

## **3.3 Methods of integration**

### **3.3.1 Integrals by inspection**

Integration is the reverse of differentiation. Our standard derivatives provide us with a source of standard integrals that we can evaluate on sight.

$$\frac{d}{dx} \left( \frac{x^{n+1}}{n+1} \right) = x^n$$

$$\therefore \int x^n dx = \frac{x^{n+1}}{n+1} + c, \quad n \neq -1$$

$$\frac{d}{dx} (ax) = a$$

$$\therefore \int a dx = ax + c$$

$$\frac{d}{dx} (\sin x) = \cos x$$

$$\therefore \int \cos x dx = \sin x + c$$

$$\frac{d}{dx} (\cos x) = -\sin x$$

$$\therefore \int \sin x dx = -\cos x + c$$

$$\frac{d}{dx} (e^x) = e^x$$

$$\therefore \int e^x = e^x + c$$

$$\frac{d}{dx} (\ln x) = \frac{1}{x}$$

$$\therefore \int \frac{1}{x} dx = \ln x + c$$

$$\frac{d}{dx} (\sinh x) = \cosh x$$

$$\therefore \int \cosh x dx = \sinh x + c$$

$$\frac{d}{dx} (\cosh x) = \sinh x$$

$$\therefore \int \sinh x dx = \cosh x + c$$

**Example Evaluate**

1. 
$$\int (3x^6 - 2x^2 + 7x + 1) dx$$

2. 
$$\int \left( \frac{4}{\sqrt{x}} + \frac{1}{2x^2} \right) dx$$

3. 
$$\int_0^{\pi} (3e^x - 4 \cos x) dx$$

4. 
$$\int_1^2 \left( x^{-3} + \frac{1}{x} - \sinh x \right) dx$$

**Answers**

1. 
$$\frac{3x^7}{7} - \frac{2x^3}{3} + \frac{7x^2}{2} + x + c$$

2. 
$$8\sqrt{x} - \frac{1}{2x} + c$$

3. 
$$3(e^{\pi} - 1)$$

4. 
$$\frac{3}{8} + \ln 2 - \cosh 2 + \cosh 1$$

### 3.3.2 Simplifying Integrals

Sometimes an integrand can be simplified before evaluating the integral.

#### Examples

$$\int \frac{t^2 - 2t^4}{t^4} dt =$$

$$=$$
$$=$$

$$\int (2 + x^2)^2 dx =$$

$$=$$

$$\int \left( \frac{1}{t^2} - 2 \right) dt$$
$$\int (t^{-2} - 2) dt$$
$$-1t^{-1} - 2t + c$$

$$\int (4 + x^4 + 4x^2) dx$$

$$4x + \frac{x^5}{5} + \frac{4}{3}x^3 + c$$

$$\int_0^{\frac{\pi}{2}} \frac{\sin 2x}{\cos x} dx =$$

$$=$$
$$=$$
$$=$$
$$=$$
$$=$$



$$\int \frac{2 \sin x \cos x}{\cos x} dx$$

$$\int 2 \sin x dx$$

$$2 [-\cos x]_0^{\pi/2}$$

$$2 \left[ -\cos \left( \frac{\pi}{2} \right) + \cos (0) \right]$$

$$2$$

**Exercise** Evaluate the following integrals.

1.  $\int \frac{1}{\sec x} dx$

2.  $\int_0^\pi (\cos^2 x + \sin^2 x) dx$

3.  $\int \frac{x^2 \sin x + 2 \sin x}{x^2 + 2} dx$

4.  $\int x^{1/3} (2 - x) dx$

5.  $\int_0^1 \frac{x^2 - 1}{x + 1} dx$

6.  $\int \sqrt[3]{x^2} dx$

$c =$  arbitrary constant

$$\sin(x) + c$$

$\pi$

$$-\cos(x) + c$$

$$\frac{3}{2}x^{4/3} - \frac{3}{7}x^{7/3} + c$$

$-\frac{1}{2}$

$$\frac{3}{5}x^{5/3} + c$$

### 3.3.3 Using Integral Tables

- The integration tables at the back of the course book contain 40 common integrals.
- The same tables will be included in the final exam for MATH 141.
- You should work out which integrals are in the tables and where they are.

**Example** Evaluate  $\int \frac{dx}{x\sqrt{2x+4}}$

**Solution** Use formula [17].

$$\int \frac{1}{x\sqrt{ax+b}} dx = \frac{1}{\sqrt{b}} \ln \left| \frac{\sqrt{ax+b} - \sqrt{b}}{\sqrt{ax+b} + \sqrt{b}} \right| + c$$

In our question

$$a = \underline{\quad}$$

$$b = \underline{\quad}$$

Therefore we have

$$\int \frac{1}{x\sqrt{ax+b}} dx =$$

2

4

$$\frac{1}{\sqrt{4}} \ln \left| \frac{\sqrt{2x+4} - \sqrt{4}}{\sqrt{2x+4} + \sqrt{4}} \right|$$

**Example** Evaluate  $\int \sin^5 x dx$

**Solution** Use formula [33]

$$\int \sin^n x dx = \frac{-1}{n} \cos x \sin^{n-1} x + \frac{n-1}{n} \int \sin^{n-2} x dx$$

$$n = \underline{\quad}$$

$$\int \sin^5 x dx = \frac{-1}{5} \cos x \sin^4 x + \frac{4}{5} \int \sin^3 x dx$$

We need to use the formula again to

find  $\int \sin^3 x dx$



$$\int \sin^n x dx = \frac{-1}{n} \cos x \sin^{n-1} x + \frac{n-1}{n} \int \sin^{n-2} x dx$$

$$n = \underline{\hspace{2cm}}$$

$$\begin{aligned} \int \sin^3 x dx &= \frac{-1}{3} \cos x \sin^2 x \\ &+ \frac{2}{3} \int \sin x dx + c \\ &= \frac{-1}{3} \cos x \sin^2 x - \frac{2}{3} \cos x + c \end{aligned}$$

$$\begin{aligned} \int \sin^5 x &= \frac{-1}{5} \cos x \sin^4 x \\ &\frac{-4}{15} \cos x \sin^2 x - \frac{8}{15} \cos x + c \end{aligned}$$

**Example** Evaluate  $\int_{2e}^{3e} \frac{1}{e^2 - x^2} dx$

**Solution** Use formula [20].

$$\int \frac{1}{a^2 - x^2} dx = \frac{1}{2a} \ln \left| \frac{x + a}{x - a} \right| + c$$

$$a = \_$$

$$\int \frac{1}{e^2 - x^2} dx =$$

$$\int_{2e}^{3e} \frac{1}{e^2 - x^2} dx =$$

*e*

$$\frac{1}{2e} \ln \left| \frac{x+e}{x-e} \right| + c$$

$$\frac{1}{2e} \left[ \ln \left| \frac{x+e}{x-e} \right| \right]_{2e}^{3e}$$

$$\begin{aligned} &= \frac{1}{2e} \left[ \ln \left( \frac{4e}{2e} \right) - \ln \left( \frac{3e}{e} \right) \right] \\ &= \frac{1}{2e} [\ln 2 - \ln 3] \\ &= \frac{1}{2e} \ln \left( \frac{2}{3} \right) \end{aligned}$$

**Example** Evaluate  $\int \frac{4x}{\sqrt{2x+7}} dx$

**Solution** Use formula [16].

$$\int \frac{x}{\sqrt{ax+b}} dx = \frac{2ax-4b}{3a^2} \sqrt{ax+b} + c$$

We need to re-write our integral so that we can use [16]

$$\int \frac{4x}{\sqrt{2x+7}} dx = 4 \int \frac{x}{\sqrt{2x+7}} dx$$

$$a = \underline{\quad}$$

$$b = \underline{\quad}$$

$$\int \frac{4x}{\sqrt{2x+7}} dx =$$

2

7

$$4 \left[ \frac{2(2)x - 4(7)}{3(2)^2} \right] \sqrt{2x + 7} + c$$



**Exercise** Use the ‘Table of Integrals’ to evaluate the following.

(a)  $\int e^{2x} \sin 3x dx$

(b)  $\int x\sqrt{9x+1} dx$

(c)  $\int x(x+2)^4 dx$

(d)  $\int_0^1 \frac{1}{1+3e^{2x}} dx$

(e)  $\int xe^x dx$

(f)  $\int_0^{\pi/2} x \sin x dx$

**Exercise 3.3.4**

$c =$  arbitrary constants

$$\frac{1}{13}e^{2x} (2 \sin 3x - 3 \cos 3x) + c$$

$$\frac{2}{81} \left[ \frac{(9x + 1)^{5/2}}{5} - \frac{(9x + 1)^{3/2}}{3} \right] + c$$

$$(x + 2)^5 \left( \frac{x + 2}{6} - \frac{2}{5} \right) + c$$

$$\frac{1}{2} [2x - \ln(1 + 3e^{2x})] + c$$

$$xe^x - e^x + c$$