calculate_acceleration(position(k));
    velocity(k) = velocity(k-1)+acceleration*Ts;
    position(k+1) = position(k)+velocity(k)*Ts;
    ivme(k) = acceleration;
end
```

part e-ii

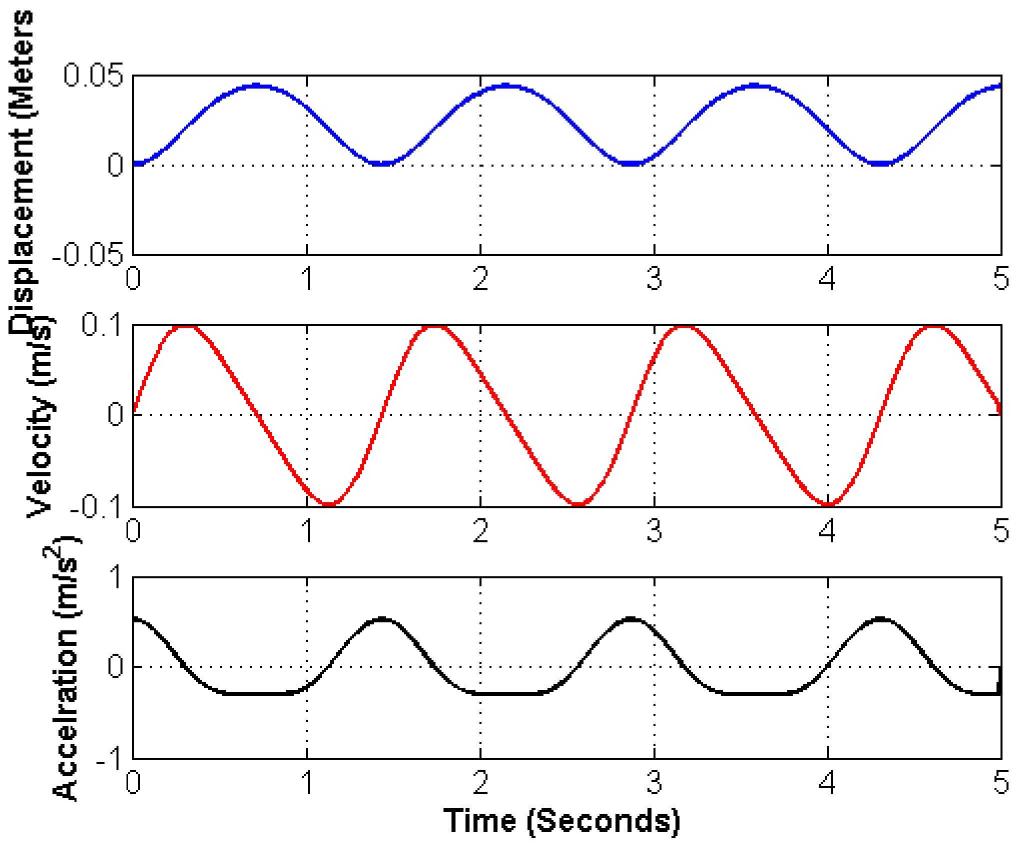
```
figure;

subplot(3,1,1);
plot(t,position,'b -','Linewidth',1.5);
grid on;
```

```
set(gca,'FontSize',12);
ylabel('Displacement (Meters)','FontSize',12,'FontWeight','Bold')

subplot(3,1,2);
plot(t,velocity,'r -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
ylabel('Velocity (m/s)','FontSize',12,'FontWeight','Bold')

subplot(3,1,3);
plot(t,ivme,'k -','Linewidth',1.5);
grid on;
set(gca,'FontSize',12);
xlabel('Time (Seconds)','FontSize',12,'FontWeight','Bold')
ylabel('Accelration (m/s^2)','FontSize',12,'FontWeight','Bold')
```



part f

As the name suggests, it has an oscillatory behaviour. Since the net force is in the direction of +x at initial position, the mass moves to the left. At some point, the force becomes negative and starts to slow down. When it stops, it starts to go back until its initial position. It cannot go further since there is no disspated energy. The oscillation does not end theoretically since the system is lossless.

```
function [acc] = calculate_acceleration(pos)

    Fm = (u0*Nturn^2*A*I^2)./(2*(0.1-pos+lr).^2);
    Fs = kspring*pos;
```

```
        Fnet1 = Fm-Fs;
        acc = Fnet1/m;

    end

end
```

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