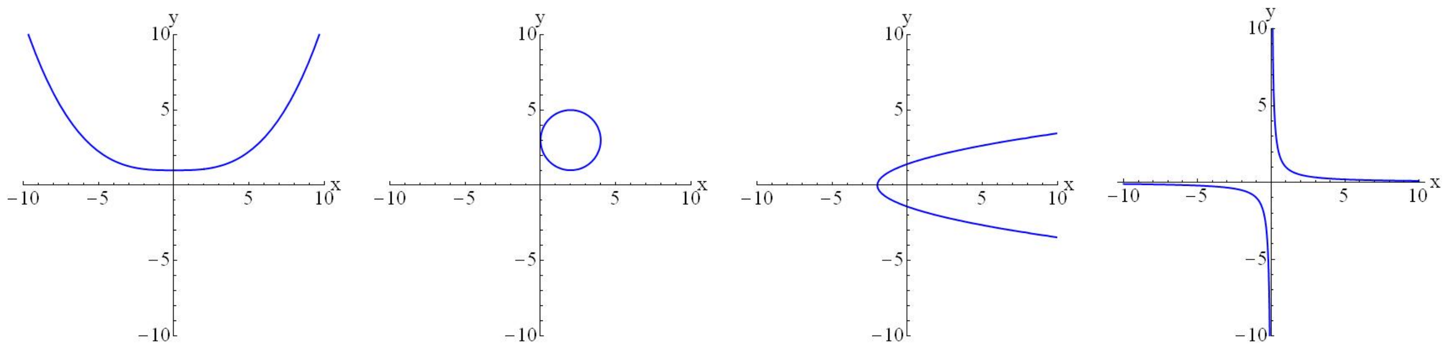
**Questions**

**1.** Which of the following set of points represents a function?




(a) (b) (c) (d)

**2.** Find the domain of the function $f(x) = \dfrac{1}{x-2} + \sqrt{x^2 - 1}$.

**3.** Find the range of the function $f(x) = 5 + \sqrt{4 - x}$.

Note: Sketching the functions $y = \sqrt{x-1}$ and $y = \frac{1}{x-1}$ by hand will be easier when we look at graphical transformations. Have a try at sketching them now, but realize sketching is a topic we will revisit in more detail in the future.

**4.** Compute the average rate of change of $f(x) = x^2$ for the interval $(x, x+h)$. Simplify so substitution of $h = 0$ does not yield $\frac{0}{0}$. What is the value when $x = 2, h = 4$? Sketch the situation by hand.

**5.** Compute the average rate of change of $f(x) = \sqrt{x-1}$ for the interval $(x, x+h)$. Simplify so substitution of $h = 0$ does not yield $\frac{0}{0}$. What is the value when $x = 2, h = 4$? Sketch the situation by hand.

**6.** Compute the average rate of change of $f(x) = \frac{1}{x-1}$ for the interval $(x, x+h)$. Simplify so substitution of $h = 0$ does not yield $\frac{0}{0}$. What is the value when $x = 2, h = 4$? Sketch the situation by hand.

**7.** Given $f(x) = x^2 - 2$, simplify the quantity $\dfrac{f(x+h) - f(x-h)}{2h}$ so that substitution of $h = 0$ does not give $\frac{0}{0}$.

*Note: The quantity* $\dfrac{f(x+h) - f(x-h)}{2h}$ *is actually the average rate of change of* $f$ *over the interval* $(x-h, x+h)$*. Do you think you could draw a sketch showing this situation? I'll include a sketch for* $x = 2$, $h = 4$ *in my solution if you want to try it.*

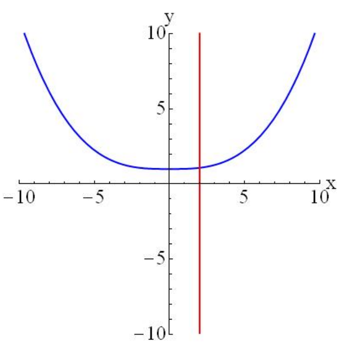
**8.** Simplify as much as possible the expression for the average rate of change of the function $f$ over the interval $(x, x+h)$,

$$\text{Average Rate of Change } = \frac{f(x+h) - f(x)}{h},$$

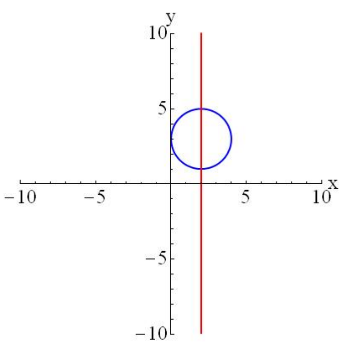
where $f(x) = 3x^2 - 5x + 6$.

**Solutions**

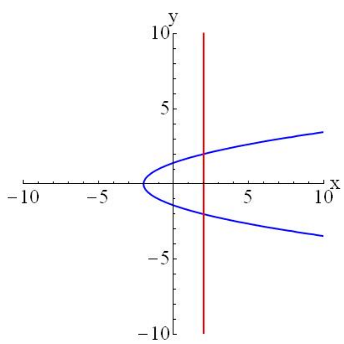
**1.** Using the vertical line test, we see only (a) and (d) represent functions.



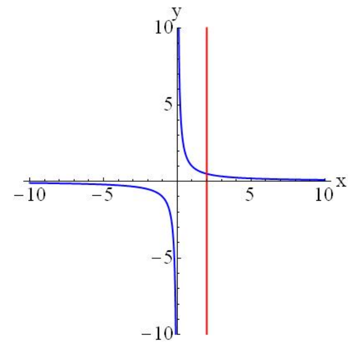
(a)



(b)



(c)



(d)

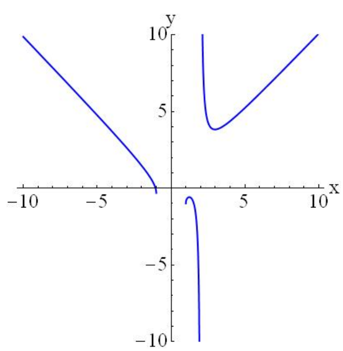
**2.** At the moment, there are two things to look for when determining domain: division by zero, and square roots.

Division by zero occurs when $x - 2 = 0 \Rightarrow x = 2$. So, $x = 2$ is not in the domain.

The quantity we are taking the square root of must be greater than or equal to zero:
$x^2 - 1 \geq 0 \Rightarrow x^2 \geq 1 \Rightarrow x \leq -1$ or $x \geq 1$.

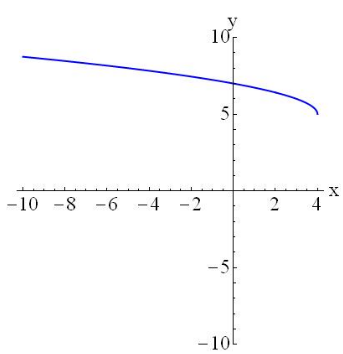
So, the domain requires $x \leq -1$ or $x \geq 1$ and $x \neq 2$. We can write this in a more compact form using interval notation: $x \in (-\infty, -1] \cup [1, 2) \cup (2, \infty)$.

Use a computer to get a sketch to verify:




**3.** Range is a bit tricky, since we have to think about what comes out of the function. The output of $\sqrt{4 - x}$ is $[0, \infty)$. If we add five to that, we get for the range $y \in [5, \infty)$.

Use a computer to get a sketch to verify:



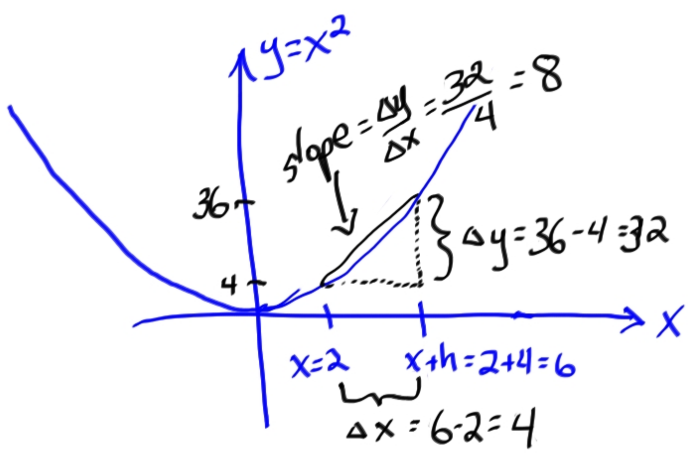
**4.** The function is a power function, so expect to factor out.

$$f(x) = x^2$$
$$f(x+h) = (x+h)^2 = x^2 + 2xh + h^2$$

$$\begin{aligned}
\text{Average Rate of Change} &= \frac{f(x+h) - f(x)}{h} \\
&= \frac{x^2 + 2xh + h^2 - x^2}{h} \\
&= \frac{2xh + h^2}{h} \\
&= \frac{h(2x+h)}{h} \\
&= 2x + h
\end{aligned}$$

When $x = 2$ and $h = 4$, the average rate of change on the interval $(x, x+h) = (2, 6)$ is $2(2) + (4) = 8$.

Sketch:



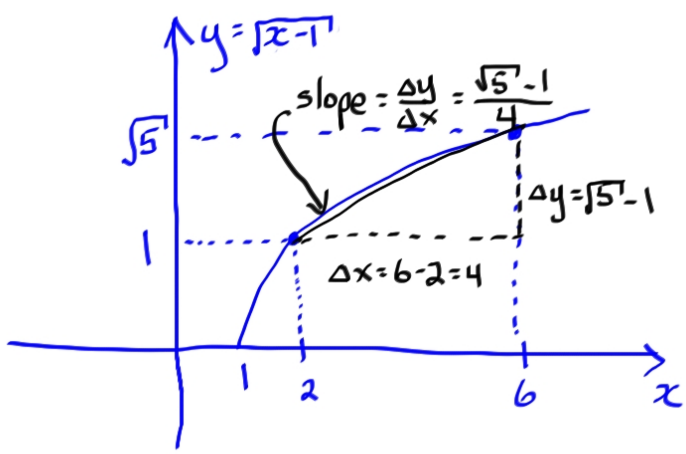
**5.** The function is a square root function, so expect to rationalize.

$$f(x) = \sqrt{x-1}$$
$$f(x+h) = \sqrt{(x+h)-1} = \sqrt{x+h-1}$$

$$\begin{aligned}
\text{Average Rate of Change} &= \frac{f(x+h)-f(x)}{h} \\
&= \frac{\sqrt{x+h-1}-\sqrt{x-1}}{h} \\
&= \frac{\sqrt{x+h-1}-\sqrt{x-1}}{h} \cdot \frac{\sqrt{x+h-1}+\sqrt{x-1}}{\sqrt{x+h-1}+\sqrt{x-1}} \\
&= \frac{(x+h-1)-(x-1)}{h(\sqrt{x+h-1}+\sqrt{x-1})} \\
&= \frac{\cancel{x}+h\cancel{-1}-\cancel{x}\cancel{+1}}{h(\sqrt{x+h-1}+\sqrt{x-1})} \\
&= \frac{\cancel{h}}{\cancel{h}(\sqrt{x+h-1}+\sqrt{x-1})} \\
&= \frac{1}{\sqrt{x+h-1}+\sqrt{x-1}}
\end{aligned}$$

When $x = 2$ and $h = 4$, the average rate of change on the interval $(x, x+h) = (2, 6)$ is $\frac{1}{\sqrt{(2)+(4)-1}+\sqrt{2-1}} = \frac{1}{\sqrt{5}+1}$.

Sketch:




Notice that this is the correct average rate of change, since:

$$\begin{aligned}
\frac{1}{\sqrt{5}+1} &= \frac{1}{\sqrt{5}+1} \cdot \frac{\sqrt{5}-1}{\sqrt{5}-1} \text{ rationalize denominator} \\
&= \frac{\sqrt{5}-1}{5-1} = \frac{\sqrt{5}-1}{4}
\end{aligned}$$

Either answer is acceptable.

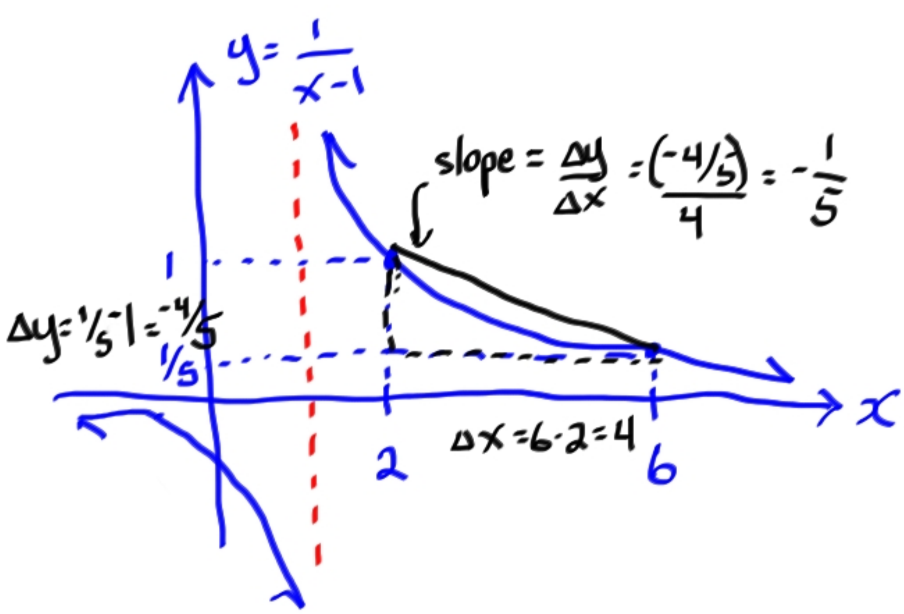
**6.** The function has a fraction (it's what we will call a *rational function*), so expect to find a common denominator.

$$f(x) = \frac{1}{x-1}$$
$$f(x+h) = \frac{1}{(x+h)-1} = \frac{1}{x+h-1}$$

$$\begin{aligned}
\text{Average Rate of Change} &= \frac{f(x+h)-f(x)}{h} \\
&= \frac{\frac{1}{x+h-1} - \frac{1}{x-1}}{h} \\
&= \frac{1}{h}\left(\frac{1}{x+h-1} - \frac{1}{x-1}\right) \\
&= \frac{1}{h}\left(\frac{x-1}{(x+h-1)(x-1)} - \frac{x+h-1}{(x+h-1)(x-1)}\right) \\
&= \frac{1}{h}\left(\frac{\cancel{x}-\cancel{1}-\cancel{x}-h+\cancel{1}}{(x+h-1)(x-1)}\right) \\
&= \frac{1}{\cancel{h}}\left(\frac{-\cancel{h}}{(x+h-1)(x-1)}\right) \\
&= \frac{-1}{(x+h-1)(x-1)}
\end{aligned}$$

When $x = 2$ and $h = 4$, the average rate of change on the interval $(x, x+h) = (2,6)$ is $\frac{-1}{(x+h-1)(x-1)} = \frac{-1}{((2)+(4)-1)((2)-1)} = -\frac{1}{5}$.

Sketch:



**7.** The function is a power function, so expect to factor out.

$$
\begin{aligned}
f(x) &= x^2 - 2 \\
f(x+h) &= (x+h)^2 - 2 = x^2 + 2xh + h^2 - 2 \\
f(x-h) &= (x-h)^2 - 2 = x^2 - 2xh + h^2 - 2
\end{aligned}
$$

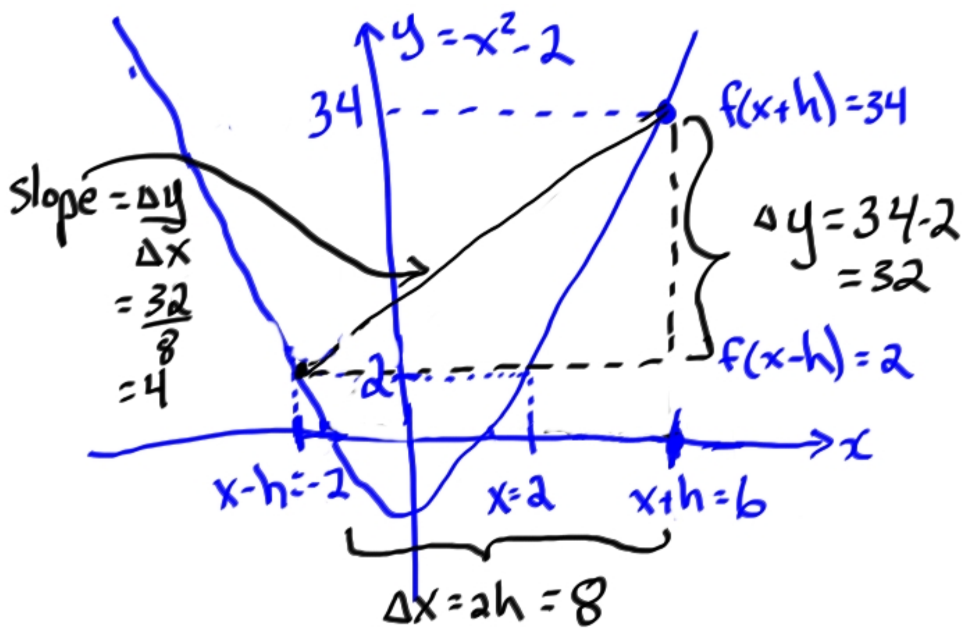
$$
\begin{aligned}
\frac{f(x+h) - f(x-h)}{2h} &= \frac{(x^2 + 2xh + h^2 - 2) - (x^2 - 2xh + h^2 - 2)}{2h} \\
&= \frac{x^2 + 2xh + h^2 - 2 - x^2 + 2xh - h^2 + 2}{2h} \\
&= \frac{\cancel{x^2} + 2xh + \cancel{h^2} - \cancel{2} - \cancel{x^2} + 2xh - \cancel{h^2} + \cancel{2}}{2h} \\
&= \frac{4xh}{2h} \\
&= 2x
\end{aligned}
$$

Notice it doesn't, in this case depend on $h$!

You weren't asked to do this, but here is a sketch of the situation:

When $x = 2$ and $h = 4$, the average rate of change on the interval $(x-h, x+h) = (2-4, 2+4) = (-2, 6)$ is $2(2) = 4$.

Sketch:



**8.** Simplify as much as possible the expression for the average rate of change of the function $f$ over the interval $(x, x + h)$,

$$\text{Average Rate of Change } = \frac{f(x+h) - f(x)}{h},$$

where $f(x) = 3x^2 - 5x + 6$.

First, let's simplify some of the quantities we need, and get the functional substitution done correctly. The tricky one is $f(x + h)$, which we find as:

$$\begin{aligned}
f(\qquad) &= 3(\qquad)^2 - 5(\qquad) + 6 \\
f(x+h) &= 3(x+h)^2 - 5(x+h) + 6 \\
&= 3(x^2 + 2xh + h^2) - 5x - 5h + 6 \\
&= 3x^2 + 6xh + 3h^2 - 5x - 5h + 6
\end{aligned}$$

Now we can simplify the average rate of change.

$$\begin{aligned}
\text{Average Rate of Change} &= \frac{f(x+h) - f(x)}{h} \\
&= \frac{(3x^2 + 6xh + 3h^2 - 5x - 5h + 6) - (3x^2 - 5x + 6)}{h} \\
&= \frac{3x^2 + 6xh + 3h^2 - 5x - 5h + 6 - 3x^2 + 5x - 6}{h} \\
&= \frac{6xh + 3h^2 - 5h}{h} \\
&= \frac{h(6x + 3h - 5)}{h} \\
&= 6x + 3h - 5
\end{aligned}$$