In [2]:

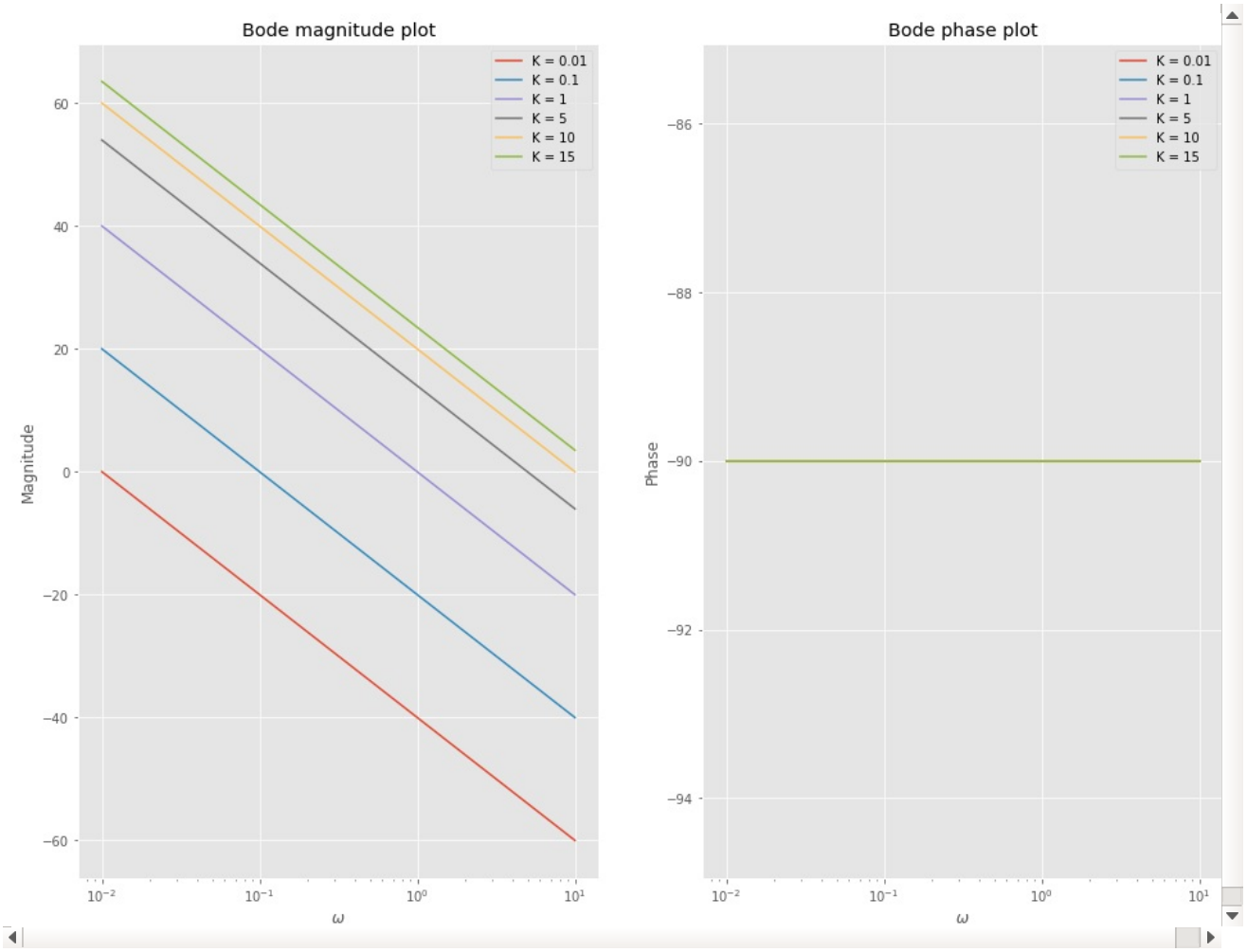
```
%matplotlib inline

import scipy as sp
from scipy import signal
import numpy as np
import matplotlib
import matplotlib.pyplot as plt

matplotlib.rcParams['figure.figsize'] = (16.0, 12.0)
matplotlib.style.use('ggplot')
```

# Интегрирующее звено

$$ W(s) = \frac{K}{s}$$

In [16]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[1, 0])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Интегрирующего звена')
```

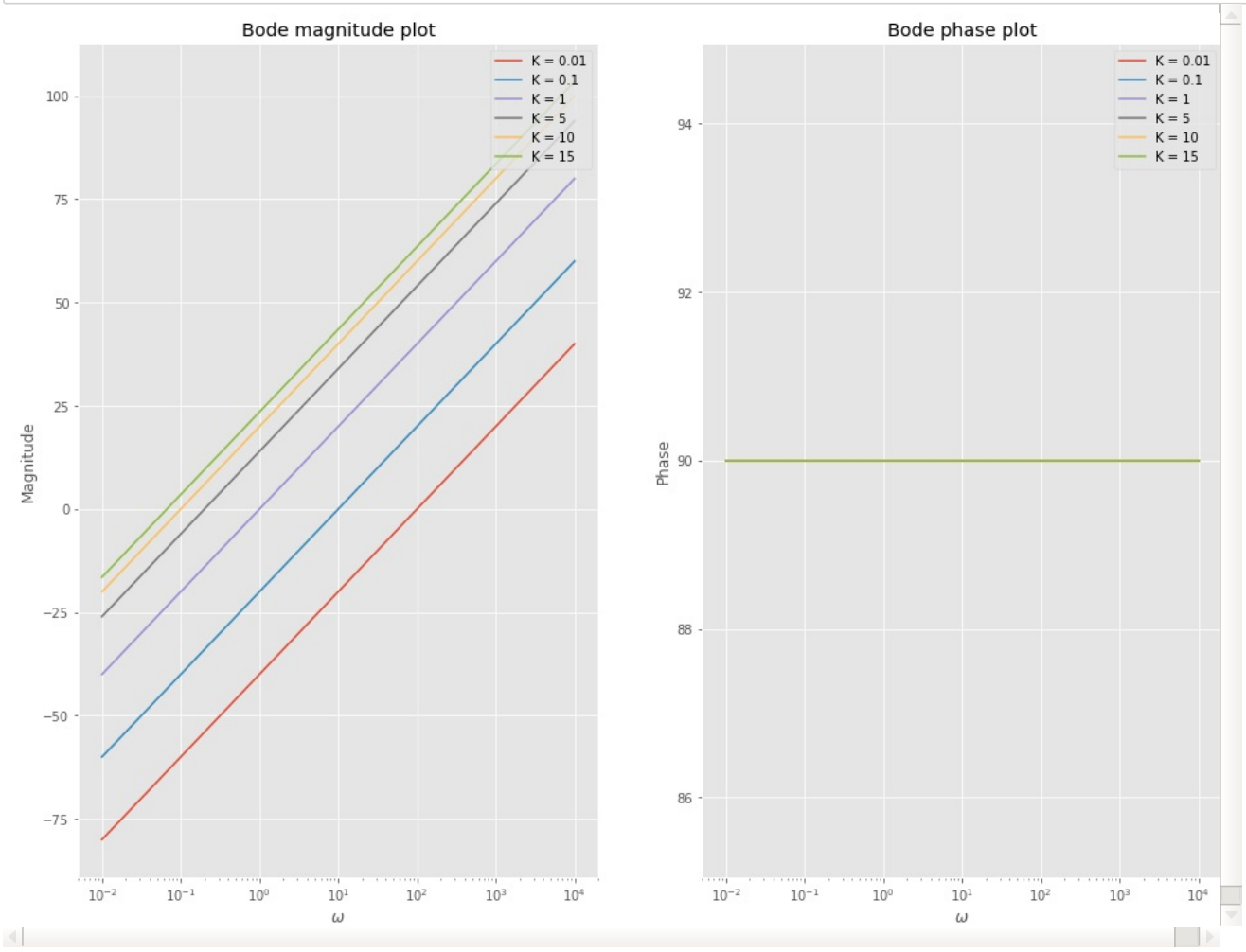



## Дифференцирующее звено

$$ W(s) = Ks$$

In [17]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i, 0],[1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Дифференцирующего звена')
```

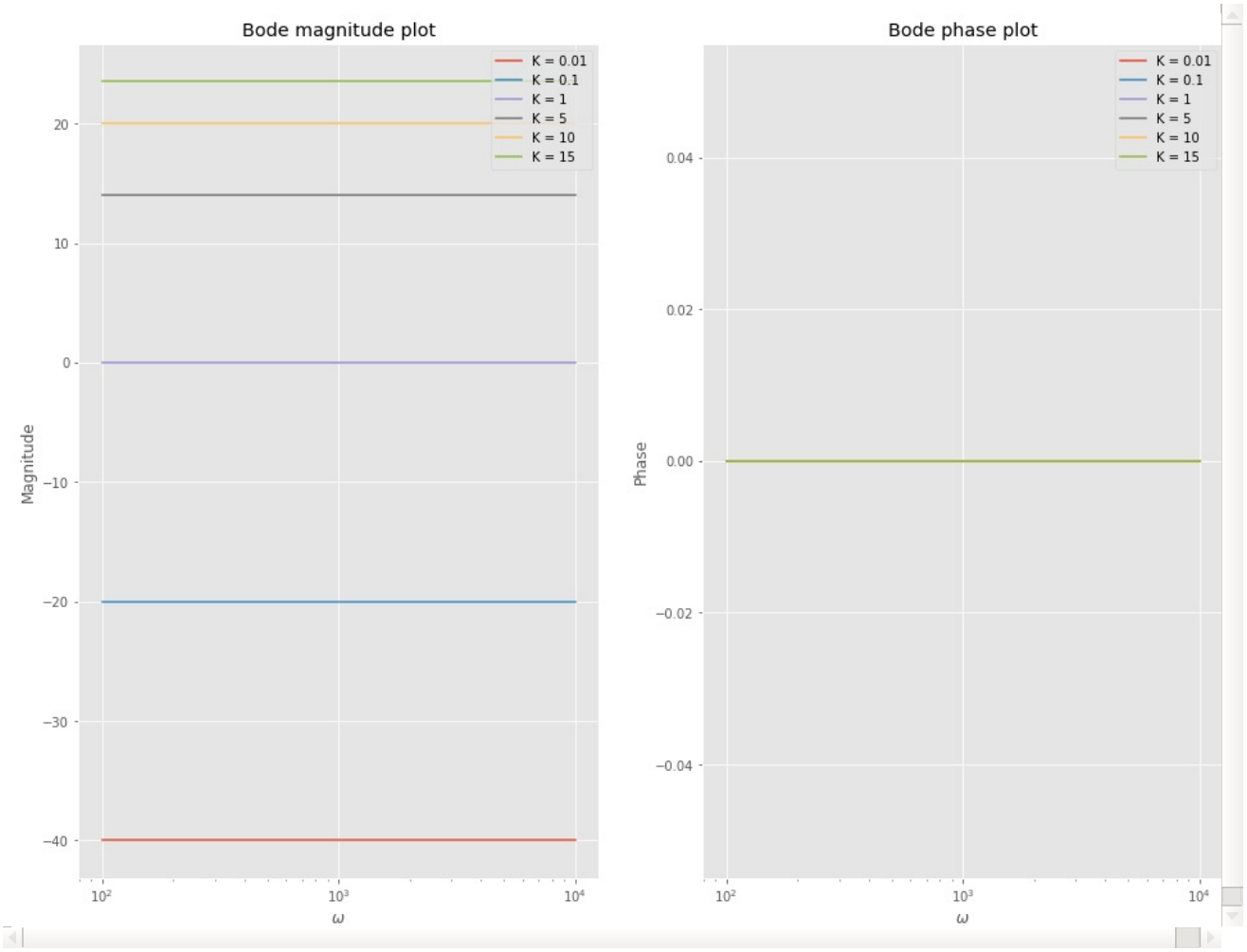


# Усилительное звено

$$ W(s) = K $$

In [18]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Усилительного звена')
```

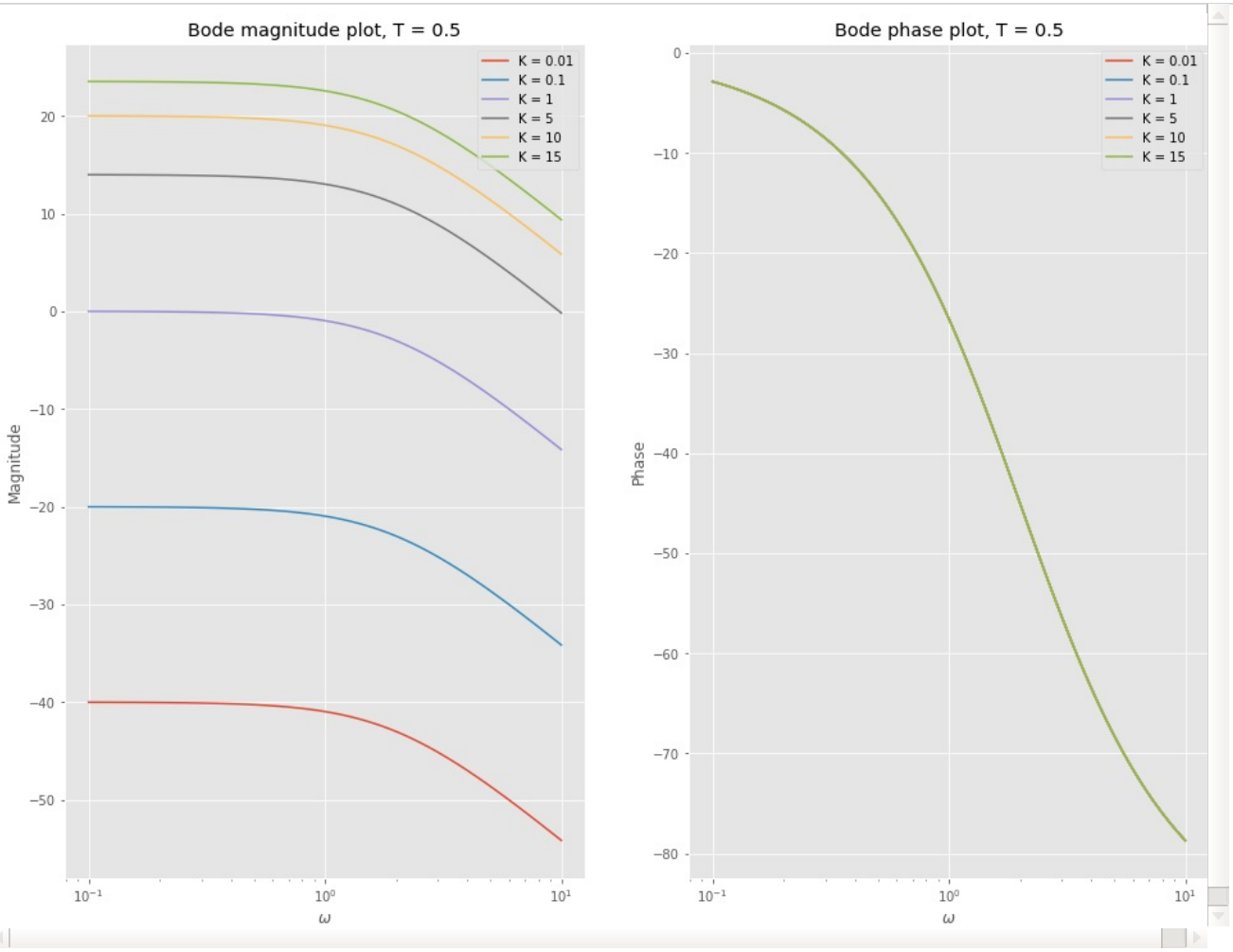



## Апериодическое звено 1-го порядка

$$ W(S) = \frac{K}{Ts + 1} $$

In [21]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 0.5

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[T, 1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 0.5');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 0.5')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Апериодическое 05')
```



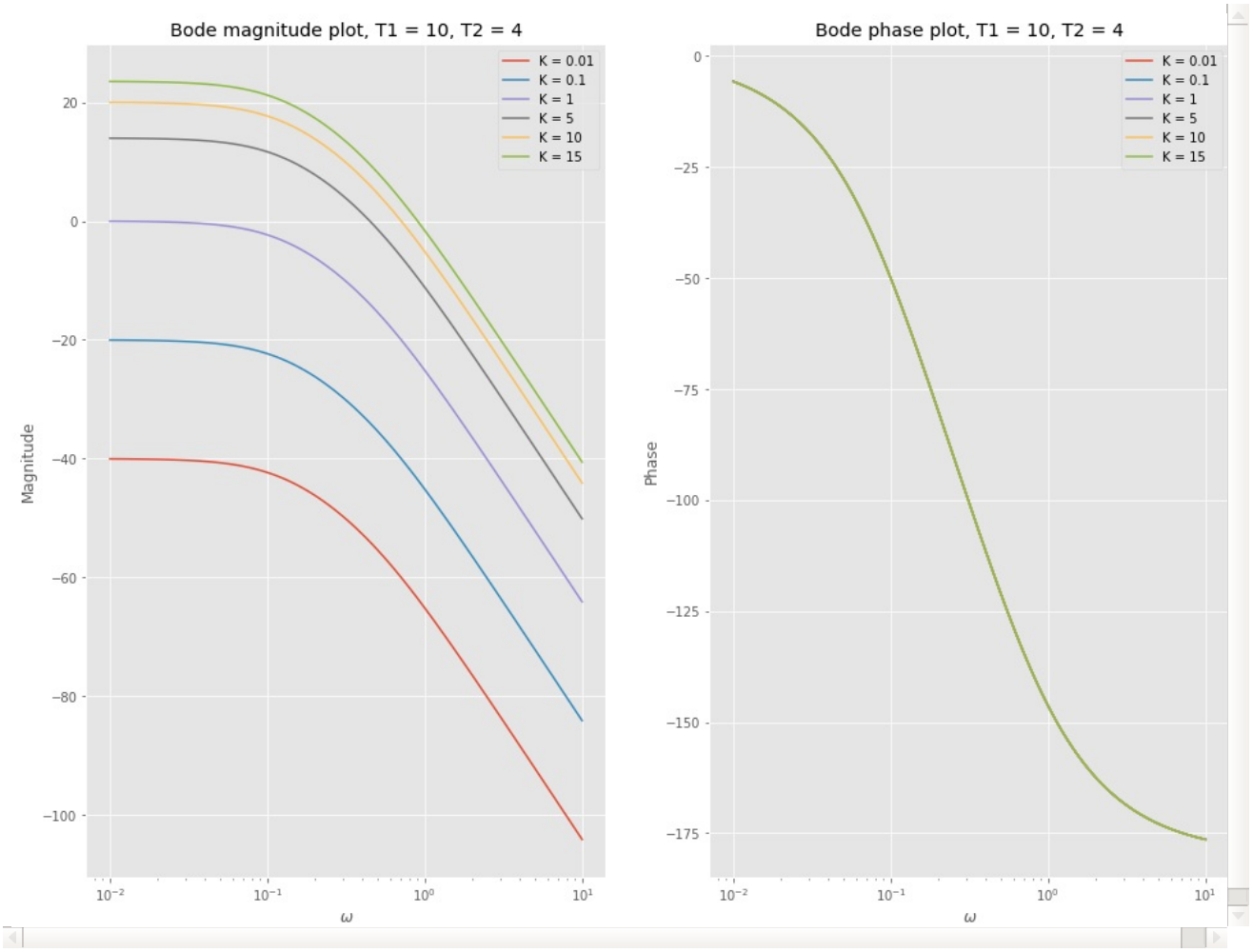
# Апериодическое звено 2-ого порядка

$T_1 > 2T_2$

$$ W(s) = \frac{K}{T_2^2s^2 + T_1s + 1} $$

In [26]:

```
T1 = 10
T2 = 4

t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];


w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[T2**2,T1, 1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T1 = 10, T2 = 4');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T1 = 10, T2 = 4')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Апериодическое2')
```



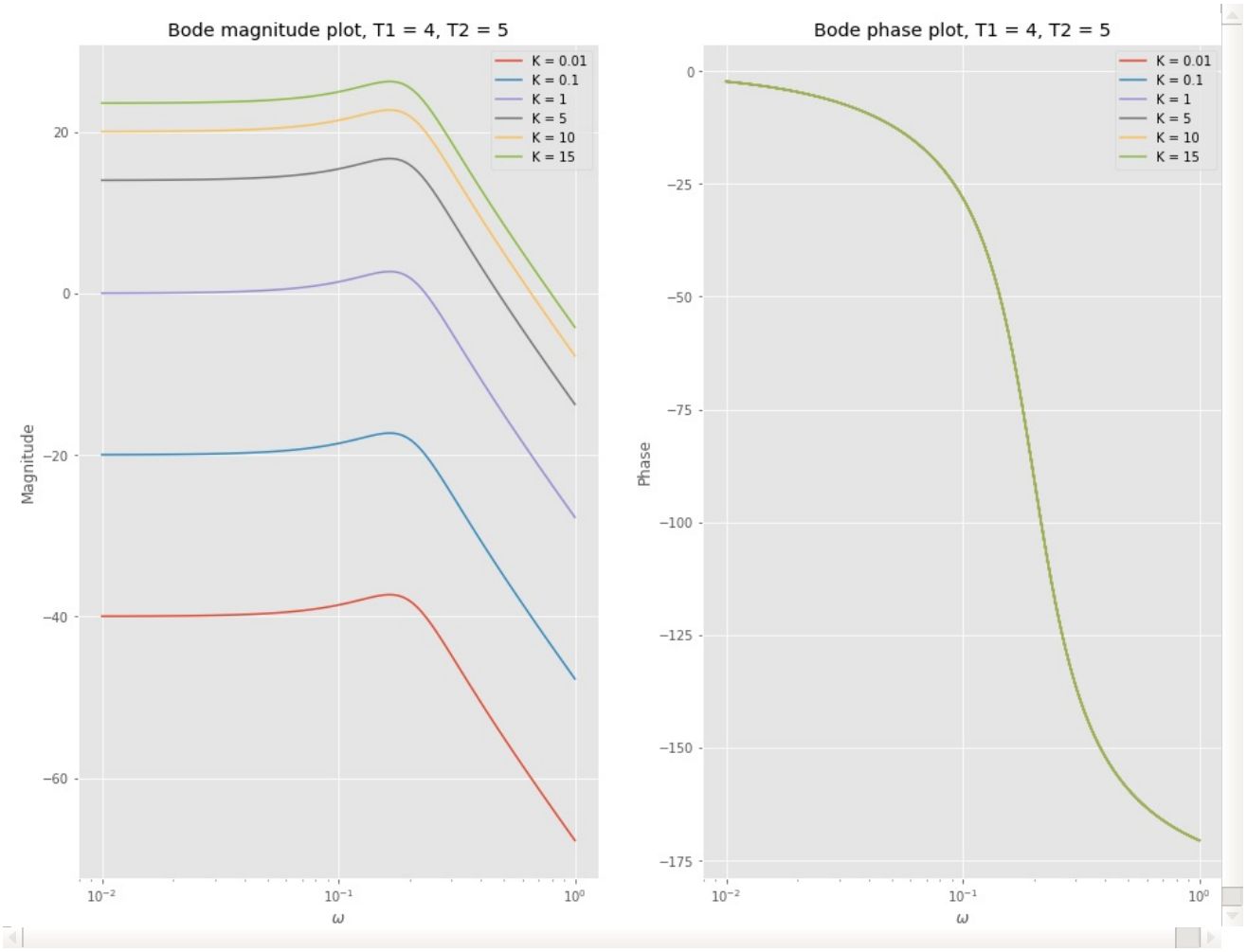

## Колебательное порядка

$T_1 < 2T_2$

$$ W(s) = \frac{K}{T_2^2s^2 + T_1s + 1} $$

In [27]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T1 = 4
T2 = 5

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[T2**2,T1, 1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T1 = 4, T2 = 5');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T1 = 4, T2 = 5')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Колебательное')
```

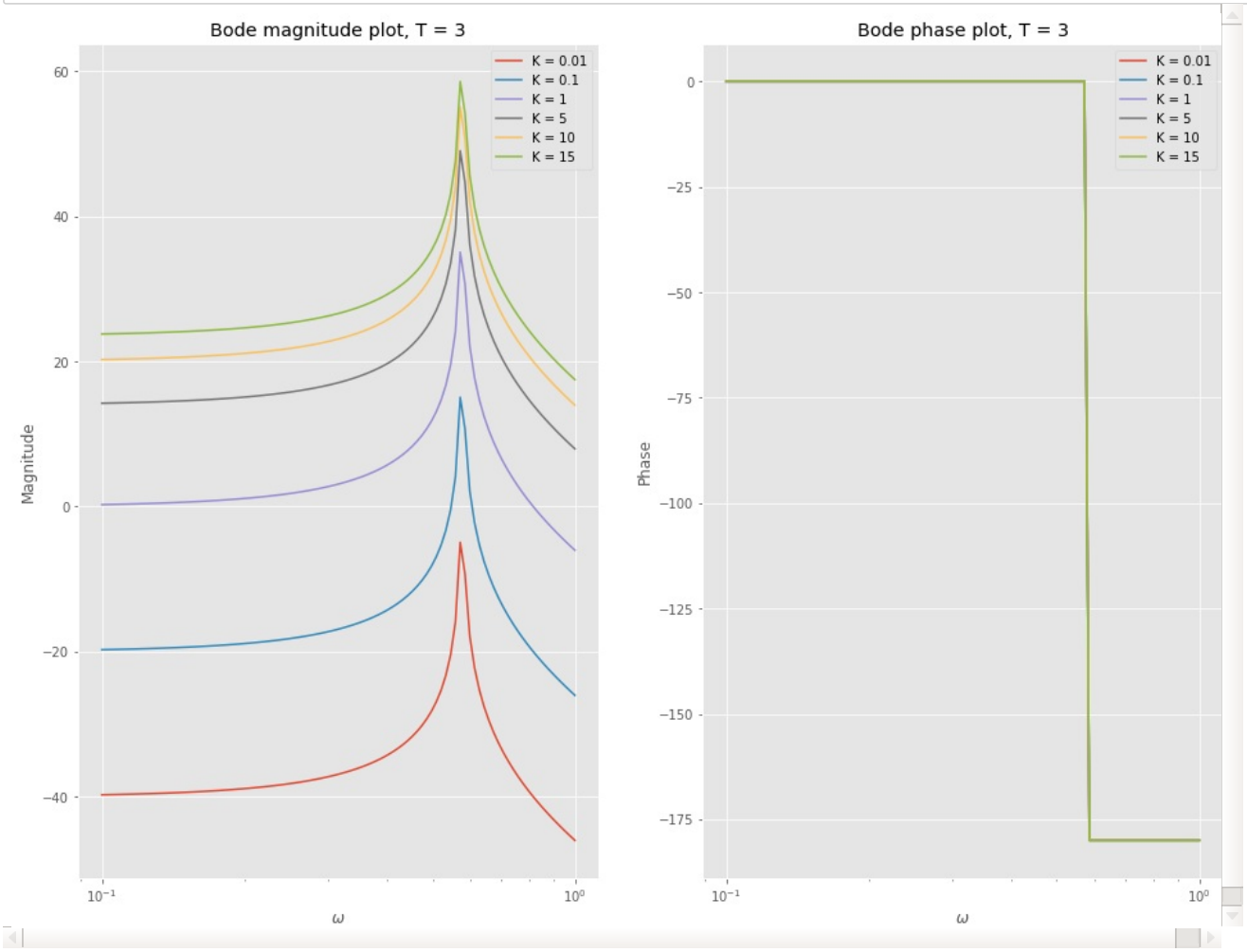



## Консервативное звено

$$ W(s) = \frac{K}{Ts^2 + 1} $$

In [28]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 3

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[T,0, 1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 3');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 3')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Консервативное')
```

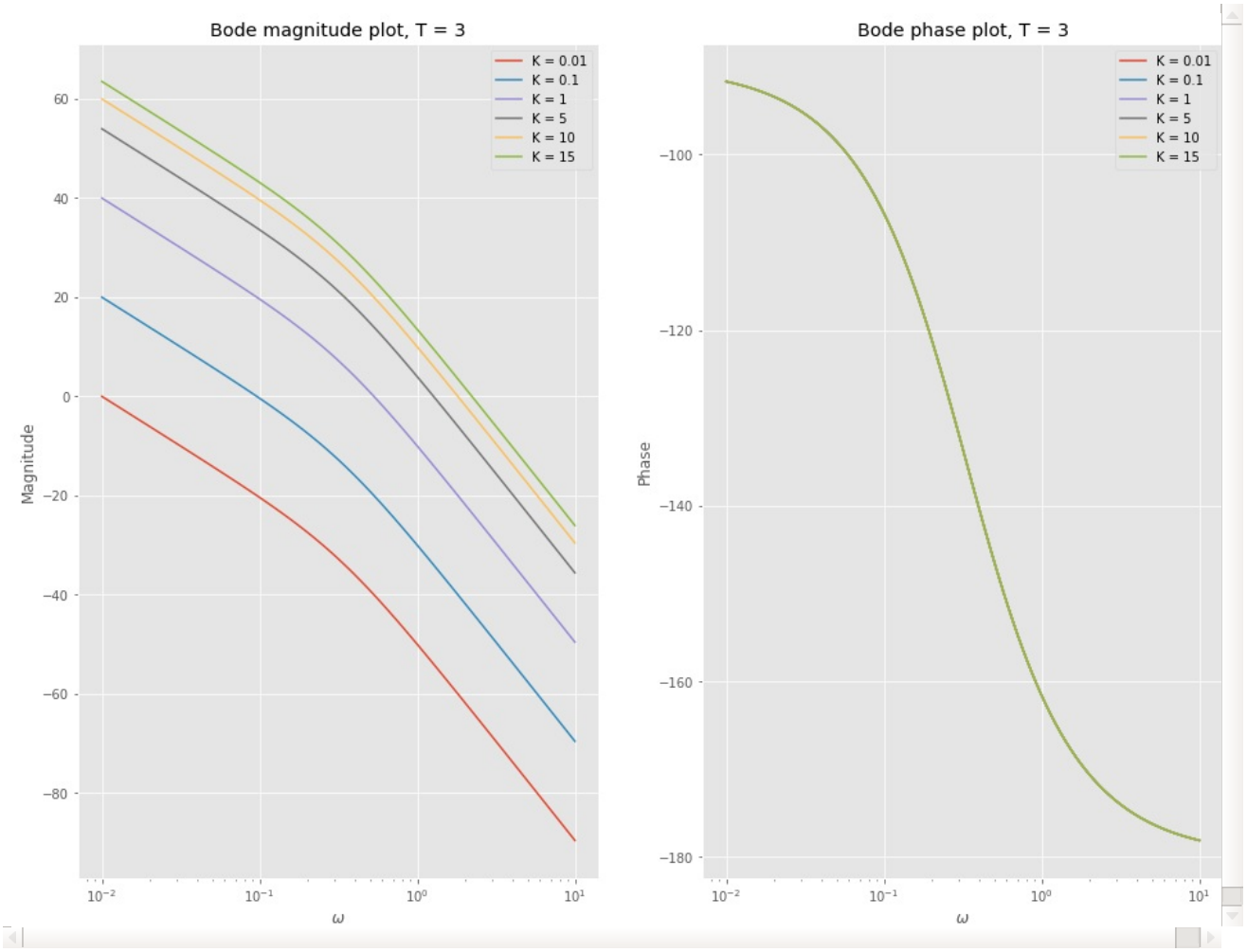


# Реальное интегрирующее звено

$$ W(s) = \frac{K}{Ts^2 + s} $$

In [30]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 3

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i],[T, 1,0])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 3');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 3')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Интегрирующее с запаздание')
```

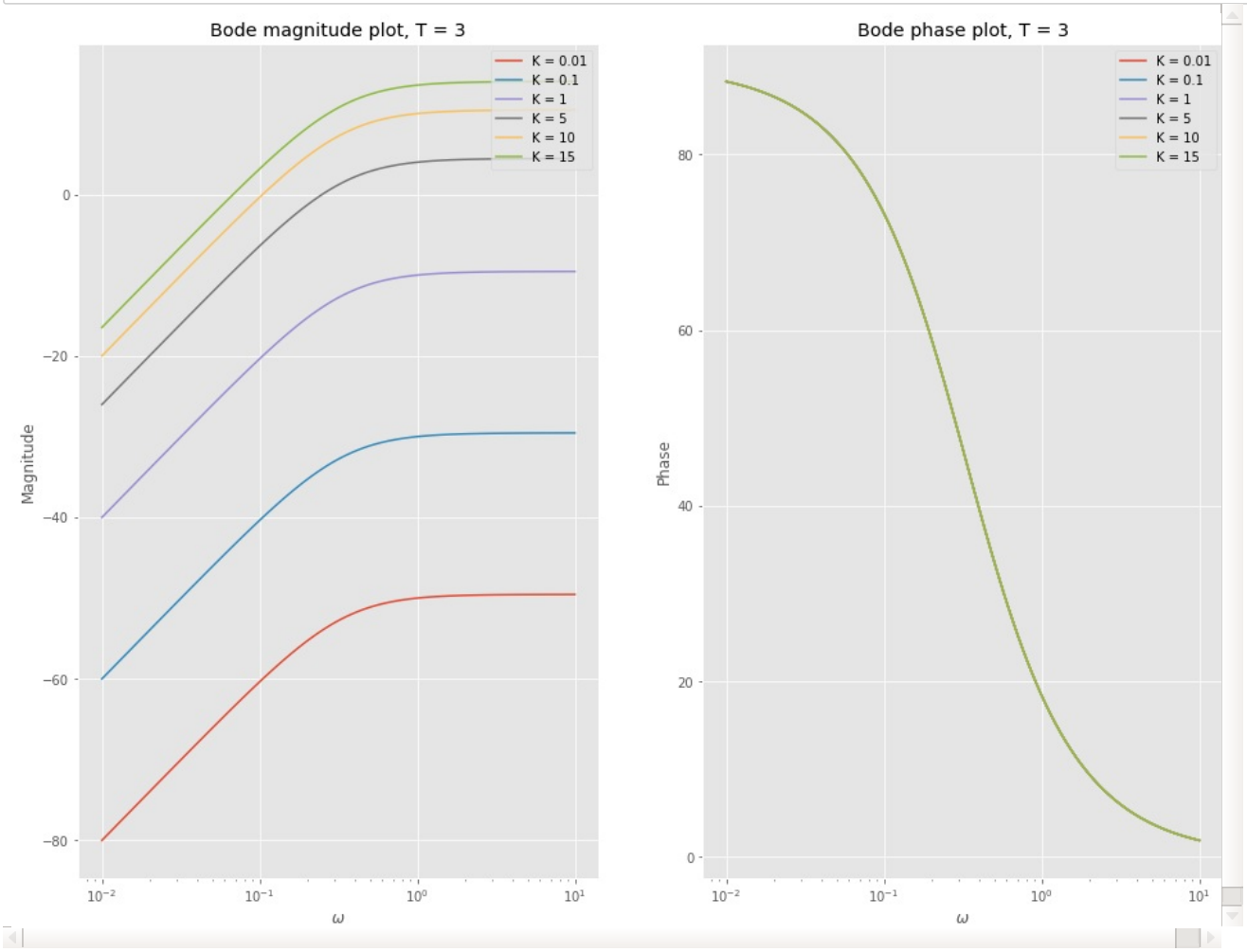



## Реальное дифференцирующее звено

$$ W(s) = \frac{Ks}{Ts + 1} $$

In [31]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 3

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i, 0],[T, 1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 3');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 3')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Дифференцирующее с запаздванием')
```

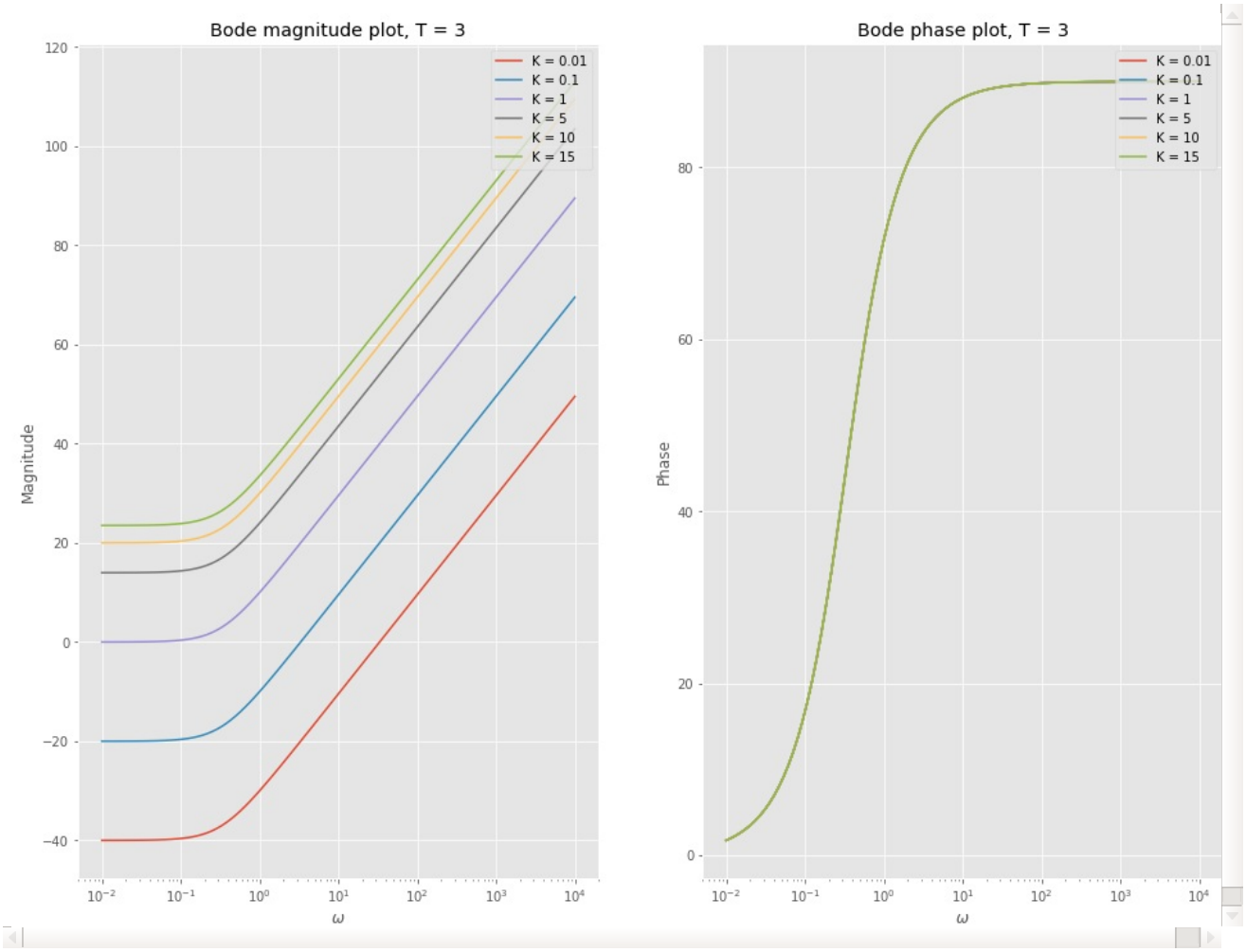


# Форсирующее звено

$$ W(s) = K(Ts+1) $$

In [33]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 3

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i*T, i],[1])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 3');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 3')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Форсирующее')
```




## Изодромное звено

$$ W(s) = \frac{K(Ts+1)}{s} $$

In [34]:

```
t = np.arange(0,25,0.01);
K = [0.01, 0.1, 1, 5, 10, 15];
T = 3

w_list = [];
mag_list = [];
phase_list = [];


for i in K:
    s = signal.lti([i*T, i],[1,0])
    w, mag, phase = signal.bode(s)
    w_list.append(w);
    mag_list.append(mag);
    phase_list.append(phase);

plt.subplot(1,2,1)
plt.semilogx(w_list[0],mag_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],mag_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],mag_list[2], label = 'K = 1')
plt.semilogx(w_list[3],mag_list[3], label = 'K = 5')
plt.semilogx(w_list[4],mag_list[4], label = 'K = 10')
plt.semilogx(w_list[5],mag_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode magnitude plot, T = 3');
plt.xlabel('$\omega$')
plt.ylabel('Magnitude')

plt.subplot(1,2,2)
plt.semilogx(w_list[0],phase_list[0], label = 'K = 0.01')
plt.semilogx(w_list[1],phase_list[1], label = 'K = 0.1')
plt.semilogx(w_list[2],phase_list[2], label = 'K = 1')
plt.semilogx(w_list[3],phase_list[3], label = 'K = 5')
plt.semilogx(w_list[4],phase_list[4], label = 'K = 10')
plt.semilogx(w_list[5],phase_list[5], label = 'K = 15')
plt.legend( loc = 1)
plt.title('Bode phase plot, T = 3')
plt.xlabel('$\omega$')
plt.ylabel('Phase')

plt.savefig('ПФ Изодромное')
```