Chapter 10 - Differentiation

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Differentiation is the most important thing in calculus so let's get to it!

Using `diff`

What about calculus? Don't worry -- Matlab will not let you down! Suppose you'd like to differentiate the function `log(6*x+2)`. You could either do it yourself or... just ask Matlab to do it with the `diff` command:

```
syms x
diff(log(6*x+2))

ans =
6/(6*x + 2)
```

Or with a symbolic function:

```
syms f(x);
f(x) = cos(x^2+2*tan(x));
diff(f(x))

ans =
-sin(2*tan(x) + x^2)*(2*x + 2*tan(x)^2 + 2)
```

It's okay if we don't plug the `x` in when we write it:

```
diff(f)

ans(x) =
-sin(2*tan(x) + x^2)*(2*x + 2*tan(x)^2 + 2)
```

Higher Derivatives

What could be easier?

Would you like to find the *third* derivative of the function `log(6*x+2)`? That's easy too -- just pass 3 as a second parameter to the `diff` command:

```
diff(log(6 * x + 2), 3)
```

```
ans =
432/(6*x + 2)^3
```

IMPORTANT

It is a common mistake to believe that the `3` in the above calculation will take the first derivative and plug in `x=3`. **It does not do this!** If you want to differentiate and then plug in just wait a bit and we'll cover that.

Higher Derivatives - An Alternate Way

It's worth noting that we could have taken the third derivative this way, though we probably wouldn't:

```
diff(diff(diff(log(6*x+2))))
```

```
ans =
432/(6*x + 2)^3
```

A Different Variable

Suppose our expression has two variables and we want the derivative with respect to one of them. As usual `x` is the default

```
syms a x
diff(a^3*x^4)
```

```
ans =
4*a^3*x^3
```

but we can tell Matlab differently.

```
diff(a^3*x^4,a)
```

```
ans =
3*a^2*x^4
```

We can even do the second derivative with respect to `a`.

```
diff(a^3*x^4,a,2)
```

```
ans =
6*a*x^4
```

Wait, that Second Parameter?

Matlab is smart. If the second parameter is a variable it will take the derivative with respect to that variable. If it's a number it will take that numbered derivative. If it sees a variable and *then* a number it will take that numbered derivative with respect to that variable.

Again with Symbolic Functions

If we have a symbolic function of multiple variables we can differentiate too:

```
syms f(x,y);
f(x,y) = 2*x^2*y^3+x*sin(x*y);
diff(f(x,y),x)

ans =
sin(x*y) + 4*x*y^3 + x*y*cos(x*y)
```

We could even take the deriative with respect to `x` and then with respect to `y`. This might only make sense to those with multidimensional calculus:

```
diff(diff(f(x,y),x),y)

ans =
2*x*cos(x*y) + 12*x*y^2 - x^2*y*sin(x*y)
```

Differentiating and then Plugging In - Using subs.

It may seem a bit late but this is the perfect time to talk about plugging things into symbolic expressions. Here's how. Suppose we simply want to plug `x=3` into `x^2-x+2`. We do:

```
subs(x^2-x+2,x,3)

ans =
8
```

So now to take the derivative and then plug in, we simply nest the commands. Here's the second derivative of `x^3+exp(x^2)` with `x=1` plugged in:

```
subs(diff(x^3+exp(x^2),2),x,1)

ans =
6*exp(1) + 6
```

Understand: `x^3+exp(x^2)` is treated as a symbolic expression by Matlab, it's not treated as a function. Then `diff(x^3+exp(x^2)` is also treated as a symbolic expression, and `diff` does its job on that symbolic expression, giving back another symbolic expression, which goes into `subs`.

Or with a function:

```
syms f(x);
f(x) = 1/(x^2+3);
subs(diff(f(x)),x,-3)

ans =
1/24
```

Understand: Even though we think of `f(x)` as a function, really `f` is a function and `f(x)` is a symbolic expression, so `diff` works just fine, followed by `subs`.

Common Mistake

A common mistake is the following:

```
syms f(x)
f(x)=x^2+5*x+3;
diff(f(6))
```

```
ans =
0
```

Do you see the problem? It's the order in which things have been done. First `6` was plugged in, yielding a constant, then the derivative was was taken, yielding `0`. Instead as we've seen, we need to do:

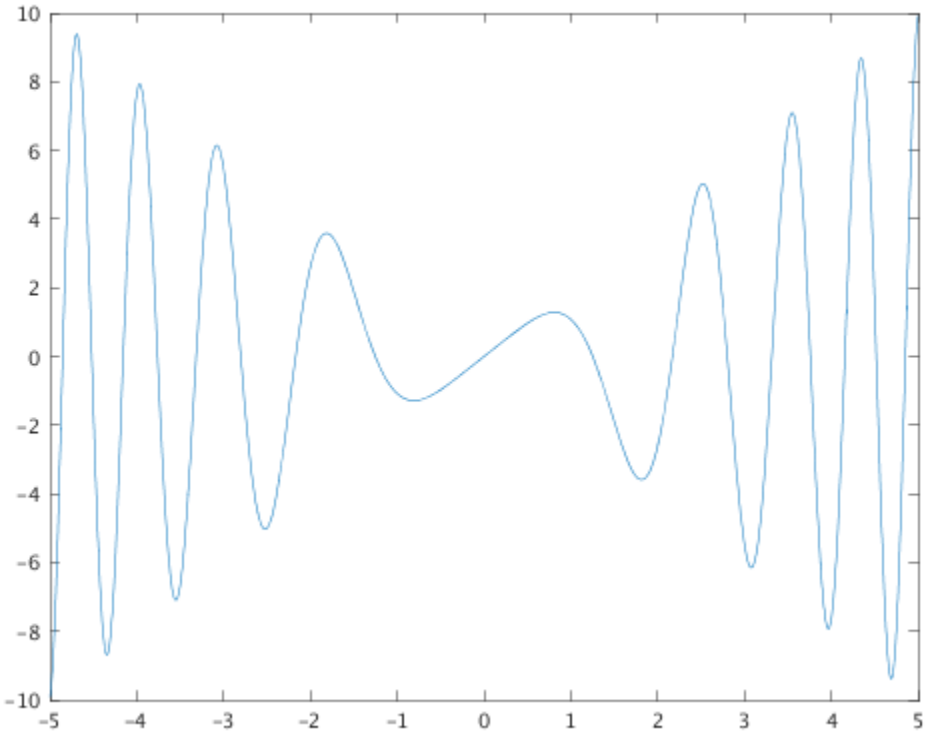
```
subs(diff(f(x)),x,6)
```

```
ans =
17
```

Plotting Derivatives

Likewise we can nest `diff` inside `fplot`. Here's an example, a plot of the derivative of `sin(x^2)`:

```
fplot(diff(sin(x^2)))
```



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