RIS - LAB 2

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LAB 4 – (TASK 1.17 – 1.23)

TASK 1.17

Given:- $T_L(s) = 0$ $\qquad r(t) = K u(t)$

$$E(s) = \frac{1}{1 + H_{wv}(s)h(s)} R(s) + \frac{H_{wl}(s)}{1 + H_{wv}(s)u(s)} T_L(s)$$

as $T_L(s) = 0$:-

$$\mathcal{L}\{K_u(t)\} = \frac{K}{s}$$

$$H_{wv}(s) = \frac{K_t}{D(s)} = \frac{k_t}{(R_a + L_a s)(J_s + b)(k_t k_e)}$$

$$G(s) = k_p + k_s \tfrac{1}{s} + k_D s$$

$$H_{wv}(s)G(s) = \frac{k_t}{(R_a + L_a s)(J_s + b) + k_t k_c} \cdot \left(k_p + k_s \tfrac{1}{s} + k_D s\right)$$

$$= \frac{(k_p s + k_I + k_D s^2) K_t}{s(R_a + L_a s)(J_s + b) + k_t k_c}$$

$$1 + H_{wv}(s)G(s) = 1 + \frac{(k_p s + k_I + k_D s^2) k_t}{s(R_a s + L_a s)(J_s + b) + k_t k_c}$$

$$= \frac{s(R_a + L_a s)(J_s + b) k_t k_c + (k_p s + k_I + k_D s^2) k_t}{s(R_a + L_a s)(J_s + b) + k_t k_c}$$

$$E(s) = \frac{\cancel{s}(R_a + L_a s)(J_s + b) k_t k_c}{s(R_a + L_a s)(J_s + b) K_t k_e + (k_p s + k_I + k_D s^2) k_t} \cdot \frac{K}{\cancel{s}}$$

$$\lim_{s \to 0} sE(s) = \frac{6(R_a + L_a s)(J_s + b) k_t k_e}{s(R_a + L_a s)(J_s + b)(k_t k_c) + (k_p s + k_I + k_D s^2) k_t}$$

$$\lim_{s \to 0} s E(s) = 0$$

TASK 1.18

Given $v(t) = k_v(t)$, $T_L(t) = l_v(t)$

$$E(s) = \frac{1}{1 + H_{wv}(s)G(s)} R(s) + \frac{H_{we}(s)}{1 + H_{wv}(s)G(s)} T_L(s)$$

$$\lim_{s \to 0} sE(s) \frac{1}{1 + H_{wv}(s)G(s)} R(s) = 0$$ as $R(s) = \frac{k}{s}$ [known from before]

$$\frac{H_{wl}(s)}{1 + H_{wv}(s)G(s)} T_L(s)$$, knowing $H_{wl}(s) = \frac{R_a + L_a s}{D(s)}$ gives:-

$$H_{wv}(s) = \frac{k_t}{(R_a + L_a s)(J_s + b) + k_t k_e}$$

$$\lim_{s \to 0} \frac{s H_{wl}(s)}{1 + H_{wv}(s)G(s)} T_L(s) = \lim_{s \to 0} \frac{\frac{s(R_a + L_a s)}{D(s)} \cdot l/s}{1 + \frac{k_t G(s)}{(R_a + L_a s)(J_s + b) + (k_t k_e)}}$$

$$= \frac{(R_a + L_a s) \cdot l}{(R_a + L_a s)(J_s + b) + k_e k_t + k_t \cdot (k_p + k_I \cdot 1/s + k_D s)}$$

$$= \frac{(R_a + L_a s) \cdot l}{(R_a + L_a s)(J_s + b) + k_e k_t + \left[\frac{k_t \cdot k_p s + k_I + k_D s^2}{s}\right]}$$

$$= \frac{(R_a + L_a s) \cdot l_s}{s[(R_a + L_a s)(J_s + b) + k_e k_t] + k_t \cdot k_p s + k_I + k_D s^2} = E(s)$$

$$\lim_{s \to 0} sE(s) = 0$$

TASK 1.19

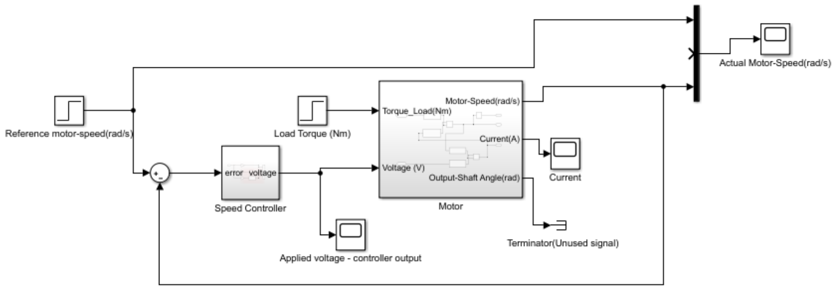

Figure 1.1 System Diagram

TASK 1.20

1)

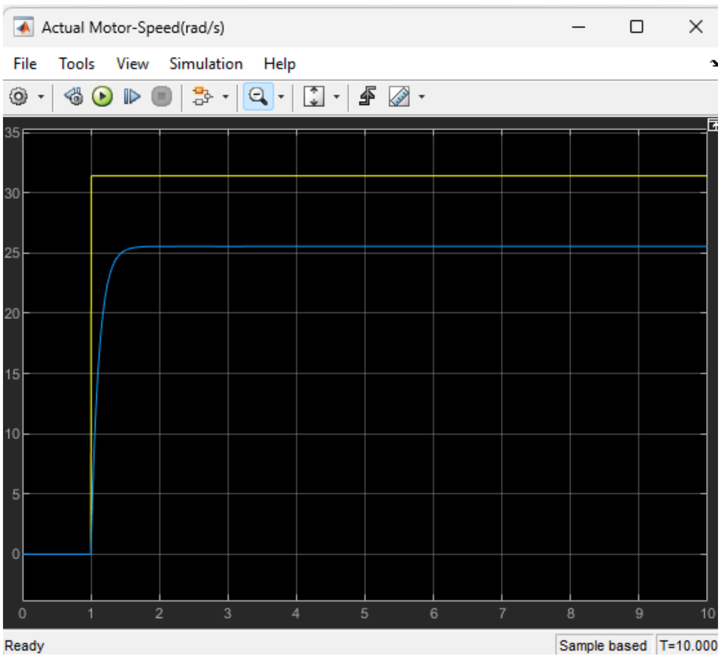

Figure 2.1: R(T) = 300 rpm and Kp = 1

r(t) = 300 rpm translates to 31.4 rad/s

w(t) = 25.25 rad/s and hence it doesn't react r(t)

steady state error e(t) is r(t) – w(t) = 6.15 rad/s

2)

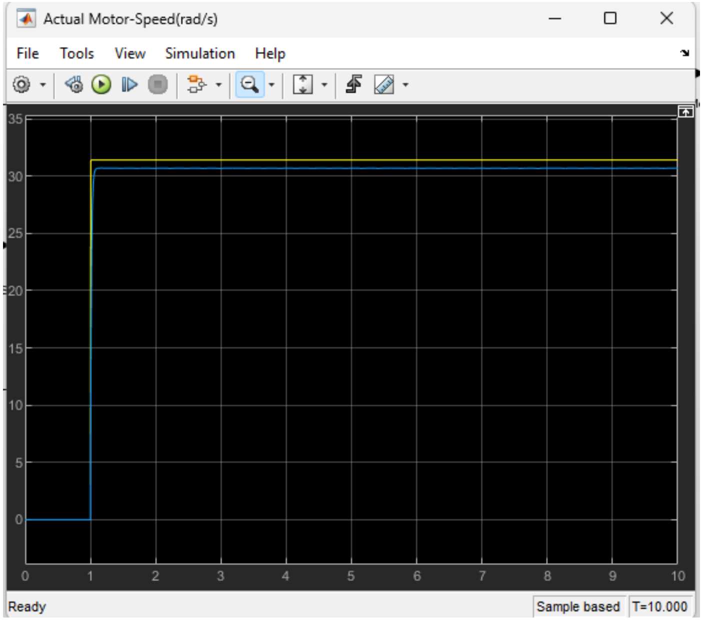

Figure 2.2: R(T) = 300rpm and Kp = 10

Here, we noticed that the larger the Kp value, the faster is the system response resulting in overshooting. Hence, we need a more specific value which is optimal i.e. not too small and not too large.

3)

Wrong. Some part of system just went berserk at KP = 10. Look at the scopes to figure out what went wrong. The moral of the story is that if we just use KP , there will always be a steady-state error. To have it converge to zero, we need a non-zero KI .

TASK 1.21

1)

For this subpart, we still use our System from Figure 1.1. We get Ki = 0.15 from discriminant of P(s) {Figure 1.37 Lab Manual}, plucking in all the values we have from previous parts. It is where there is no steady state error when system reaches steady state (overlap of reference and actual speed) and the discriminant is about 0.

The results are as follows:

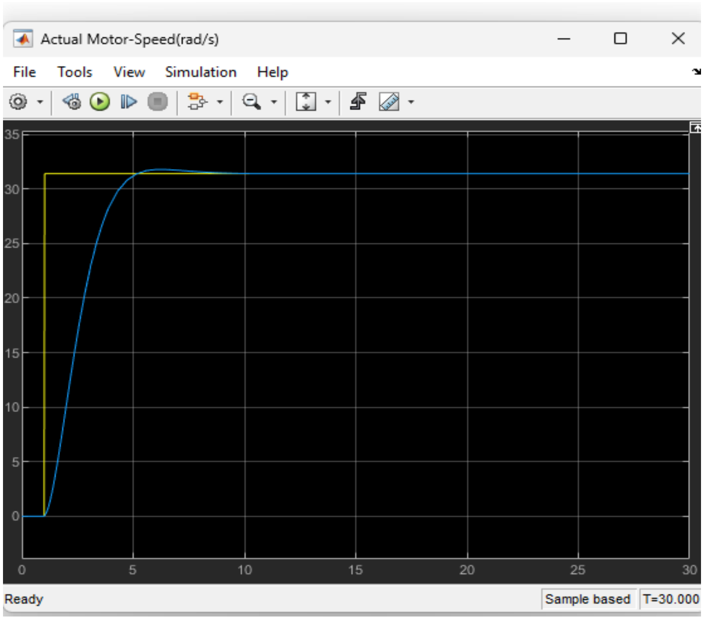

Figure 3.1: Kd = 0, Kp = 0.0084 and Ki = 0.15

2)

Using a Ki value of 0.18 which is slightly above the threshold, we do get a ripple as follows:

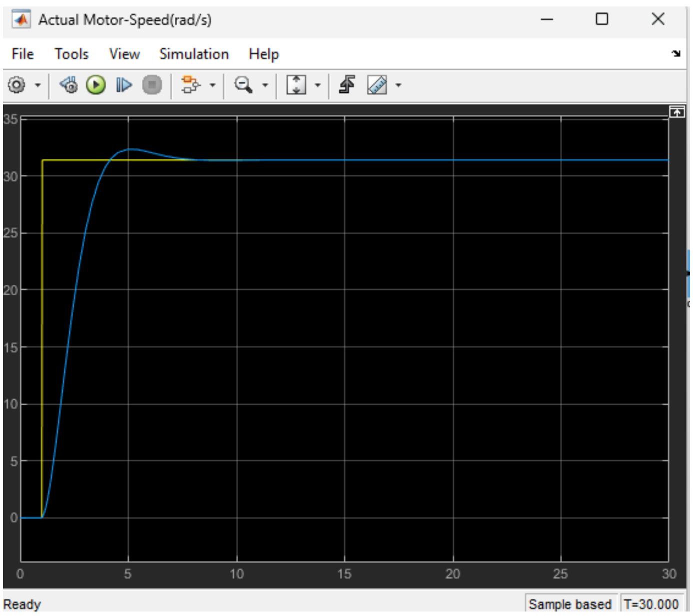

Figure 3.2: Kd = 0, Kp = 0.0084 and Ki = 0.18

3)

For the next part to check stall current, it is within safe range (5A) and is as follows:

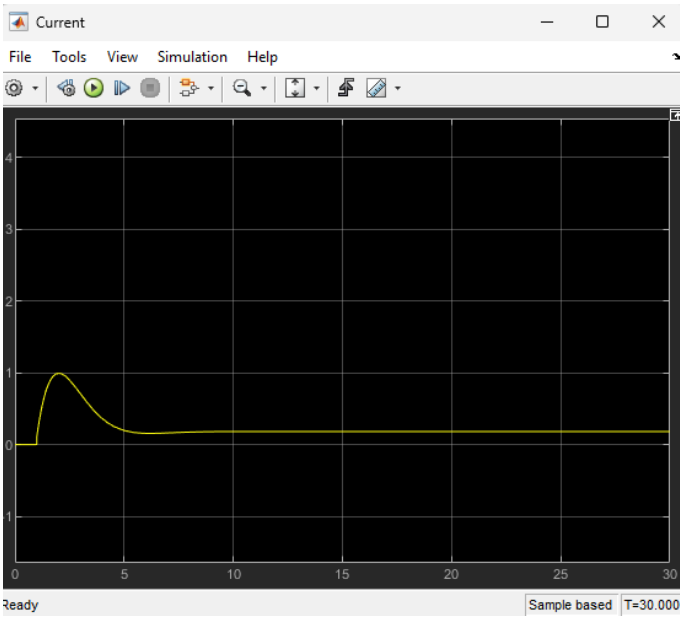

Figure 3.3: Current Scope

4)

Moving on to the next sub-part, we add a step load-torque disturbance which is half of stall torque at t=15s. We get the results as follows:

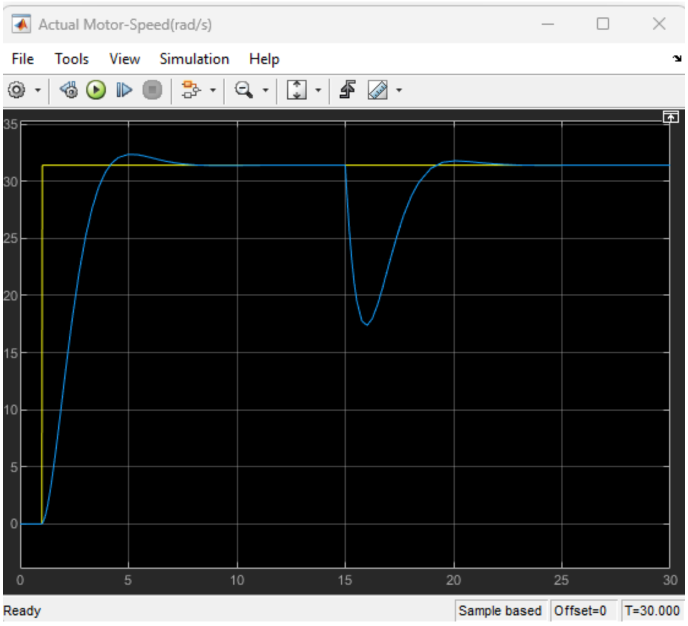

Figure 3.4: Step load torque with half of stall torque at t=15s

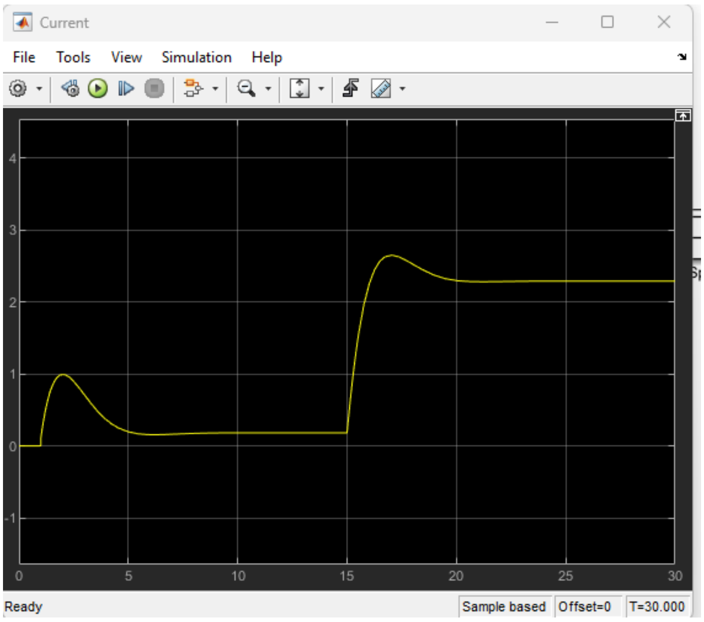

Figure 3.5: Current Scope

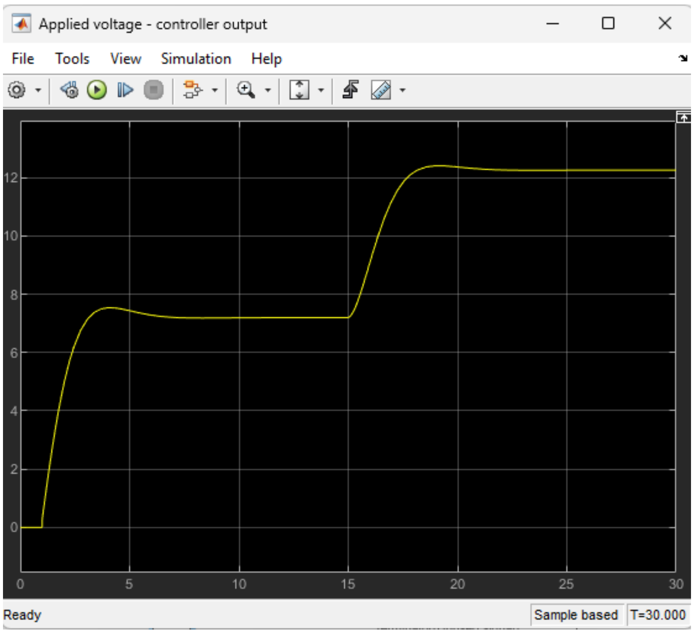

Figure 3.6: Current Scope

The steady state error is still 0 as we can infer from the graph that the two lines will eventually overlap. Moreover, the values are in safe range as we can see from the graph.

5)

Moving on, we apply a reference-speed signal which is sinusoidal and with amplitude of 5 rad/s and bias of 15rad/s and the frequency of sine-wave to be 1rad/s. We keep step torque-load at t=15s .

Our Actual Motor speed scope matches the scope from figure 1.14 from lab manual so we check the Current and Voltage scopes and get the results as follows:

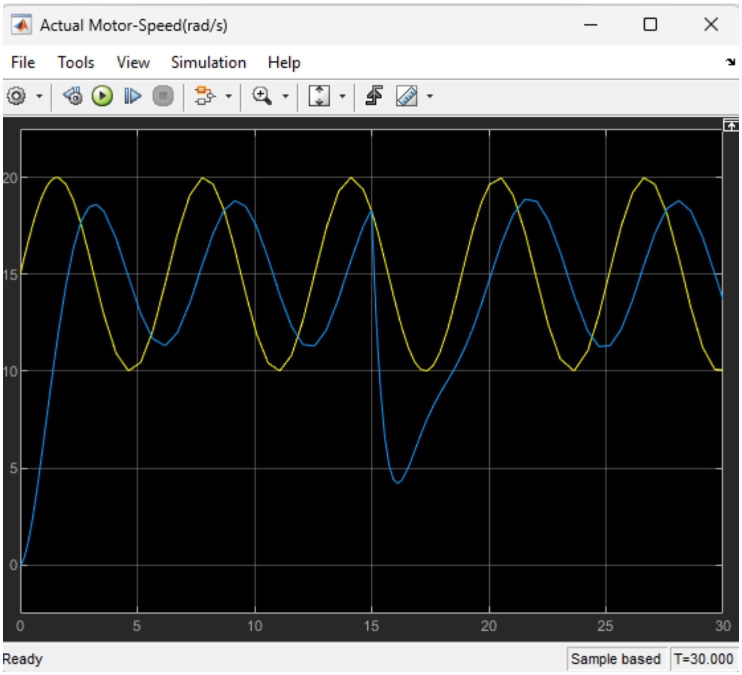

Figure 3.7: Current Scope

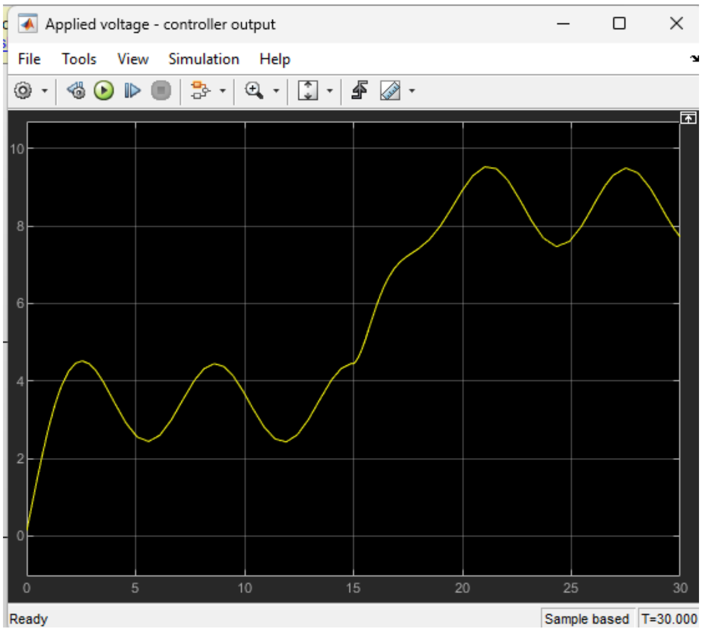

Figure 3.8: Voltage Scope

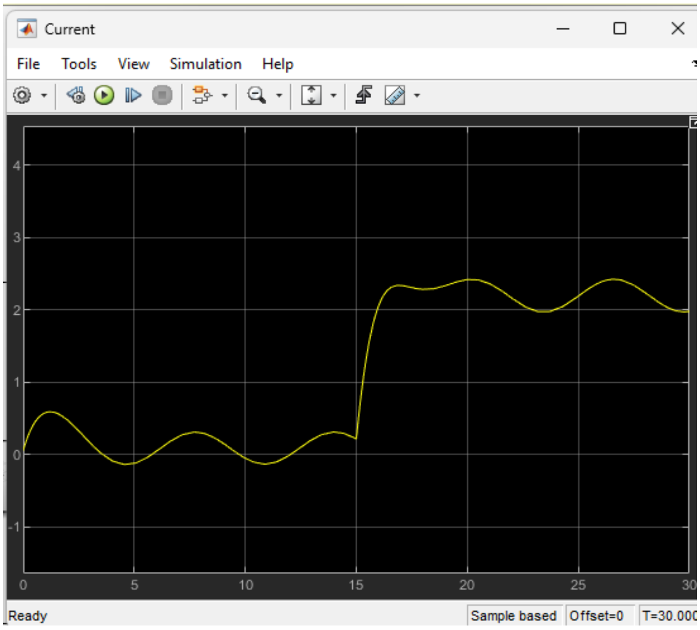

Figure 3.9: Current Scope

As we can see, both scopes are within defined limits i.e., 5A for Current and 12V for Voltage.

6)

Finally with the last subpart, we plot Bode plot for Error E(s) and get the expected results.

$$E(s) = \frac{1}{1 + H_{\omega v}(s)\,G(s)} R(s) + \frac{H_{\omega \ell}(s)}{1 + H_{\omega v}(s)\,G(s)} T_L(s)$$
$$\triangleq H_{er}(s)\,R(s) + H_{e\ell}(s)\,T_L(s)$$

TASK 1.22

Using the instructions and code for this part from the manual, we get the following results:

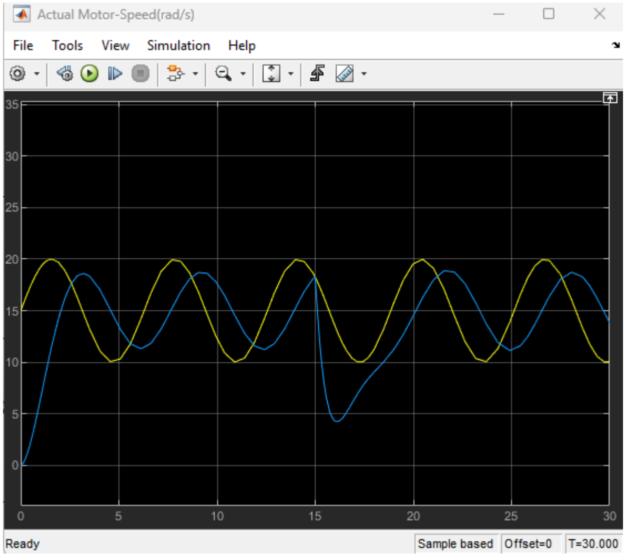

Figure 4.1: Actual Motor Speed scope

Using the values from the graph above, we get:

For Amplitude Difference:

$$Amplitude\ reference = 19.95 - 15.085 = 4.865$$

$$Amplitude\ obtained = 4.1$$

$$Amplitude\ Difference = 4.865 - 4.1 = 0.765$$

For Phase Difference:

$$Peak\ reference\ value\ (x - axis) = 28.057$$

$$Peak\ real\ speed\ value\ (x - axis) = 26.698$$

$$Phase\ Difference = 26.698 - 28.057 = -1.359$$

The degree equivalent is:

$$Phase\ Difference = -77.865$$

We can assure the values obtained are correct by using MATLAB as follows:

```
Continuous-time transfer function.

>> bode(T) % plot
>> grid on;
>> w=1; % rad/s
>> [mag, phase]= bode(T,w)

mag =

    0.6320


phase =

  -84.7823
```

Figure 5.1

As we can see from Figure 5.1, our calculations are very close to the theoretical values.

TASK 1.23

We get our system to be as follows:

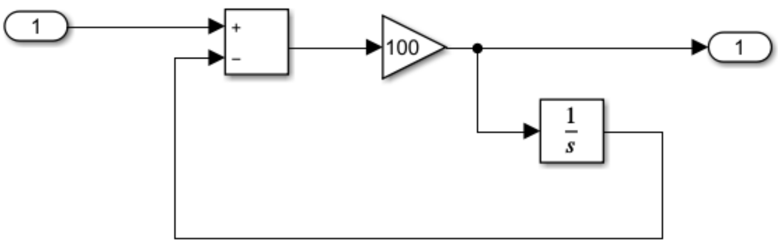

Figure 6.1

$$Input = I(s) \quad and \quad Output = O(s)$$

$$100 * \left[I(s) - \left(O(s) * \frac{1}{s} \right) \right] = O(s)$$

$Cross\ Multiplication$

$$100 * s * I(s) = O(s) * (s + 100)$$

$$\frac{O(s)}{I(s)} = \frac{100 * s}{s + 100}$$