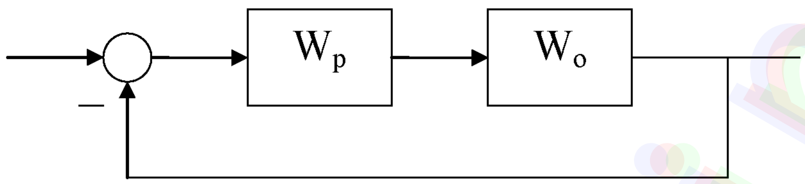
Вариант 1

$a_0 = 2$,
$a_1 = 4$,
$a_2 = 3$,
$a_3 = 1$;

Исследование системы управления при типовых законах управления. Передаточная функция объекта имеет вид:

$$W_0(s) = \frac{1}{a_0 s^3 + a_1 s^2 + a_2 s + a_3}.$$



В соответствии с вариантом:

$$W_0(s) = \frac{1}{2s^3 + 4s^2 + 3s + a_3}.$$

```
>> a0 = 2; a1 = 4; a2 = 3; a3 = 1;
>> w0 = tf([1], [a0 a1 a2 a3])

Transfer function:
            1
-----------------------
2 s^3 + 4 s^2 + 3 s + 1
```

1. Определить граничное значение $k_г$ передаточного коэффициета регулятора при пропорциональном законе управления по формуле:

$$k_г = \frac{a_1 a_2}{a_0} - a_3 = \frac{4*3}{2} - 1 = 5$$

```
>> kg = a1*a2/a0 - a3;
```

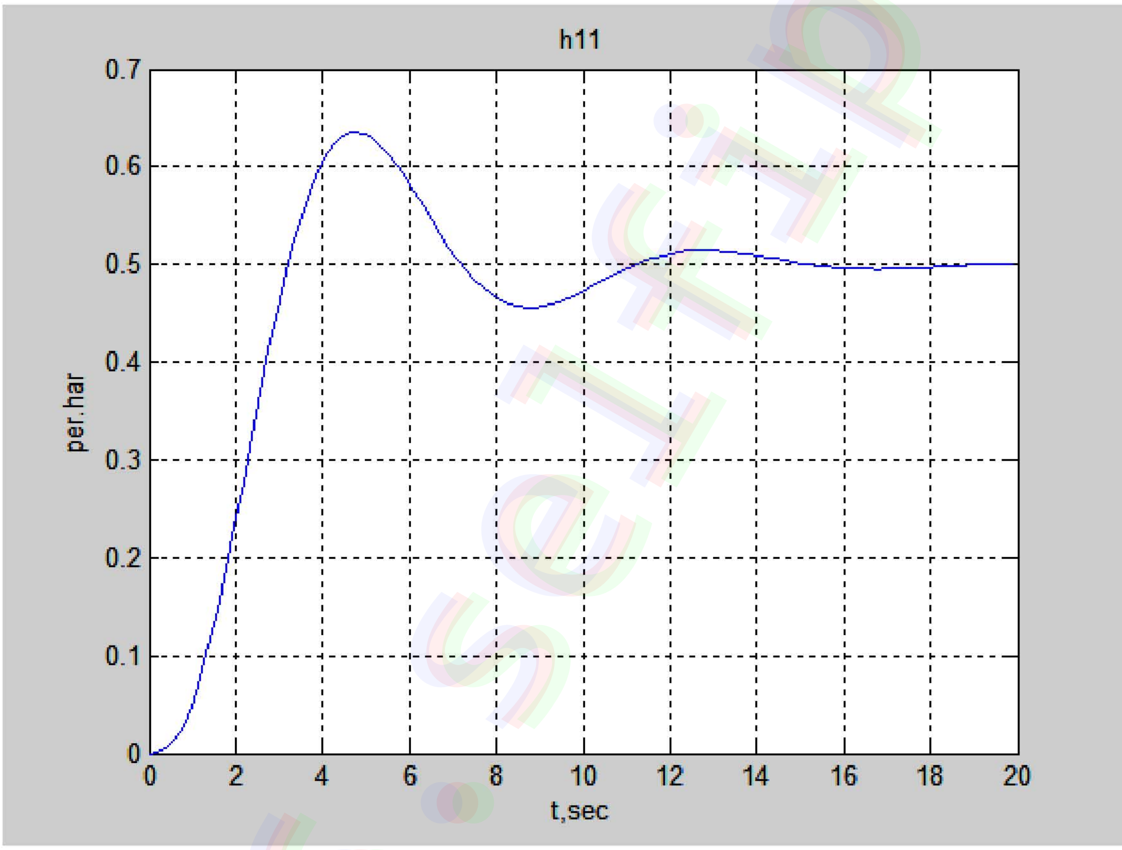
2. Определить по переходной характеристике время регулирования $\mathbf{t_р}$, перерегулирование $\boldsymbol{\sigma}$ и установившуюся ошибку $\mathbf{e_\infty}$ при П-регуляторе:

$$W_P(s) = k_П$$

$$k_П = \alpha k_г$$

$$\alpha = 0.2;\ 0.4;\ 0.8;$$

```
>> wp1 = 0.2*kg;
>> w11 = series(wp1,w0);
>> h11 = feedback(w11, 1);
>> [y,t] = step(h11);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h11'), grid
```



$h_m = 0.64$

$h_\infty = 0.5$

$\Delta = 0.05 * h_\infty = 0.025$

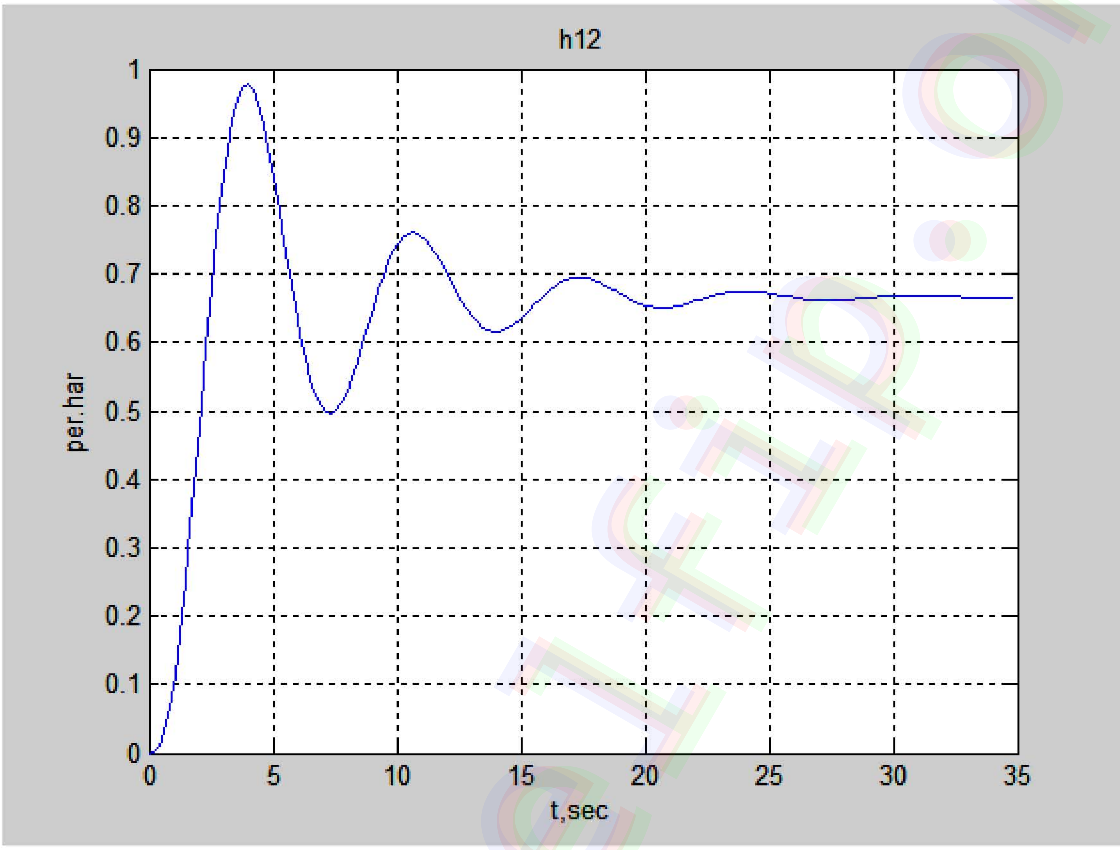
$t_p = 10$ с

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 28\%$$

```
>> 1/(1+w11)
Transfer function:
2 s^3 + 4 s^2 + 3 s + 1
-----------------------
2 s^3 + 4 s^2 + 3 s + 2
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s\frac{1}{1+W(s)}\frac{1}{s} = 0.5$$

```
>> wp2 = 0.4*kg;
>> w12 = series(wp2,w0);
>> h12 = feedback(w12, 1);
>> [y,t] = step(h12);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h12'), grid
```



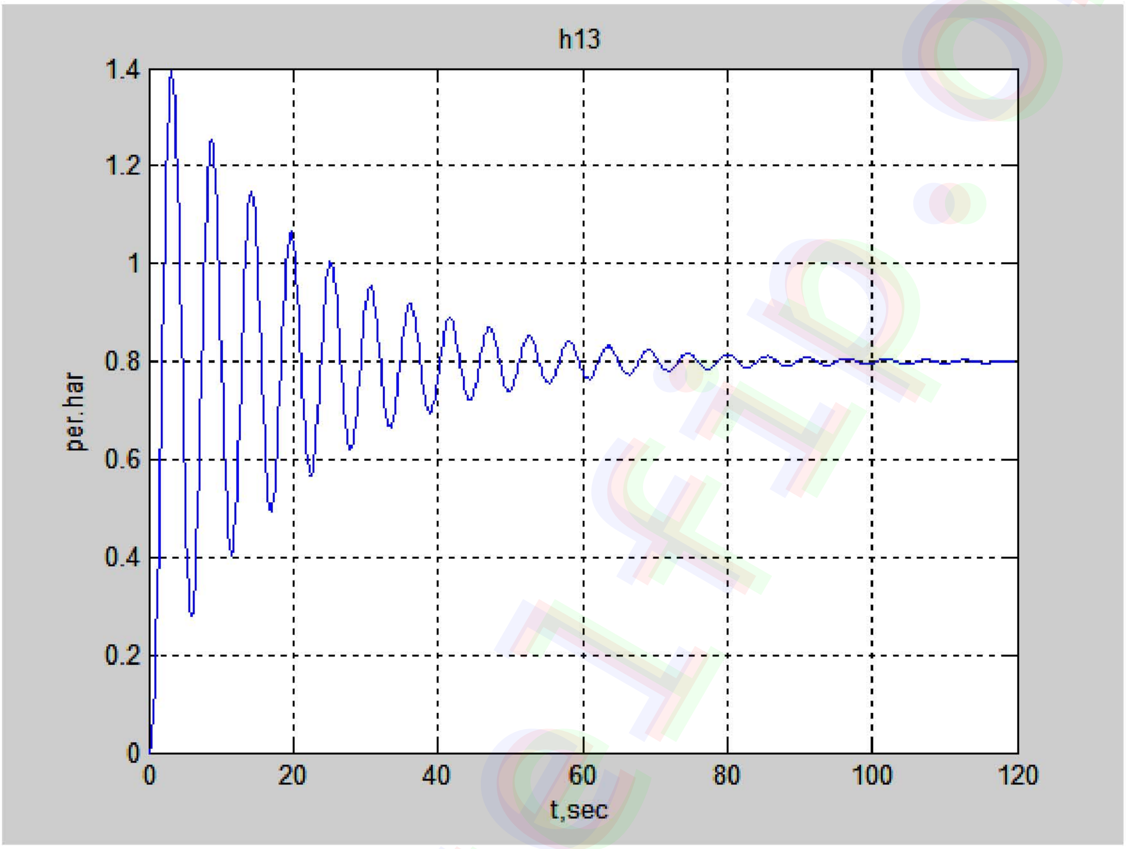
$h_m = 0.98$
$h_\infty = 0.67$
$\Delta = 0.05 * h_\infty = 0.034$
$t_p = 15$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 46\%$$

```
>> 1/(1+w12)
Transfer function:
2 s^3 + 4 s^2 + 3 s + 1
-----------------------
2 s^3 + 4 s^2 + 3 s + 3
```

$$e_\infty = \lim_{s \to 0} sE(s) = \lim_{s \to 0} s \frac{1}{1+W(s)} \frac{1}{s} = 0.33$$

```
>> wp3 = 0.8*kg
>> wp3 = tf([0.8*kg],[1])
>> w13 = series(wp3,w0);
>> h13 = feedback(w13, 1);
>> [y,t] = step(h13);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h13'), grid
```



$h_m = 1.4$

$h_\infty = 0.8$

$\Delta = 0.05 * h_\infty = 0.034$

$t_p = 50$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 75\%$$

```
>> 1/(1+w13)
Transfer function:
2 s^3 + 4 s^2 + 3 s + 1
-----------------------
2 s^3 + 4 s^2 + 3 s + 5
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s\frac{1}{1+W(s)}\frac{1}{s} = 0.2$$

K	0.2	0.4	0.8
t_p	10	15	50
σ	28%	46%	75%
e_∞	0.5	0.33	0.2

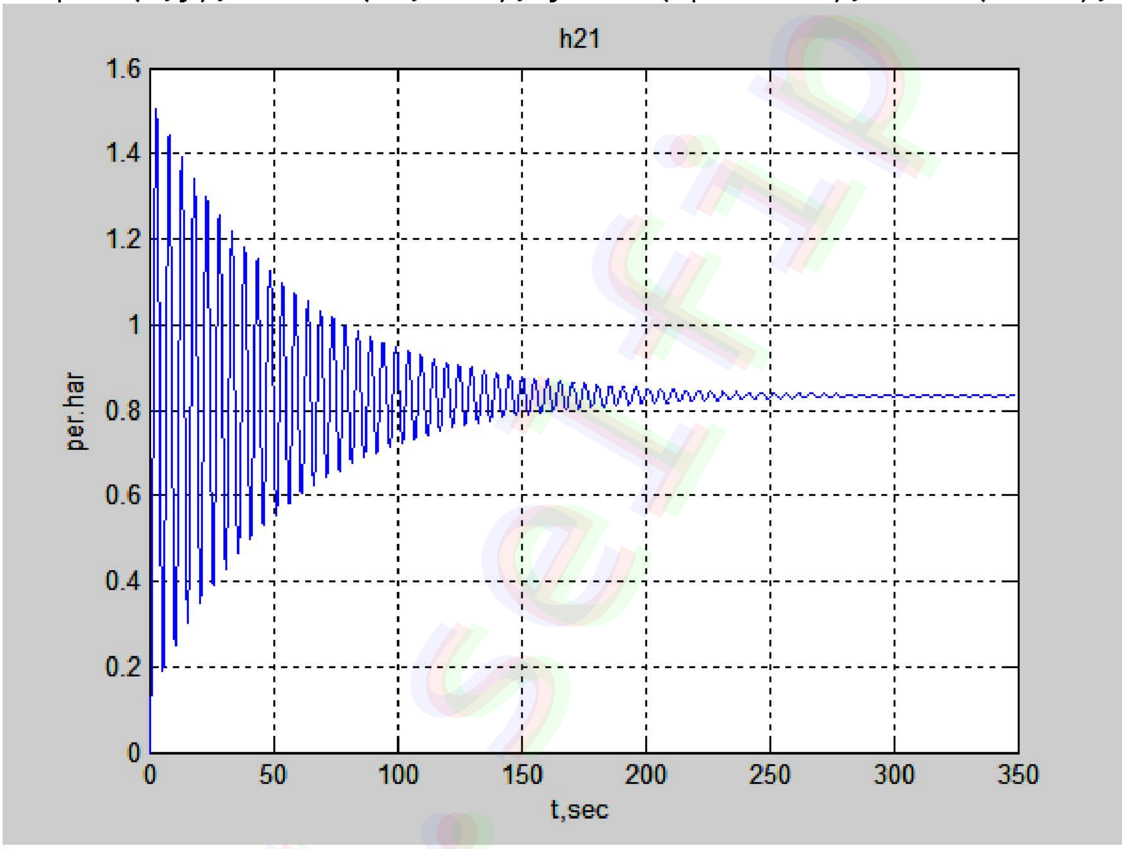
3. Определить по переходной характеристике время регулирования $\mathbf{t_p}$, перерегулирование $\boldsymbol{\sigma}$ и установившуюся ошибку $\mathbf{e_\infty}$ при ПД-регуляторе:

$$W_P(s) = k_П + k_Д s$$

$$k_П = k_г$$

$$k_Д = 0.2;\ 0.4;\ 0.8;$$

```
>> wpd1 = tf([0.2 kg], [1]);
>> w21 = series(wpd1,w0);
>> h21 = feedback(w21, 1);
>> [y,t] = step(h21);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h21'), grid
```



$h_m = 1.5$

$h_\infty = 0.83$

$\Delta = 0.05 * h_\infty = 0.042$

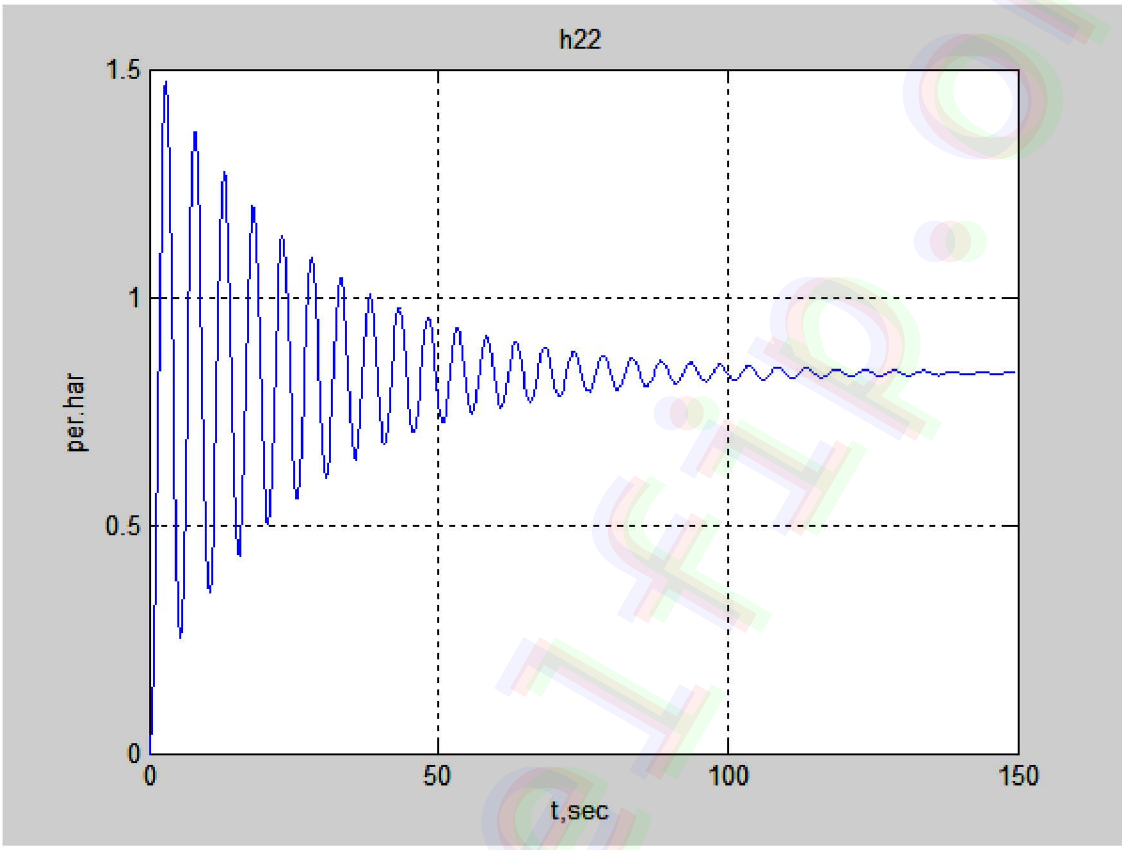
$t_p = 140$ с

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 81\%$$

```
>> 1/(1+w21)
Transfer function:
 2 s^3 + 4 s^2 + 3 s + 1
-------------------------
2 s^3 + 4 s^2 + 3.2 s + 6
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s \frac{1}{1+W(s)} \frac{1}{s} = 0.17$$

```
>> wpd2 = tf([0.4 kg], [1]);
>> w22 = series(wpd2,w0);
>> h22 = feedback(w22, 1);
>> [y,t] = step(h22);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h22'), grid
```



$h_m = 1.47$

$h_\infty = 0.83$

$\Delta = 0.05 * h_\infty = 0.042$

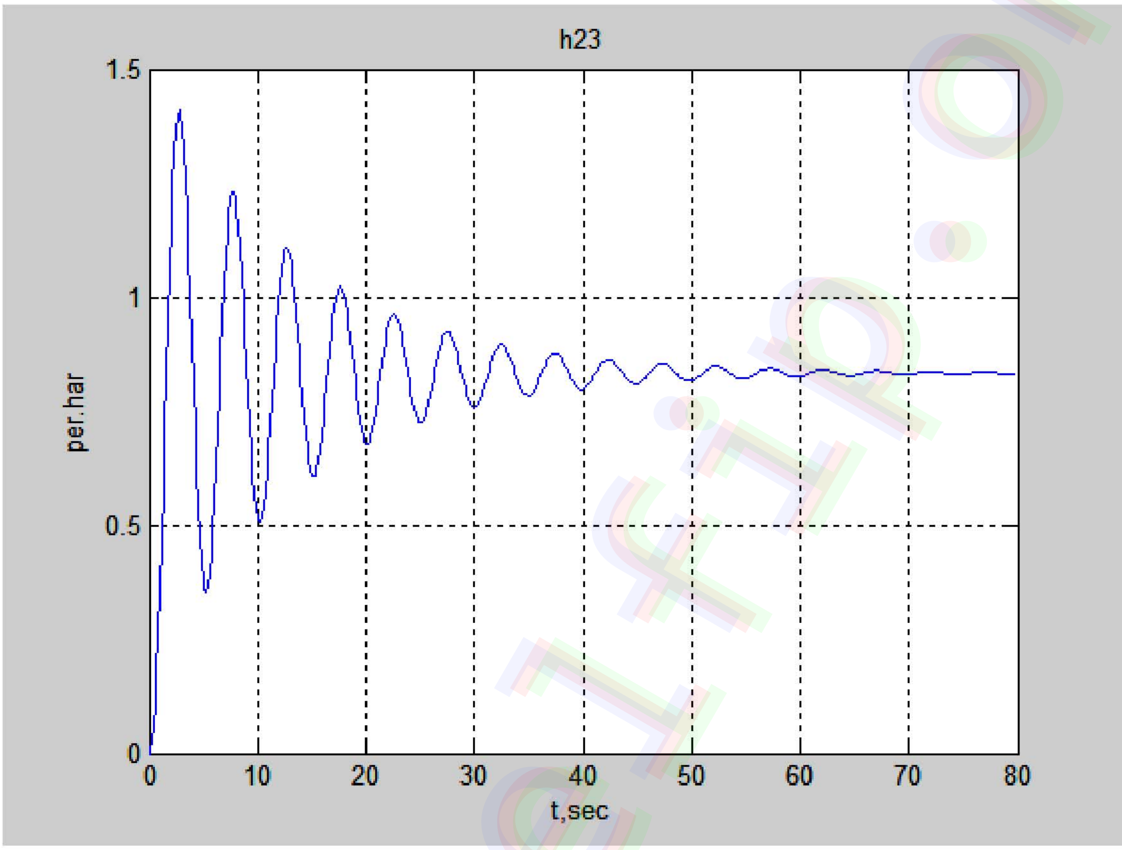
$t_p = 70$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 77\%$$

```
>> 1/(1+w22)
Transfer function:
 2 s^3 + 4 s^2 + 3 s + 1
-------------------------
2 s^3 + 4 s^2 + 3.4 s + 6
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s\frac{1}{1+W(s)}\frac{1}{s} = 0.17$$

```
>> wpd3 = tf([0.8 kg], [1]);
>> w23 = series(wpd3,w0);
>> h23 = feedback(w23, 1);
>> [y,t] = step(h23);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h23'), grid
```



$h_m = 1.4$

$h_\infty = 0.83$

$\Delta = 0.05 * h_\infty = 0.042$

$t_p = 30$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 68\%$$

```
>> 1/(1+w23)
Transfer function:
 2 s^3 + 4 s^2 + 3 s + 1
-------------------------
2 s^3 + 4 s^2 + 3.8 s + 6
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s\frac{1}{1+W(s)}\frac{1}{s} = 0.17$$

K	0.2	0.4	0.8
t_p	140	70	30
σ	81%	77%	68%
e_∞	0.17	0.17	0.17

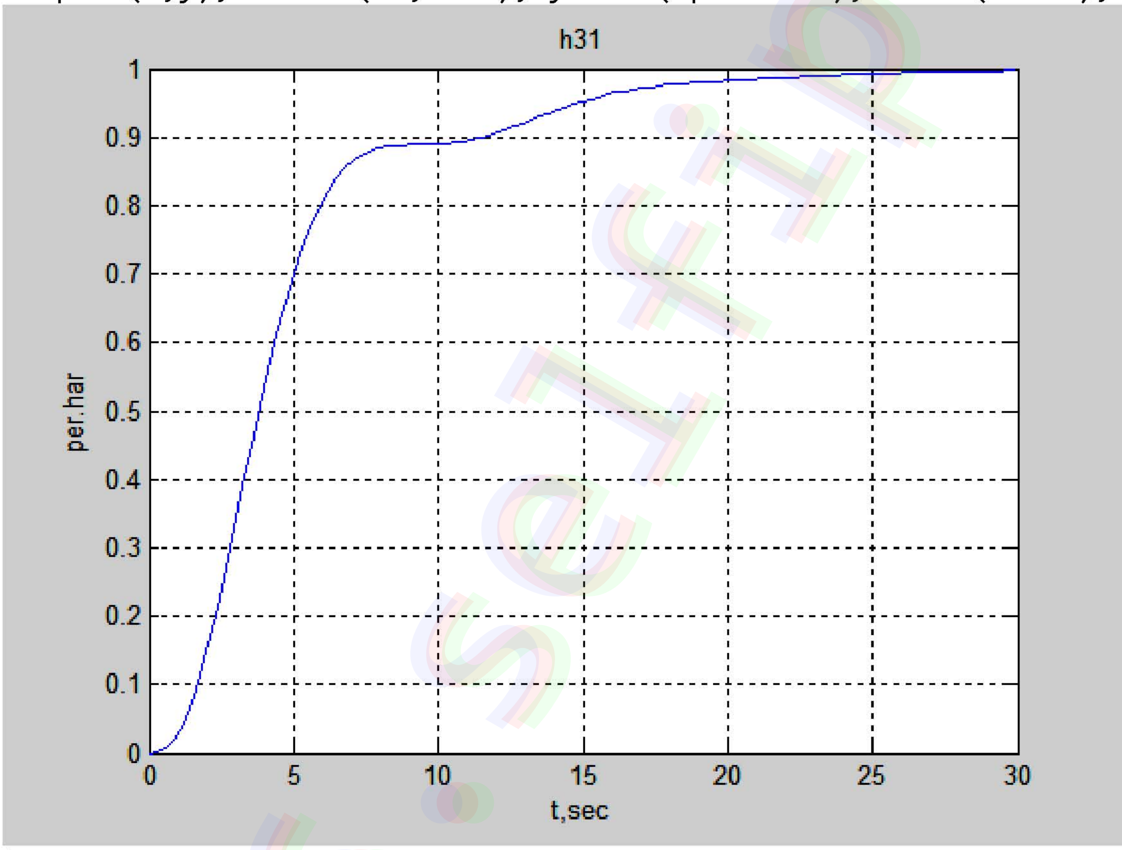
4. Определить по переходной характеристике время регулирования $\mathbf{t_p}$, перерегулирование $\boldsymbol{\sigma}$ и установившуюся ошибку $\mathbf{e_\infty}$ при ПИ-регуляторе:

$$W_P(s) = k_П + k_И \frac{1}{s}$$

$$k_П = 0.1k_г$$

$$k_И = 0.2;\ 0.4;\ 0.8;$$

```
>> wpi1 = tf([0.1*kg 0.2], [1 0]);
>> w31 = series(wpi1,w0);
>> h31 = feedback(w31, 1);
>> [y,t] = step(h31);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h31'), grid
```



$h_m = 0.99$

$h_\infty = 0.99$

$\Delta = 0.05 \cdot h_\infty = 0.05$

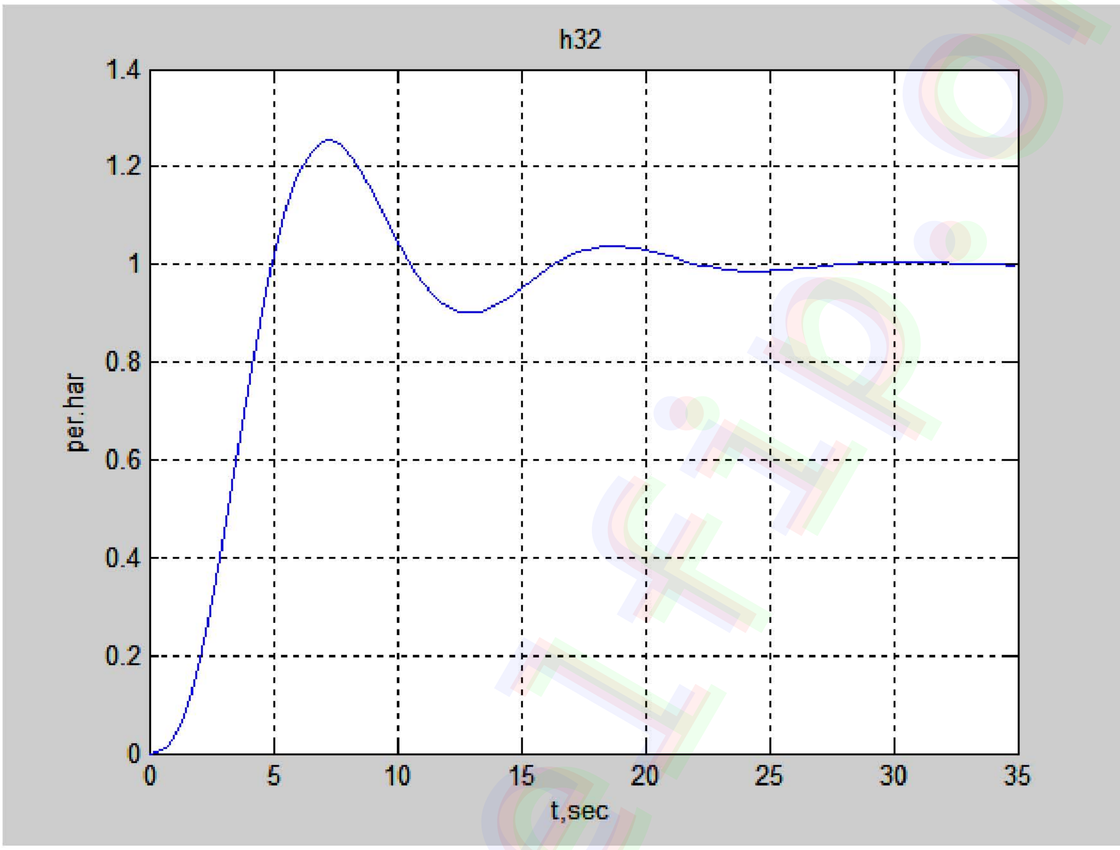
$t_p = 14$ с

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 0$$

```
>> 1/(1+w31)
Transfer function:
     2 s^4 + 4 s^3 + 3 s^2 + s
-----------------------------------
2 s^4 + 4 s^3 + 3 s^2 + 1.5 s + 0.2
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s \frac{1}{1+W(s)} \frac{1}{s} = 0$$

```
>> wpi2 = tf([0.1*kg 0.4], [1 0]);
>> w32 = series(wpi2,w0);
>> h32 = feedback(w32, 1);
>> [y,t] = step(h32);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h32'), grid
```



$h_m = 1.25$

$h_\infty = 1$

$\Delta = 0.05 * h_\infty = 0.05$

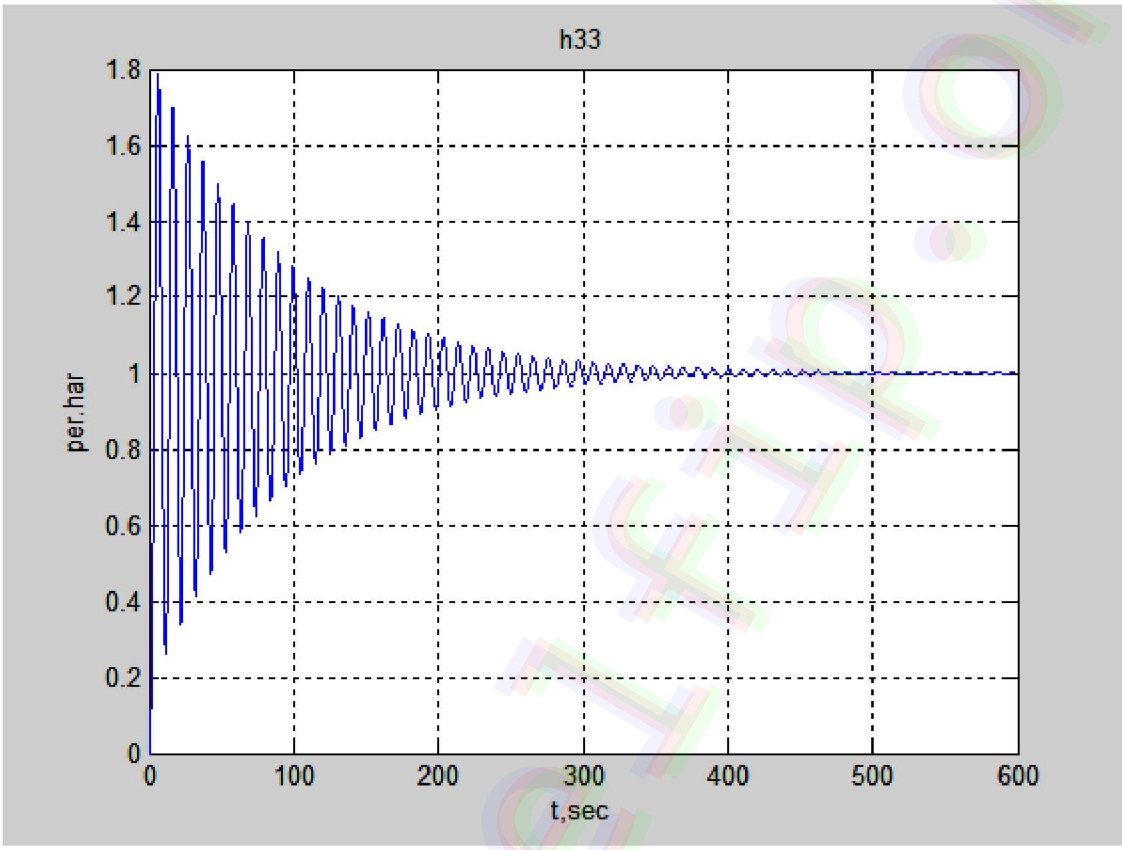
$t_p = 15$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 25\%$$

```
>> 1/(1+w32)
Transfer function:
     2 s^4 + 4 s^3 + 3 s^2 + s
-----------------------------------
2 s^4 + 4 s^3 + 3 s^2 + 1.5 s + 0.4
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s \frac{1}{1+W(s)} \frac{1}{s} = 0$$

```
>> wpi3 = tf([0.1*kg 0.8], [1 0]);
>> w33 = series(wpi3,w0);
>> h33 = feedback(w33, 1);
>> [y,t] = step(h33);
>> plot(t,y), xlabel('t,sec'), ylabel('per.har'), title('h33'), grid
```



$h_m = 1.78$

$h_\infty = 1$

$\Delta = 0.05 * h_\infty = 0.05$

$t_p = 250$ c

$$\sigma = \frac{h_m - h(\infty)}{h(\infty)} * 100\% = 78\%$$

```
>> 1/(1+w33)
Transfer function:
     2 s^4 + 4 s^3 + 3 s^2 + s
-----------------------------------
2 s^4 + 4 s^3 + 3 s^2 + 1.5 s + 0.8
```

$$e_\infty = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s \frac{1}{1+W(s)} \frac{1}{s} = 0$$

K	0.2	0.4	0.8
$\mathbf{t_p}$	14	15	250
σ	0	25%	78%
$\mathbf{e_\infty}$	0	0	0

5. Постройте на одном рисунке графики функций h11, h21, h31

```
>> t=[0:0.1:100];
>> [y1,t]=step(h11,t);
>> [y2,t]=step(h21,t);
>> [y3,t]=step(h31,t);
>> plot(t,y1,'-',t,y2,'--',t,y3,':'), xlabel('t,sec'),
ylabel('per.har'), title('h11, h21, h31'), text(95, 0.55, 'h11'),
text(95, 0.95, 'h21'), text(95, 1.05, 'h31'),  grid
```