

# Practical 15

Figure 1:

15. Locate the poles of  $f(z) = \frac{1}{5z^4+26z^2+5}$  and specify their order.

1

Figure 2:

<code>poles(F(s))</code>	Poles of the transfer function $F(s)$
<code>zeros(F(s))</code>	Zeros of the transfer function $F(s)$
<code>poles_and_zeros(F(s),opts)</code>	Image of the Poles/zeros-distribution of the transfer function $F(s)$ in the complex s-plane

```
→ kill(all);
(%o0) done

→ load(coma);
coma v.2.1 (Wilhelm Haager, 2019-05-21)
(%o1) /usr/share/maxima/5.45.1/share/contrib/coma/coma.mac

→ zeros(s^2-1);
(%o2) [1.0, -1.0]

Simple zeros at 1, -1.

→ zeros((s^4-1)/(s^4+1));
(%o3) [1.0 %i, -1.0, -0.99999 %i, 0.99999]

Simple zeros at ±1, ±i.

→ zeros(5·s^4+26·s^2+5);
(%o4) [0.44721 %i, -0.44721 %i, -2.236 %i, 2.236 %i]

Simple zeros at ±sqrt(5) i, ±i/sqrt(5)

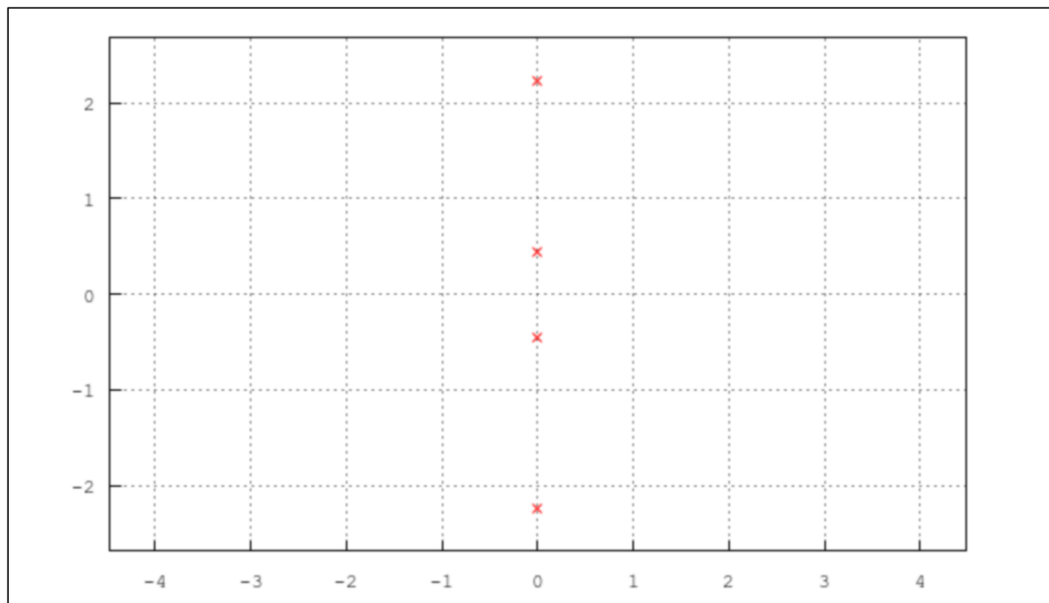
→ zeros(1/(5·s^4+26·s^2+5));
(%o5) []

No zeros

→ poles(1/(5·s^4+26·s^2+5));
(%o6) [0.44721 %i, -0.44721 %i, -2.236 %i, 2.236 %i]
```

Simple poles at  $\pm\sqrt{5} i$ ,  $\pm i/\sqrt{5}$

```
→ poles_and_zeros(1/(5·s4+26·s2+5));
(%t7)
```



```
(%o7)
```

A pole is indicated by a × mark, a zero by a ° mark.

```
→ float(sqrt(5));
(%o8) 2.236
```

```
→ float(1/sqrt(5));
(%o9) 0.44721
```

## 2

Example

```
→ kill(all);
(%o0) done
```

```
→ load(coma);
coma v.2.1 (Wilhelm Haager, 2019-05-21)
(%o1) /usr/share/maxima/5.45.1/share/contrib/coma/coma.mac
```

```
→ f(s):=(s2+2)/(s2-1);
```

```
(%o2) f(s):= 
$$\frac{s^2 + 2}{s^2 - 1}$$

```

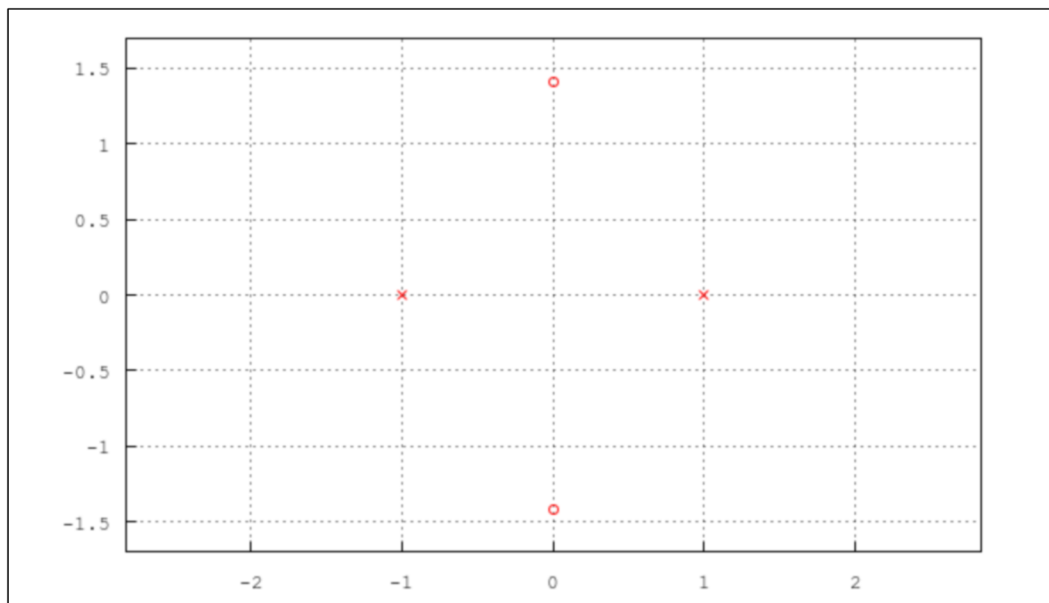
```
→ zeros(f(s));
(%o3) [1.4142 %i, -1.4142 %i]
```

Simple zeros at  $\pm\sqrt{2}i$

```
→ poles(f(s));
(%o4) [1.0, -1.0]
```

Simple poles at  $\pm 1$ .

```
→ poles_and_zeros(f(s));
(%t5)
```



```
(%o5)
```

### 3

Example

```
→ kill(all);
(%o0) done
```

```
→ load(coma);
coma v.2.1 (Wilhelm Haager, 2019-05-21)
(%o1) /usr/share/maxima/5.45.1/share/contrib/coma/coma.mac
```

```
→ f(s):=1/(s^2*(s+4));
```

```
(%o2) f(s):= \frac{1}{s^2 (s+4)}
```

→ `zeros(f(s));`

(%o3) **[]**

No zeros

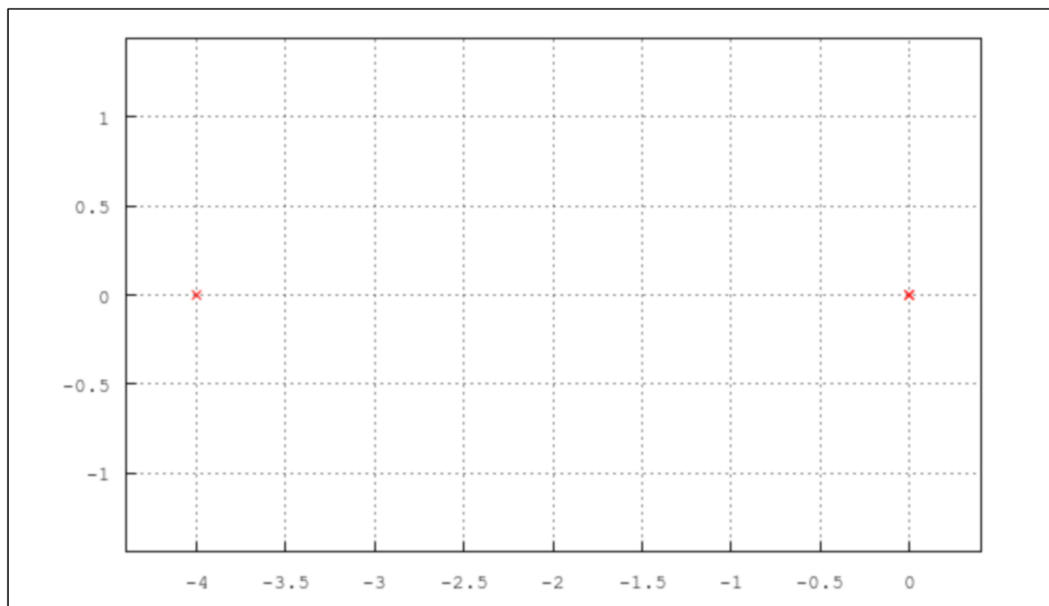
→ `poles(f(s));`

(%o4) **[0,0,-4.0]**

Poles of order 2 at 0 and a simple at -4.

→ `poles_and_zeros(f(s));`

(%t5)



(%o5)

## 4

### Exercise

Figure 3: (a), (c), (e)

1. Locate the zeros of the following functions and determine their order.

(a)  $(1 + z^2)^4$ .

(b)  $\sin^2 z$ .

(c)  $z^2 + 2z + 2$ .

(d)  $\sin z^2$ .

(e)  $z^4 + 10z^2 + 0$ .

Figure 4:

**2.** Locate the poles of the following functions and determine their order.

(a)  $(z^2 + 1)^{-3} (z - 1)^{-4}$ .

(b)  $z^{-1} (z^2 - 2z + 2)^{-2}$ .

(c)  $(z^6 + 1)^{-1}$ .

(d)  $(z^4 + z^3 - 2z^2)^{-1}$ .

(e)  $(3z^4 + 10z^2 + 3)^{-1}$ .