STEP Support Programme

STEP 2 Equations and Inequalities Topic Notes

Equations

- For a quadratic equation, use the discriminant $\left(b^2-4ac\right)$ to find how many real roots the equation has.
- Substitutions can be used to turn a complicated equation into a simpler one (usually given to you, $x=t+\frac{1}{t}$ is a common one). Don't forget to find the values of the original variable.
- For other equations you could **sketch a graph** to work out how many real roots there are. For example, to find out how many real roots of the equation $x^3-3x+1=0$ there are you could sketch $y=x^3-3x+1$ (locate the turning points!) and see how many times it intersects the x axis. You could instead draw two graphs (e.g. $y=x^3-3x$ and $y=-1$) and see how many times they intersect.
- If $a<b$ and a *continuous* function $\mathrm{f}(x)$ has $\mathrm{f}(a)<0$ and $\mathrm{f}(b)>0$, (or vice versa) then there is a root of the equation in the interval $[a,b]$. This is a special case of the intermediate value theorem.
- If a cubic has roots α, β and γ then we can write:

  $$x^3+bx^2+cx+d\equiv(x-\alpha)(x-\beta)(x-\gamma)\,.$$

  Expanding the brackets and equating coefficients gives us:

  $$\begin{aligned}\alpha+\beta+\gamma&=-b\\ \alpha\beta+\beta\gamma+\gamma\alpha&=c\\ \alpha\beta\gamma&=-d\,.\end{aligned}$$

  You then then work out things like $\alpha^2+\beta^2+\gamma^2=(\alpha+\beta+\gamma)^2-2(\alpha\beta+\beta\gamma+\gamma\alpha)$
  Expand $(\alpha+\beta+\gamma)^2$ to see why this is true.
  There are similar equations for other polynomials.

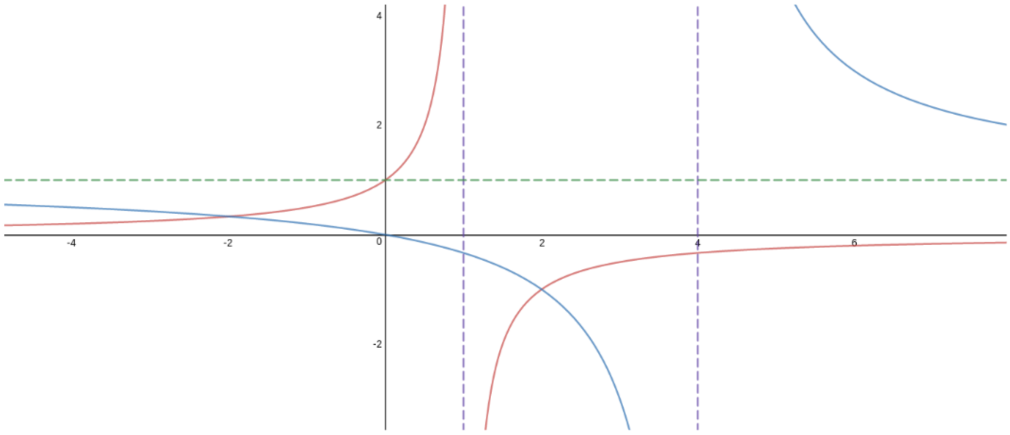
Inequalities

- You can sometimes use completing the square to show that something is always positive or negative.
- If trying to show that $A\geqslant B$ it might be easier to show that $A-B\geqslant 0$. For example to show that $p^2+q^2\geqslant 2pq$ try showing that $p^2+q^2-2pq\geqslant 0$.
- If $A>B$ and $C>D$ then $A+C>B+D$.
- If $A>B>0$ or $0>A>B$ then $\dfrac{1}{A}<\dfrac{1}{B}$.
  This is not true if the signs of A and B are different!
- Do **not** multiply or divide an inequality by something involving x (or another variable). You might be multiplying by something negative! (Addition or subtraction is fine).

- When solving inequalities, **graphs are your friends!** Replace the inequality with an equals sign, solve to find the intersections and then use your graph to solve the inequality.

Example 1: $\dfrac{1}{1-x} < \dfrac{x}{x-4}$

Start by sketching the two graphs $y = \dfrac{1}{1-x}$ and $y = \dfrac{x}{x-4}$.

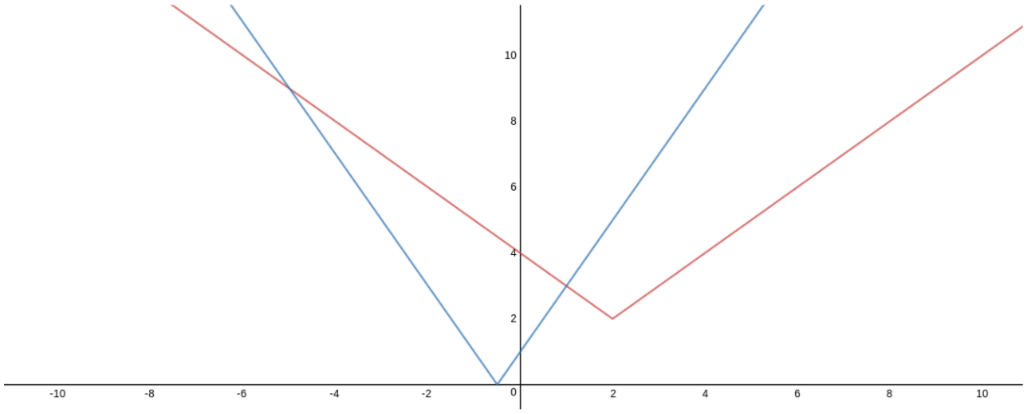


Solving the equation $\dfrac{1}{1-x} = \dfrac{x}{x-4}$ gives the points of intersection as $x = \pm 2$. You can then use the graph to see where the blue line is above the red line to give a final answer of $x < -2$ or $1 < x < 2$ or $x > 4$.

As an alternative method you could have multiplied throughout by $(1-x)^2(x-4)^2$ (which is fine as we know that this is positive) and then solved $(1-x)(x-4)^2 < x(1-x)^2(x-4)$ which is equivalent to $(x-1)(x-4)(x^2-4) > 0$. There are quite a few places you can make sign errors along the way, and I would still draw a graph to solve this last inequality!

Example 2: $|x-2| + 2 \geqslant |2x+1|$

Again, start by drawing two graphs. When $x < 2$ then $|x-2| + 2 = -(x-2) + 2 = 4 - x$ and when $x > 2$ we have $|x-2| + 2 = (x-2) + 2 = x$. Similarly for the other graph.



To find one point of intersection you need to solve $-(x-2) + 2 = -(2x+1)$ (giving $x = -5$) and for the other you need to solve $-(x-2) + 2 = 2x + 1$ (giving $x = 1$). We then want to find where the red line is above (or on) the blue line so we have $-5 \leqslant x \leqslant 1$.