2.4 Loci, regions and z→w transformations

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS locus • perpendicular bisector • Möbius transformation

Loci, regions and z→w transformations

Objective

Describe and sketch standard loci in the Argand diagram (circles, bisectors, Apollonius circles, argument half-lines) with their interior regions, and find the image of a locus under a Möbius transformation $w = \dfrac{az+b}{cz+d}$ by making z the subject and equating moduli or arguments (FP2 3.3–3.4).

1 Key knowledge and worked examples

Locus toolkit. $|z-a| = b$: circle, centre a, radius b. $|z-a| = |z-b|$: perpendicular bisector of a and b. $|z-a| = k|z-b|$, $k \neq 1$: a circle (square and collect). $\arg(z-a) = \beta$: half-line from a at angle β. For regions, replace $=$ by $<$ or $>$ and test one convenient point. Under $w = \dfrac{az+b}{cz+d}$: make z the subject, then take moduli (or arguments) of both sides. A circle through the pole $z = -\frac{d}{c}$ maps to a line; otherwise circle to circle.

Worked example – image of a circle (WFM02 June 2025 Q3). $w = \dfrac{9i - iz}{1+z}$ ($z \neq -1$), P on $|z| = 1$. Rearranging: $z(w+i) = 9i - w$, so $z = \dfrac{9i-w}{w+i}$ and $|z| = 1$ forces $|9i - w| = |w+i|$, i.e. $u^2 + (v-9)^2 = u^2 + (v+1)^2$, so $20v = 80$ and the image is the line $v = 4$ – the perpendicular bisector of $9i$ and $-i$. Spot-check: $z = i \mapsto 5+4i$, $z = -i \mapsto -5+4i$.

2 Practice

2.1 Describe fully the locus given by $|z - 2i| = 3$. [2]

2.2 Describe fully the locus given by $|z-3| = |z+1|$. [2]

2.3 Show that the locus $|z-2| = 2|z+1|$ is a circle, and state its centre and radius. [4]

2.4 Describe the locus given by $\arg\left(\dfrac{z-1}{z+1}\right) = \dfrac{\pi}{2}$. [3]

3 Exam-style questions

3.1 *(Original.)* The transformation T from the z-plane to the w-plane is given by $w = \dfrac{1}{z}$, $z \neq 0$. Show that T maps the circle $|z-2| = 2$ onto the straight line $\operatorname{Re} w = \frac{1}{4}$, and sketch this line. [5]

3.2 *(Edexcel IAL WFM02 June 2025 Q3.)* The transformation T from the z-plane to the w-plane is given by $w = \dfrac{9i - iz}{1 + z}$, $z \neq -1$. The point P represents the complex number z, where $|z| = 1$. (a) Sketch the locus of P as z varies. (b) Given that the image under T of the locus of P, where $z \neq -1$, is the line l, determine, in simplest form, a Cartesian equation for l. (c) Write down the image under T of the point $z = i$ and verify that it lies on l. [9]