**Calculus I**
**Practice Problems 10: Answers**

1. $\int_1^3 (2t+1)^3\, dt =$

**Answer**.

$$\int_1^3 (2t+1)^3 dt = \frac{1}{2}\int_3^7 u^3 du = \frac{1}{2}\frac{u^4}{4}|_3^7 = \frac{1}{8}(7^4 - 3^4)$$

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2. $\int_{-1}^1 (4x^3 - 2x^2 + 1) dx =$

**Answer**. Since $x^3$ is an odd function and the domain is symmetric about 0, the first term contributes nothing. Thus the integral is equal to

$$\int_{-1}^1 (-2x^2+1)dx = (-2x^3/3 + x)|_{-1}^1 = \frac{2}{3}$$

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**3.** Calculate the definite integrals:

a) $\int_{-4}^4 (x^2 - 3 + \cos x) dx$

**Answer**. Since this is an even function and the domain is symmetric about 0, the integral is

$$2\int_0^4 (x^2 - 3 + \cos x)dx = 2\Big[\frac{x^3}{3} - 3x + \sin x\Big]_0^4 = 2\Big[\frac{64}{3} - 12 + \sin(4)\Big] = \frac{56}{3} + 2\sin(4)\ .$$

b) $\int_0^{\pi/4} \frac{\sin x}{\cos^3 x} dx$

**Answer**. Let $u = \cos x,\ du = -\sin x dx$. When $x = 0, u = 1$ and when $x = \pi/4,\ u = \sqrt{2}/2$. Thus

$$\int_0^{\pi/4} \frac{\sin x dx}{\cos^3 x} = -\frac{1}{2}\int_1^{\sqrt{2}/2} u^{-3} du = \frac{1}{2} u^{-2}|_1^{\sqrt{2}/2} = \frac{1}{2}(\frac{1}{2/4} - 1) = \frac{1}{2}\ .$$

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4. Integrate:

a) $\int_1^4 \frac{1}{\sqrt{y}(\sqrt{y}+1)^2} dy$

**Answer**. Let $u = y^{1/2},\ \ du = (1/2)y^{-1/2}dy$. When $y = 1,\ u = 1$ and when $y = 4,\ u = 2$. Thus

$$\int_1^4 \frac{1}{\sqrt{y}(\sqrt{y}+1)^2} dy = 2\int_1^2 \frac{du}{(u+1)^2} = -2(u+1)^{-1}|_1^2 = -2[\frac{1}{3} - \frac{1}{2}] = \frac{1}{3}$$

b) $\int_0^{\pi/2} \cos^2 x \sin x dx =$

**Answer**. $= -\frac{\cos^3 x}{3}|_0^{\pi/2} = \frac{1}{3}$

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5. Evaluate

a) $\dfrac{d}{dx}\displaystyle\int_0^{2x+1} \cos t dt$

**Answer**. Let $u = 3x + 1$. By the fundamental theorem of the calculus $d/du \int_0^u \cos t dt = \cos u$. Now, by the chain rule

$$\frac{d}{dx}\int_0^{2x+1} \cos t dt = (\frac{d}{du}\int_0^u \cos t dt)(\frac{du}{dx}) = (\cos u)(2) = 2\cos(2x+1) .$$

b) $\dfrac{d}{dx}\displaystyle\int_0^{x^2} t^3 dt$

**Answer**. Let $u = x^2$. By the fundamental theorem of the calculus $d/du \int_0^u t^3 dt = u^3$. Now, by the chain rule

$$\frac{d}{dx}\int_0^{x^2} t^3 dt = (\frac{d}{du}\int_0^u t^3 dt)(\frac{du}{dx}) = u^3(2x) = (x^2)^3(2x) = 2x^7 .$$

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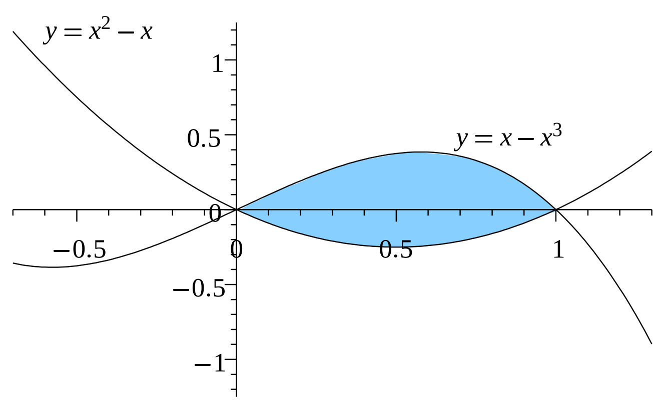
6. Find the area of the region in the right half plane ($x > 0$) bounded by the curves $y = x - x^3$ and $y = x^2 - x$.

**Answer**. First, we find the points of intersection of the curves by solving the equation $x - x^3 = x^2 - x$. This becomes $x^3 + x^2 - 2x = 0$, which has the solutions $x = -2, 0, 1$. Since we are interested only in $x > 0$, the range of integration is the interval $(0, 1)$. From the graph (see the figure), the cubic curve lies above the quadratic, so the area is

$$\int_0^1 [(x - x^3) - (x^2 - x)]dx = \int_0^1 (-x^3 - x^2 + 2x)dx = -\frac{1}{4} - \frac{1}{3} + 1 = \frac{5}{12} .$$

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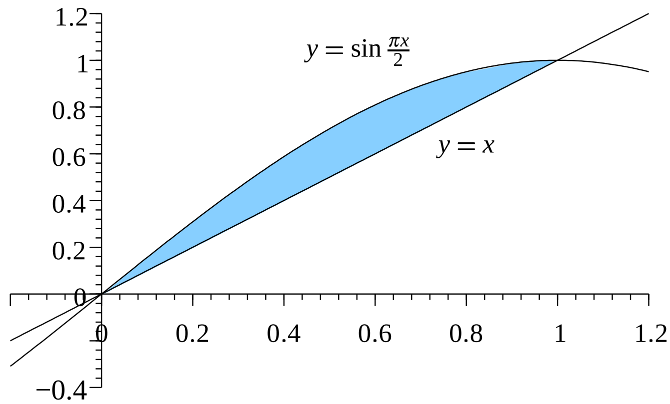
7. Find the area of the region in the first quadrant bounded by the curves $y = \sin \frac{\pi}{2}x$ and $y = x$.

**Answer**. The curves intersect at $x = 0,\ 1$, and the sine curve is above the line (see the figure), so the area is

$$\int_0^1 (\sin \frac{\pi}{2}x - x)dx = \frac{2}{\pi}(-\cos \frac{\pi}{2}x) - \frac{x^2}{2}\Big|_0^1 = (\frac{2}{\pi}(0) - \frac{1}{2}) - (\frac{2}{\pi}(-1) - 0) = \frac{2}{\pi} - \frac{1}{2}$$

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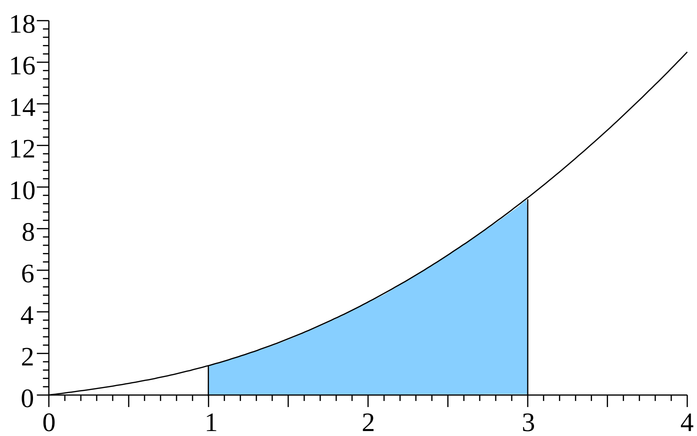
8. Find the area of the region under the curve $y = x\sqrt{x^2+1}$, above the $x$-axis and bounded by the lines $x = 1$ and $x = 3$.

**Answer**. The area (see the figure) is given by $\int_1^3 x\sqrt{x^2+1}dx$. Let $u = x^2+1,\ du = 2xdx$. When $x = 1,\ u = 2$ and when $x = 3,\ u = 10$. This substitution leads to:

$$\int_1^3 x\sqrt{x^2+1}dx = \frac{1}{2}\int_2^{10} u^{1/2}du = \frac{1}{2}\frac{2}{3}u^{3/2}\big|_2^{10} = \frac{1}{3}(10\sqrt{10}-2\sqrt{2})\ .$$

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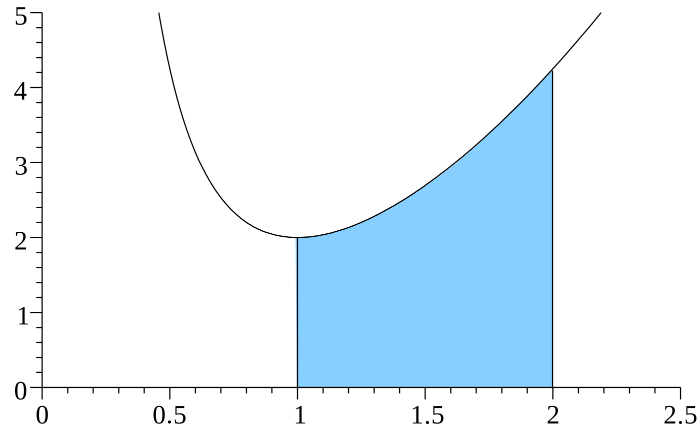
9. Find the area under the curve $y = x^2 + x^{-2}$, above the $x$-axis and between the lines $x = 1$ and $x = 2$.

**Answer**. The area is

$$\int_1^2 (x^2+x^{-2})dx = (\frac{x^3}{3} - x^{-1})\big|_1^2 = (\frac{8}{3}-\frac{1}{2}) - (\frac{1}{3}-1) = \frac{17}{6}$$




10. What is the area of the region bounded by the curves $y = x^3 - x$ and $y = 3x$?

**Answer**. First find the points of intersection:

$$x^3 - x = 3x \quad \text{or} \quad x^3 = 4x$$

has the solutions $x = -2, 0, 2$. The line $y = 3x$ lies below the curve $y = x^3 - x$ in the interval (-2,0) and above that curve in the interval (0,2) (see the accompanying figure). The areas of these two regions are given by the integrals:

$$\int_{-2}^{0} [(x^3 - x - 3x)]dx\,, \quad \int_{0}^{2} [3x - (x^3 - x)]dx\,.$$

Since the two intervals are symmetric about 0, and the integrand is an odd function, these two integrals are the same. Thus the area is

$$2\int_{0}^{2} [3x - (x^3 - x)]dx = 2\int_{0}^{2} (4x - x^3)dx = 2(2x^2 - \frac{x^4}{4})\Big|_0^2 = 2(8 - 16/4) = 8\,.$$