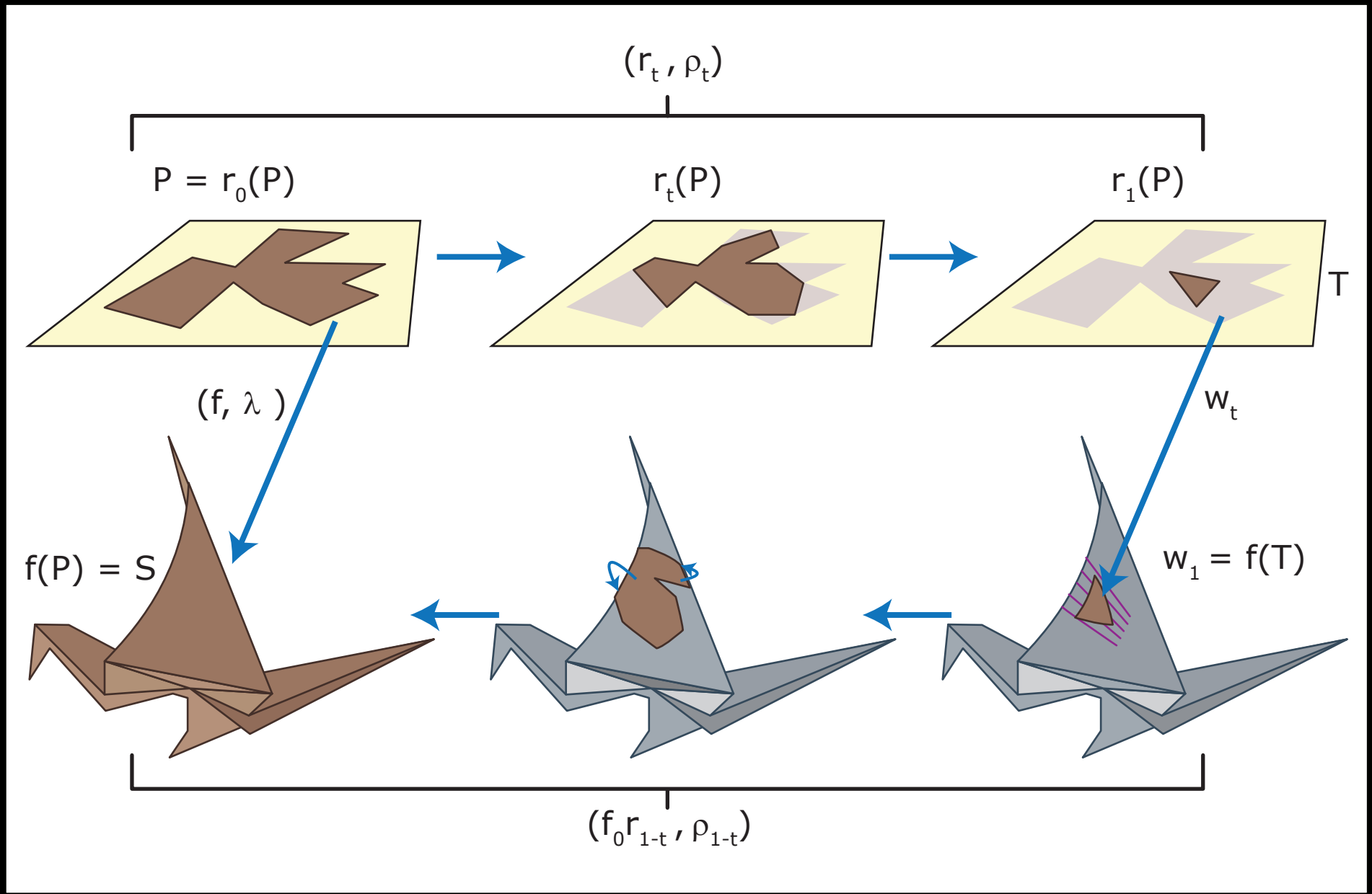

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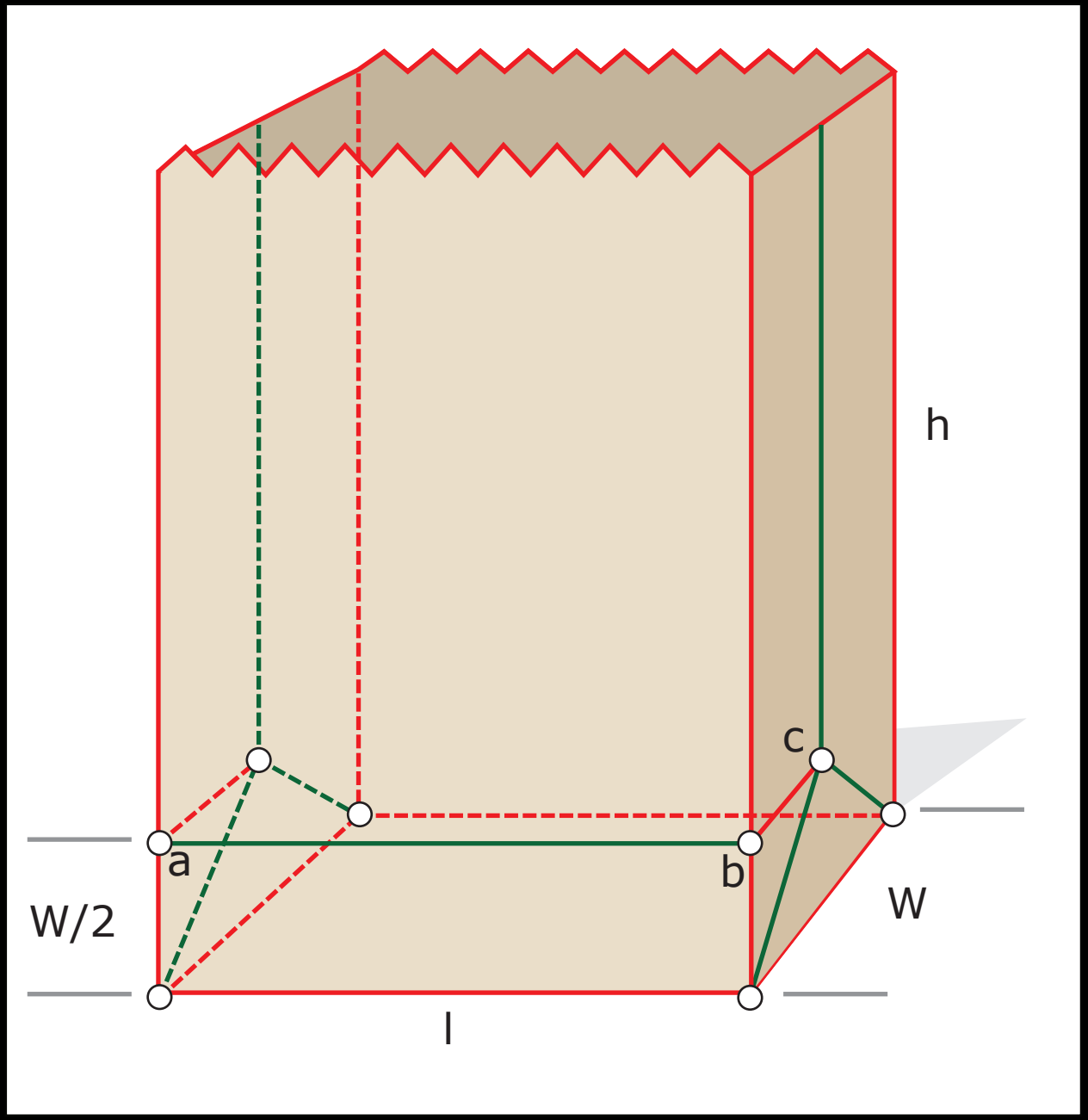

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See also http://erikdemaine.org/papers/PaperBag_OSME2006/.

NATURE SERIES.

HOW TO DRAW A STRAIGHT LINE;

A

LECTURE ON LINKAGES.

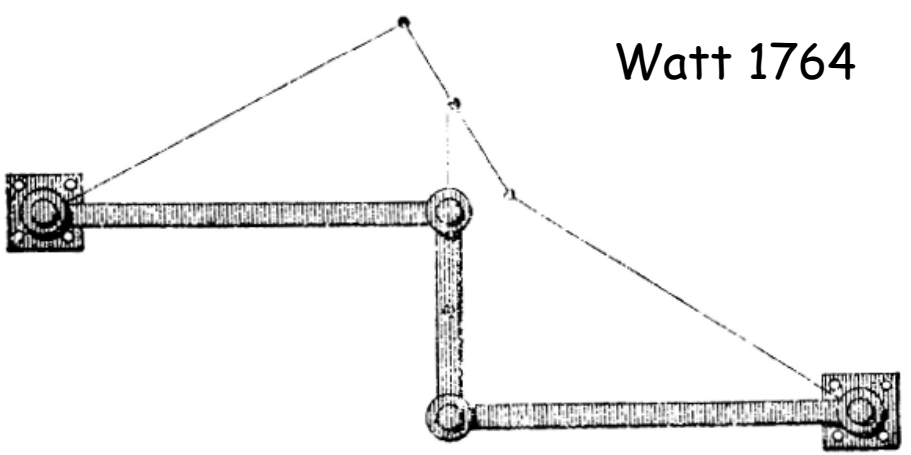
BY

A. B. KEMPE, B.A.,

OF THE INNER TEMPLE, ESQ.;
MEMBER OF THE COUNCIL OF THE LONDON MATHEMATICAL SOCIETY;
AND LATE SCHOLAR OF TRINITY COLLEGE, CAMBRIDGE.

WITH NUMEROUS ILLUSTRATIONS.

London :
1877.



Watt 1764

Fig. 2.

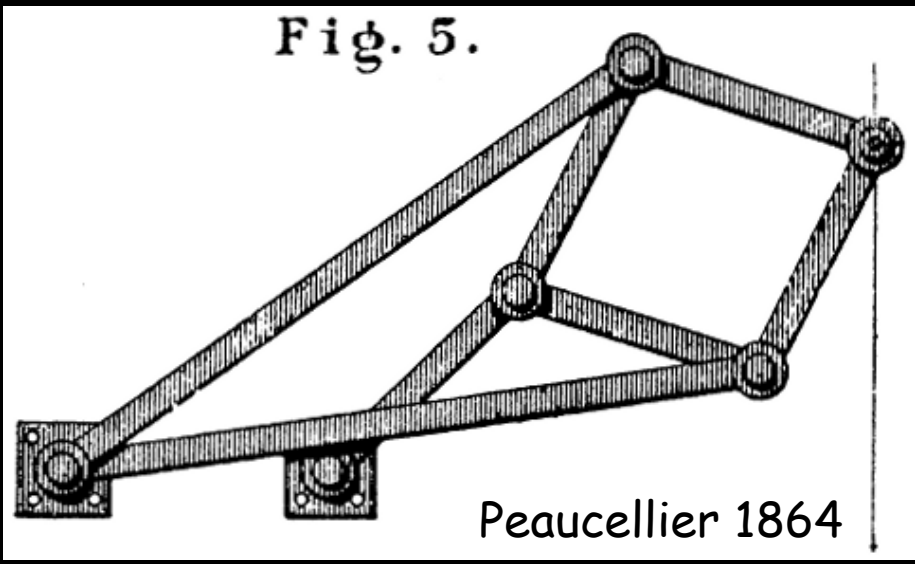


Fig. 5.

Peaucellier 1864

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Source: Kempe, A. B. *How to Draw a Straight Line*. MacMillan and Co., 1877.
Co.

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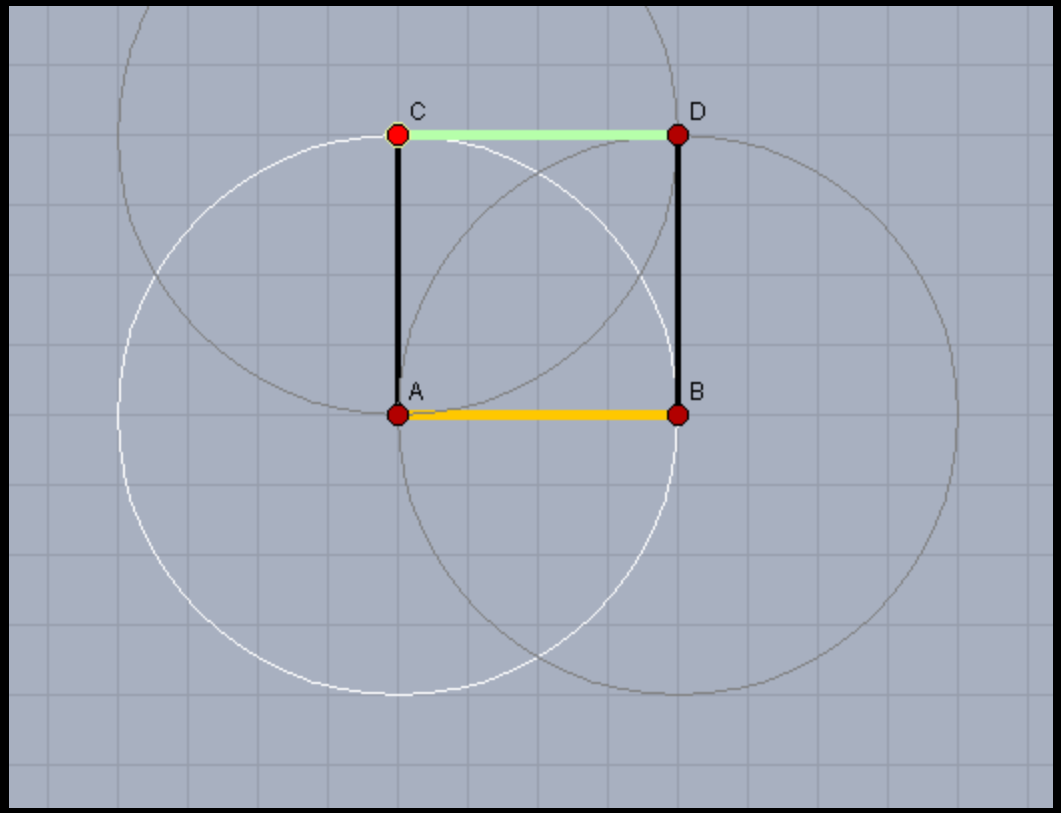

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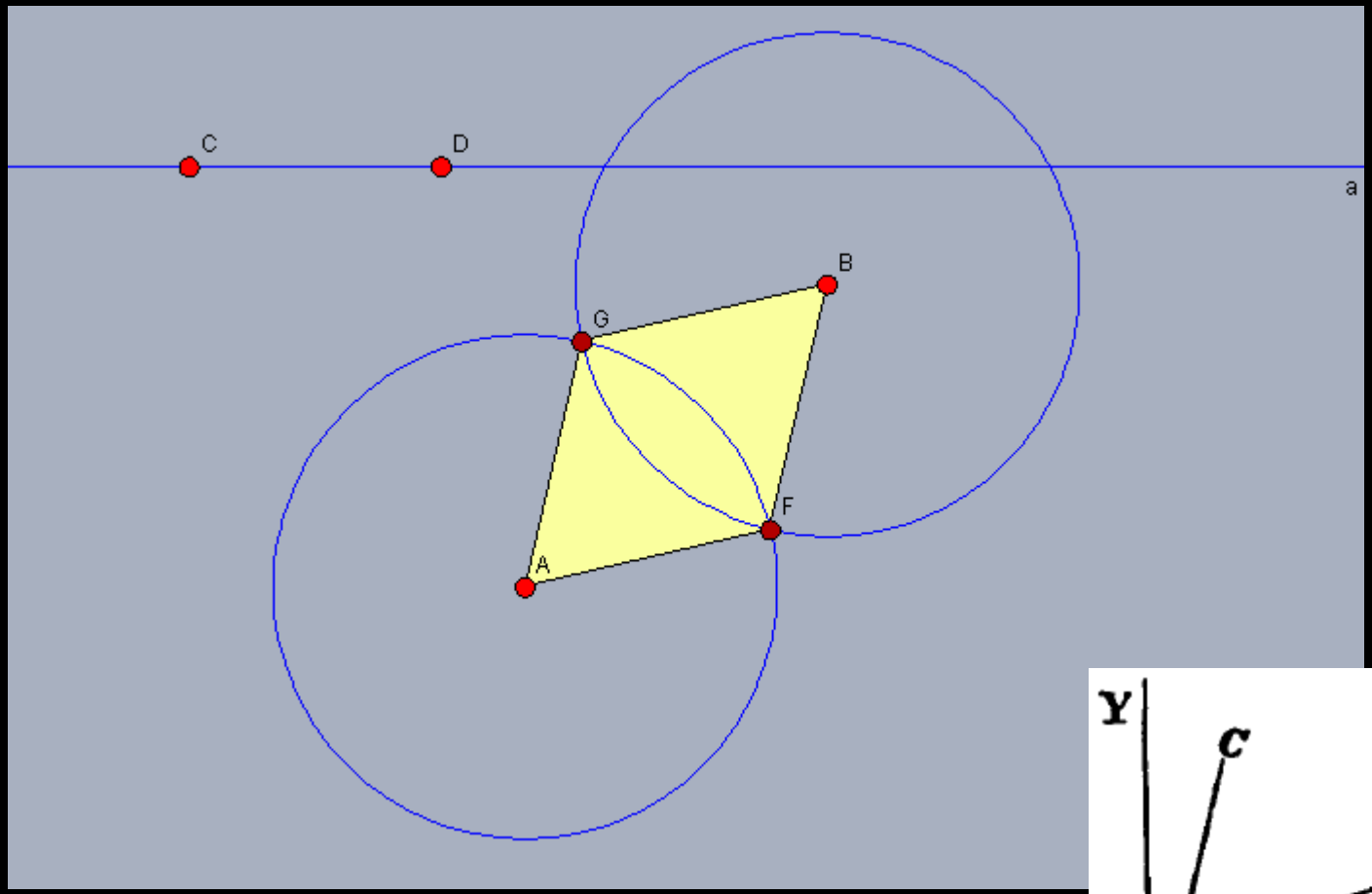

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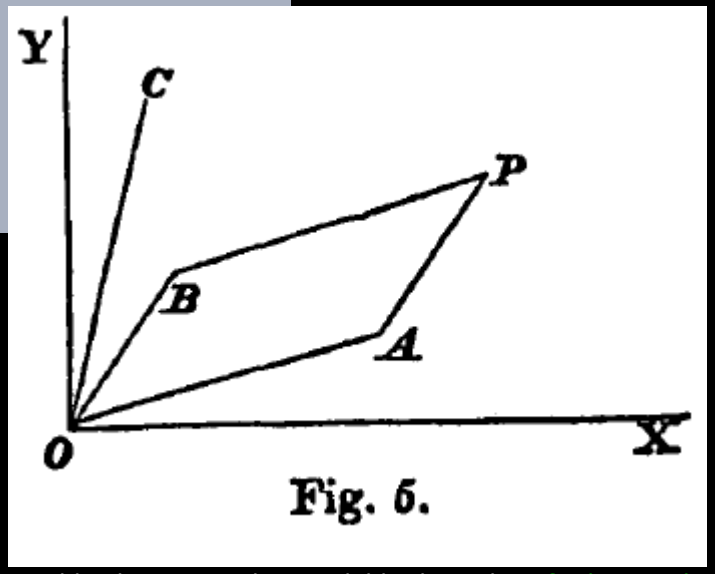

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Source: Kempe, A. B. *On a General Method of describing Plane Curves of the nth degree by Linkwork*, 1876.

```
> subs({x=r/2*cos(alpha)+r/2*cos(beta),
        y=r/2*sin(alpha)+r/2*sin(beta)},
       x^3*y-5*x*y^2);
```

$$\left(\frac{1}{2}r\cos(\alpha)+\frac{1}{2}r\cos(\beta)\right)^3\left(\frac{1}{2}r\sin(\alpha)+\frac{1}{2}r\sin(\beta)\right)-5\left(\frac{1}{2}r\cos(\alpha)+\frac{1}{2}r\cos(\beta)\right)\left(\frac{1}{2}r\sin(\alpha)+\frac{1}{2}r\sin(\beta)\right)^2 \tag{1}$$

```
> expand(%);
```

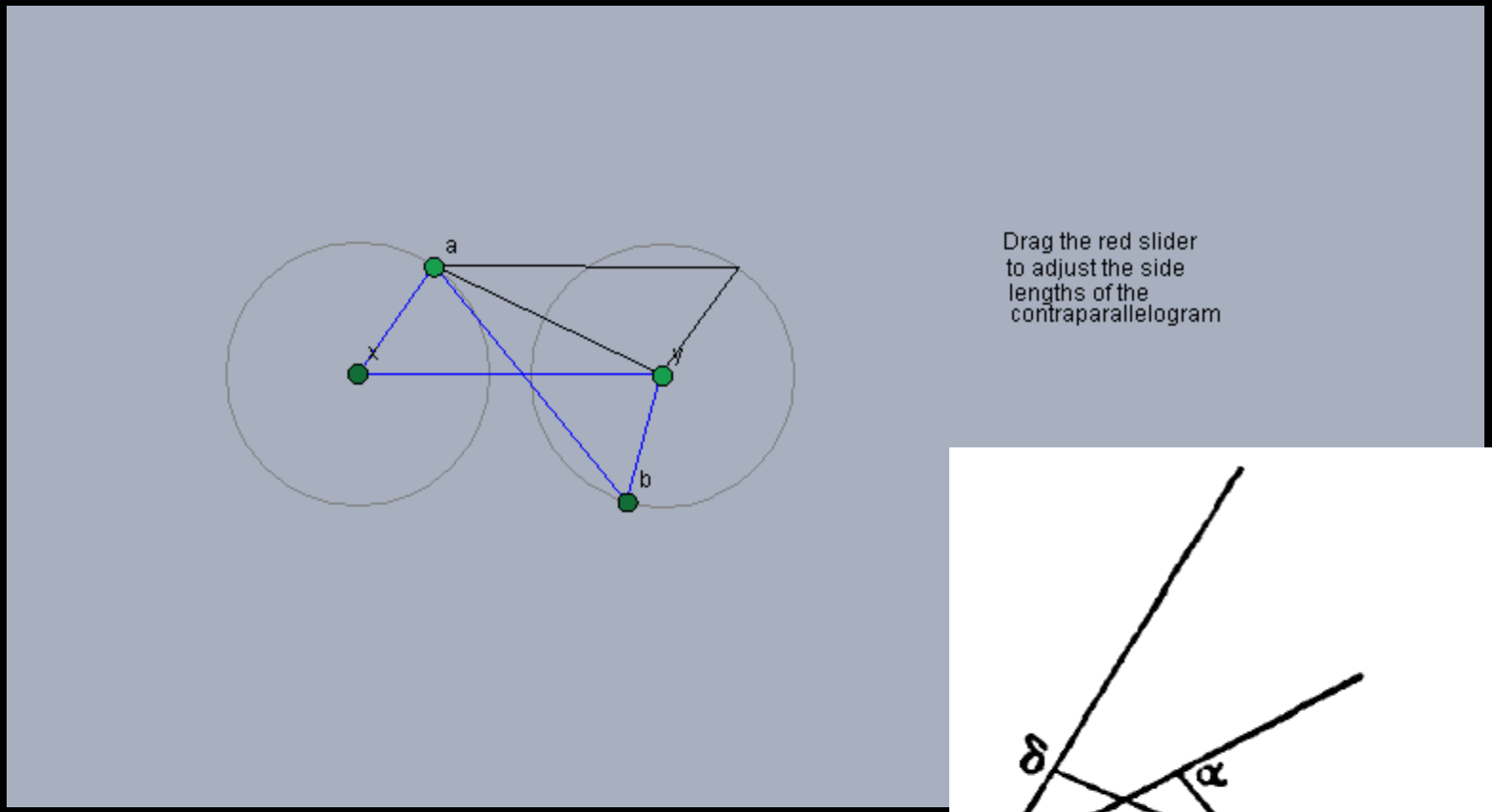
$$\frac{1}{16}r^4\cos(\alpha)^3\sin(\alpha)+\frac{1}{16}r^4\cos(\alpha)^3\sin(\beta)+\frac{3}{16}r^4\cos(\alpha)^2\cos(\beta)\sin(\alpha) \tag{2}$$
$$+\frac{3}{16}r^4\cos(\alpha)^2\cos(\beta)\sin(\beta)+\frac{3}{16}r^4\cos(\alpha)\cos(\beta)^2\sin(\alpha)+\frac{3}{16}r^4\cos(\alpha)\cos(\beta)^2\sin(\beta)$$
$$+\frac{1}{16}r^4\cos(\beta)^3\sin(\alpha)+\frac{1}{16}r^4\cos(\beta)^3\sin(\beta)-\frac{5}{8}r^3\cos(\alpha)\sin(\alpha)^2-\frac{5}{4}r^3\cos(\alpha)\sin(\alpha)\sin(\beta)$$
$$-\frac{5}{8}r^3\cos(\alpha)\sin(\beta)^2-\frac{5}{8}r^3\cos(\beta)\sin(\alpha)^2-\frac{5}{4}r^3\cos(\beta)\sin(\alpha)\sin(\beta)-\frac{5}{8}r^3\cos(\beta)\sin(\beta)^2$$

```
> combine(%,trig);
```

$$\frac{1}{128}r^4\sin(4\beta)+\frac{1}{128}r^4\sin(4\alpha)+\frac{1}{16}r^4\sin(2\alpha)+\frac{1}{32}r^4\sin(\beta+3\alpha)+\frac{1}{64}r^4\sin(-\beta+3\alpha) \tag{3}$$
$$+\frac{3}{32}r^4\sin(\beta+\alpha)+\frac{3}{64}r^4\sin(2\beta+2\alpha)+\frac{1}{16}r^4\sin(2\beta)+\frac{1}{32}r^4\sin(3\beta+\alpha)-\frac{1}{64}r^4\sin(-3\beta$$
$$+\alpha)-\frac{15}{32}r^3\cos(\alpha)+\frac{5}{32}r^3\cos(3\alpha)-\frac{5}{32}r^3\cos(2\alpha-\beta)+\frac{15}{32}r^3\cos(2\alpha+\beta)-\frac{5}{32}r^3\cos(\alpha$$
$$-2\beta)+\frac{15}{32}r^3\cos(\alpha+2\beta)-\frac{15}{32}r^3\cos(\beta)+\frac{5}{32}r^3\cos(3\beta)$$

```
>
```

Maple worksheet by Erik Demaine:
http://courses.csail.mit.edu/6.849/fall10/lectures/L08_applets/L08_trig.mws.



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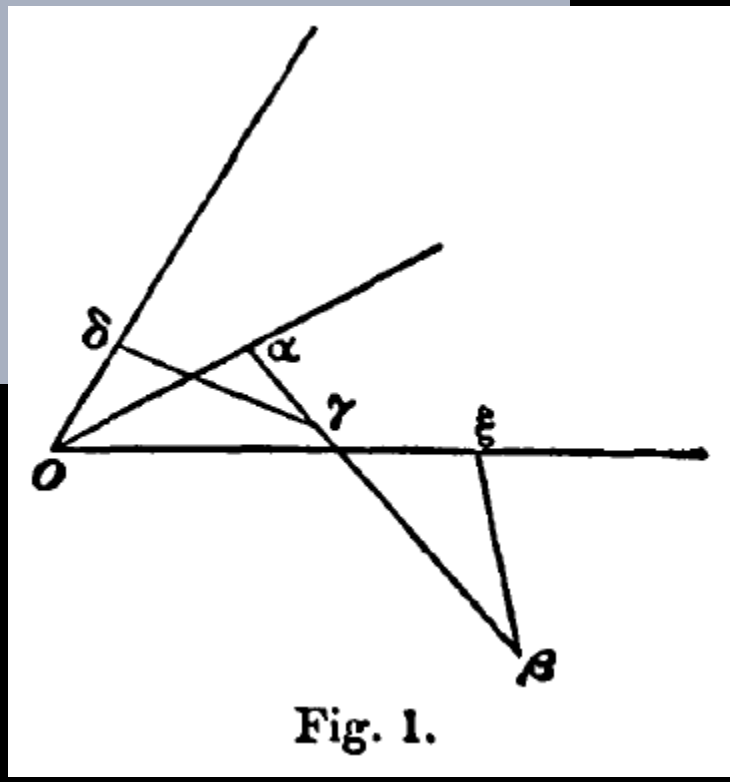

Fig. 1.

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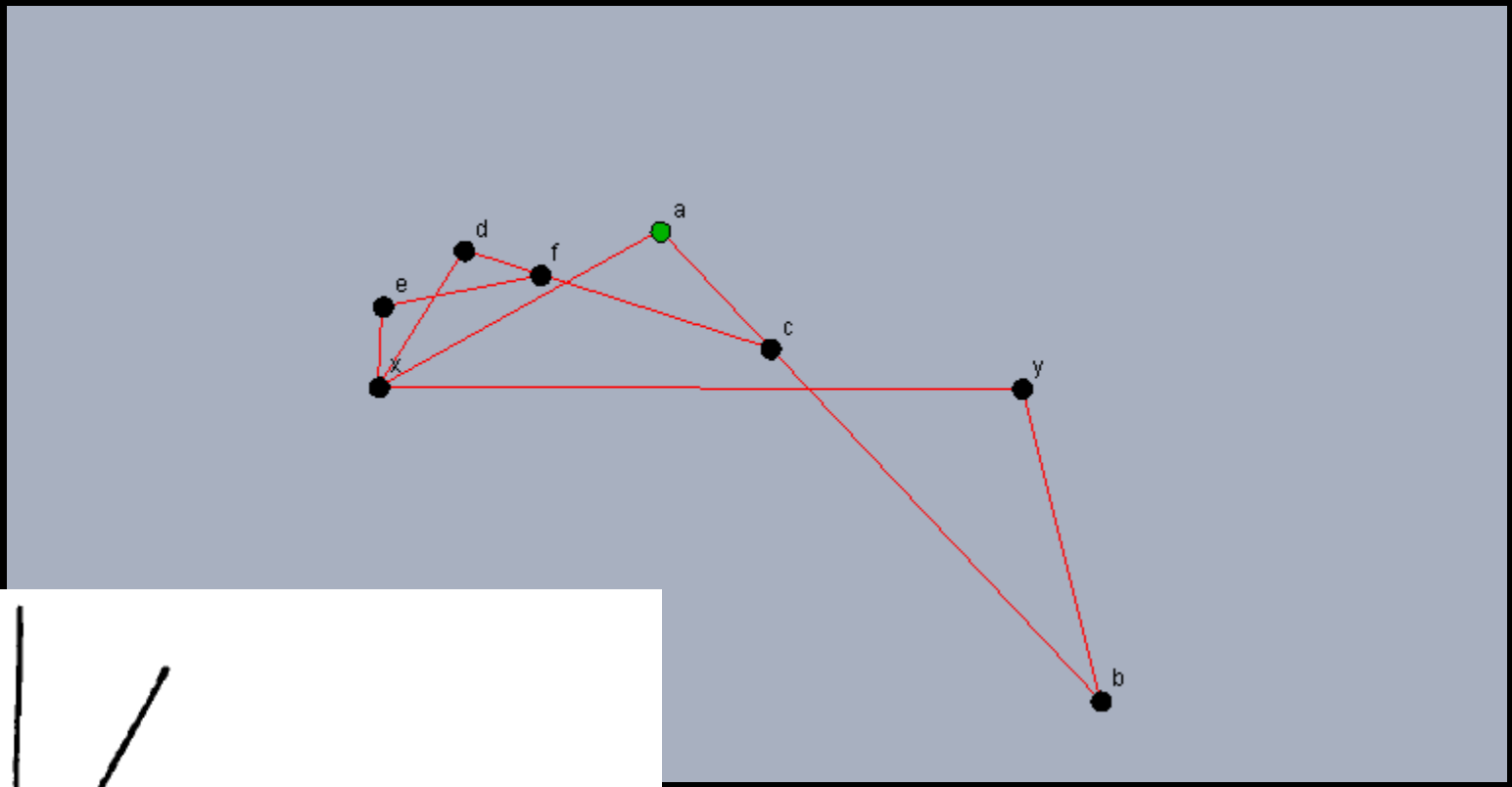

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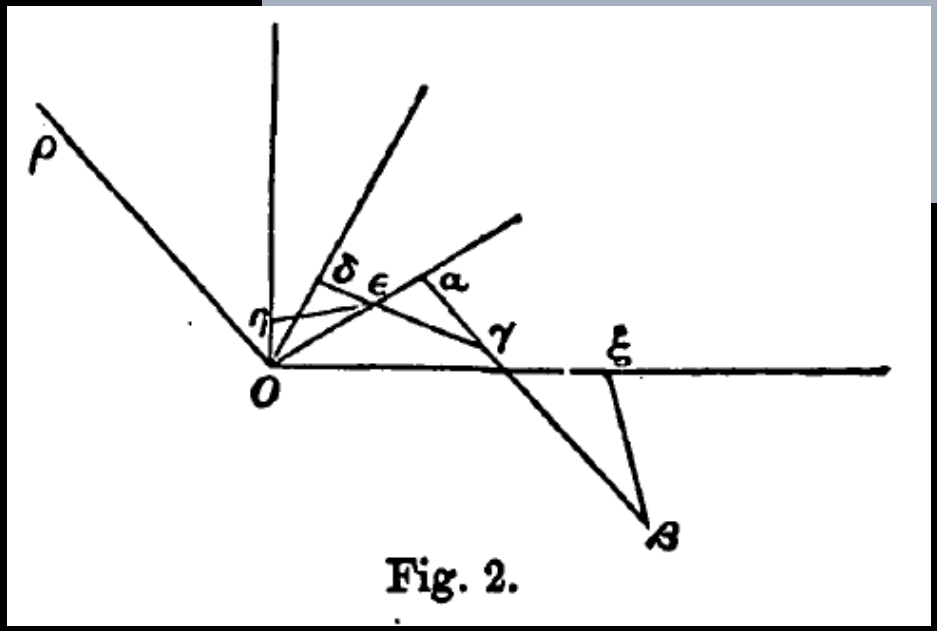

Fig. 2.

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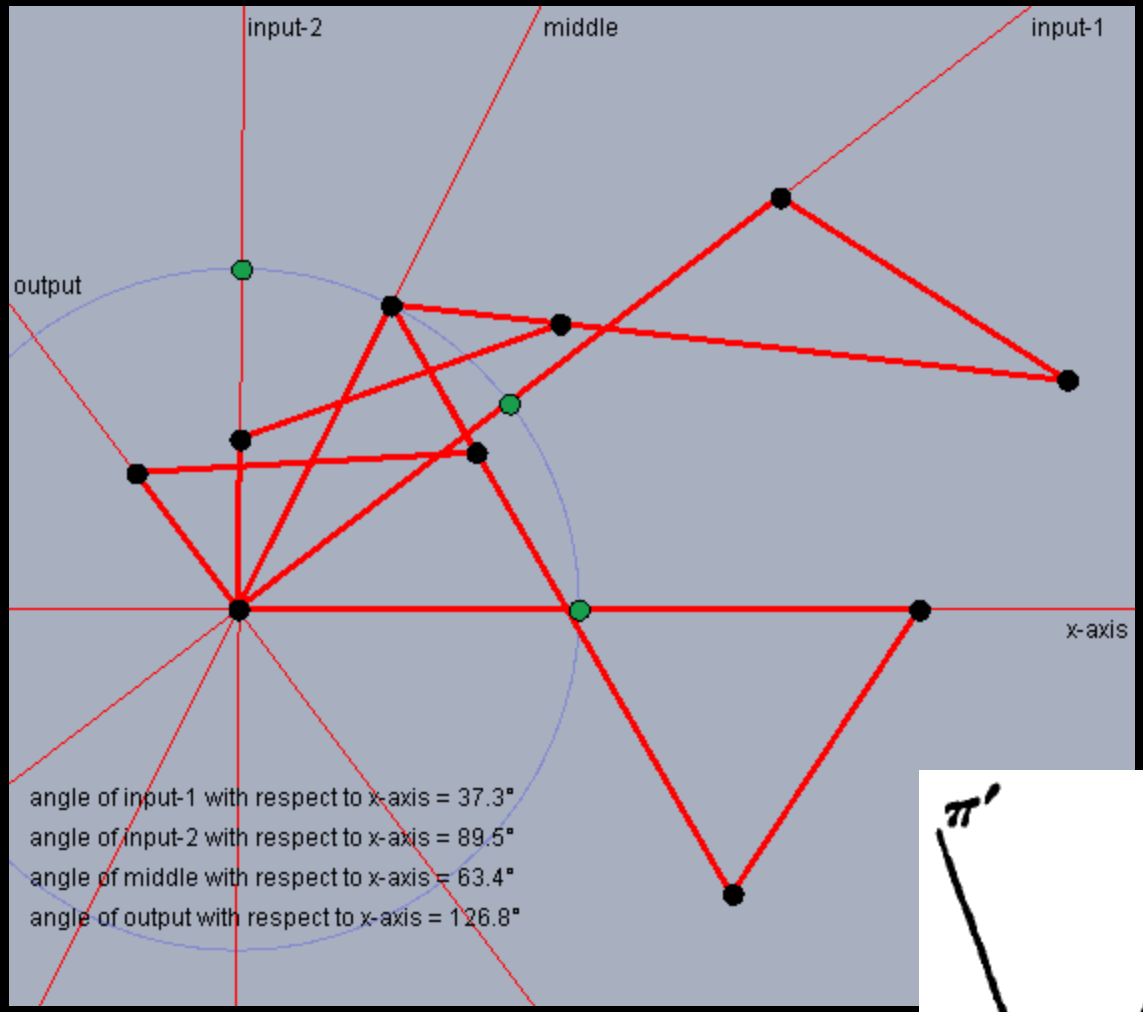
Source: Kempe, A. B. *On a General Method of describing Plane Curves of the nth degree by Linkwork*, 1876.



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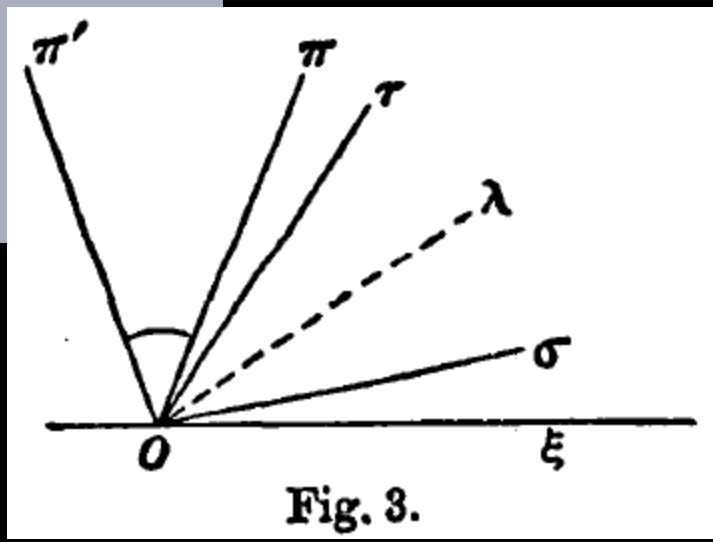

Fig. 3.

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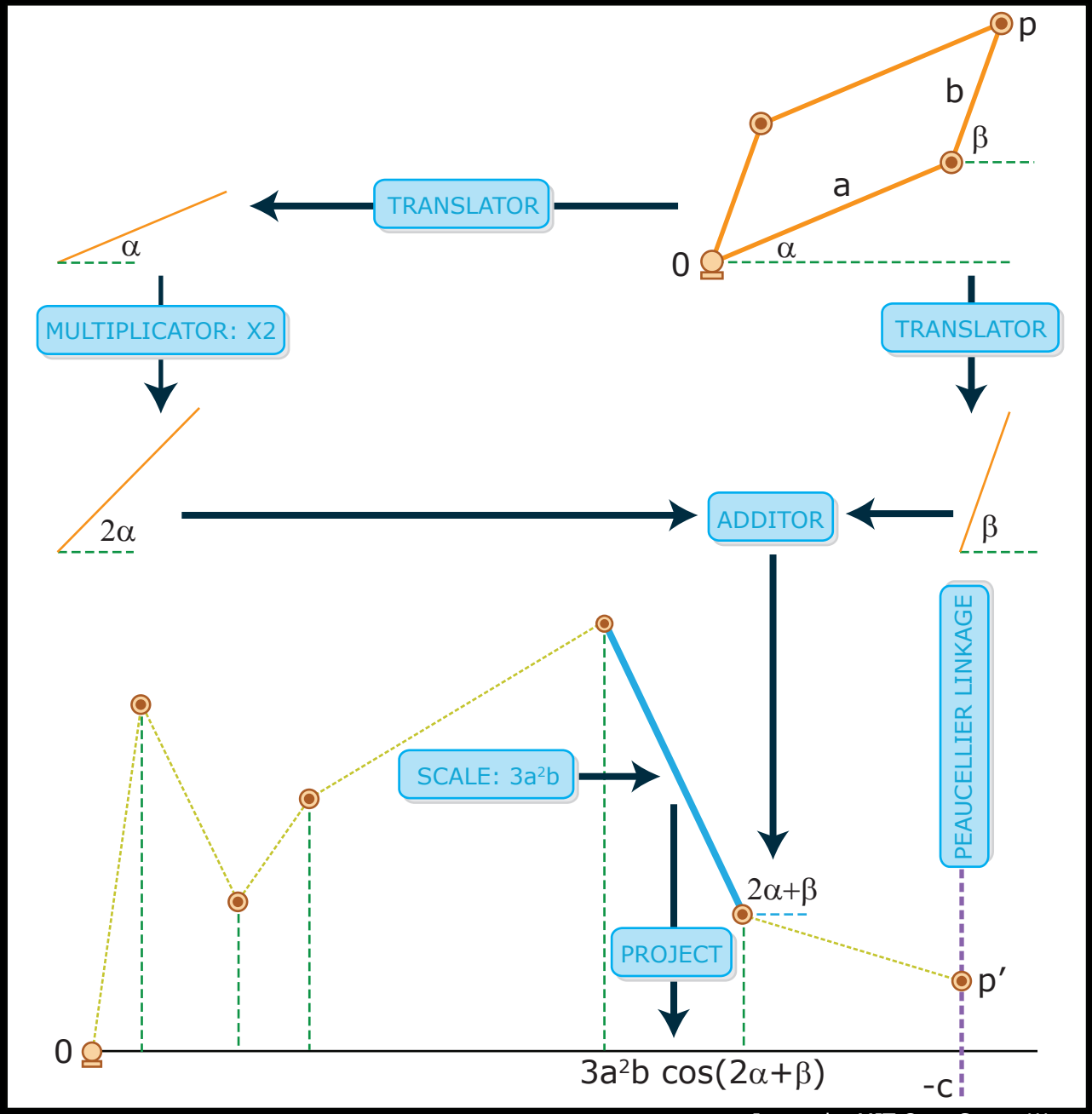

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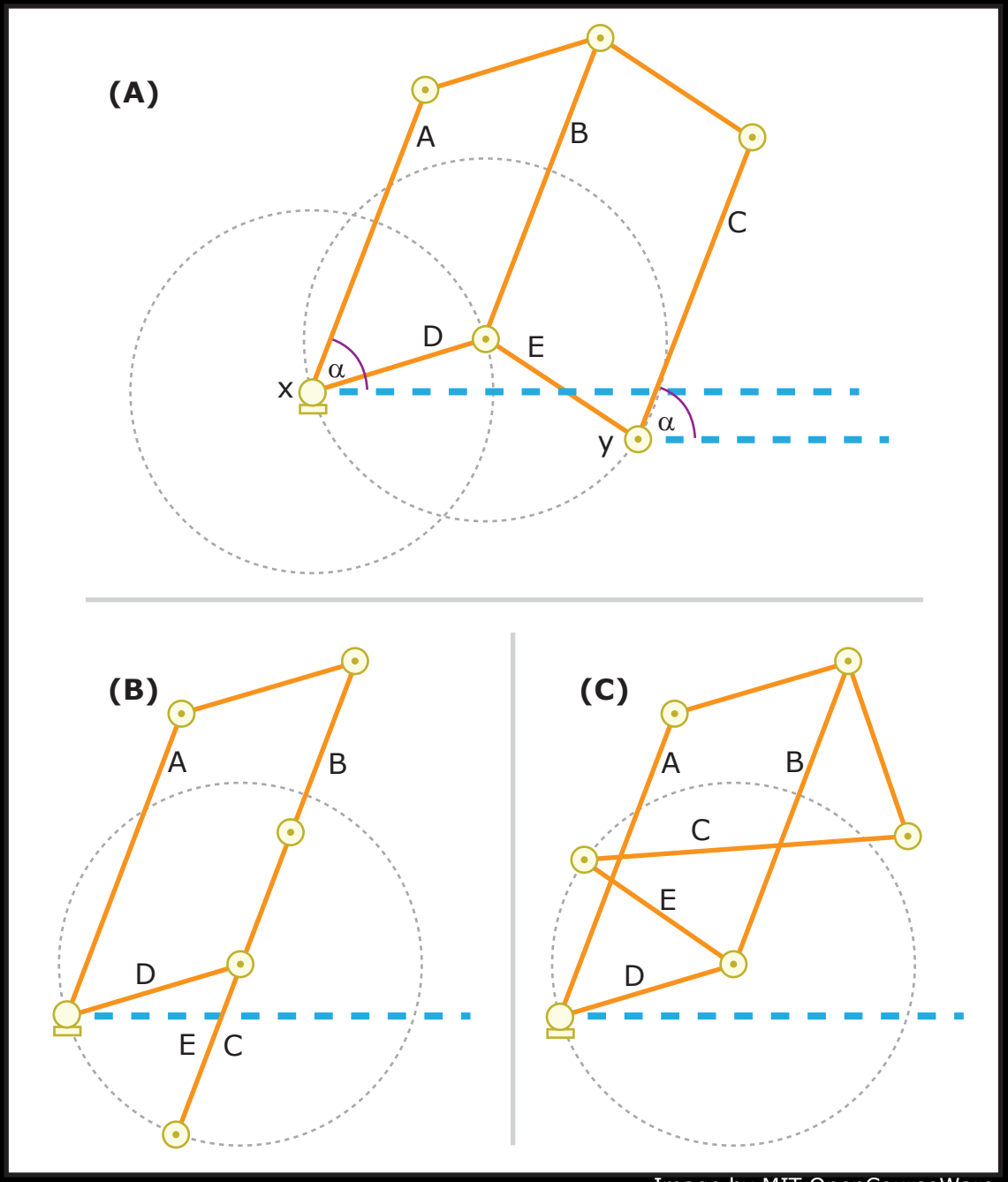

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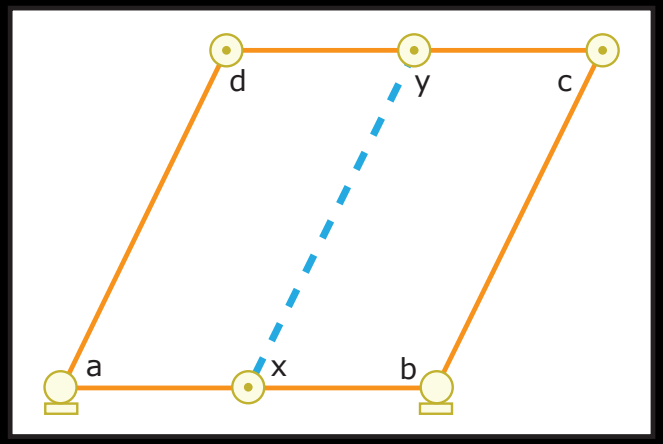

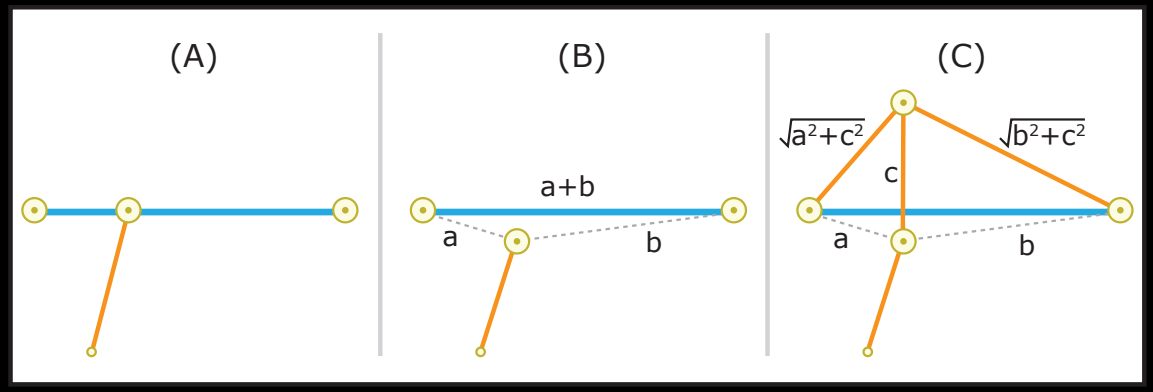

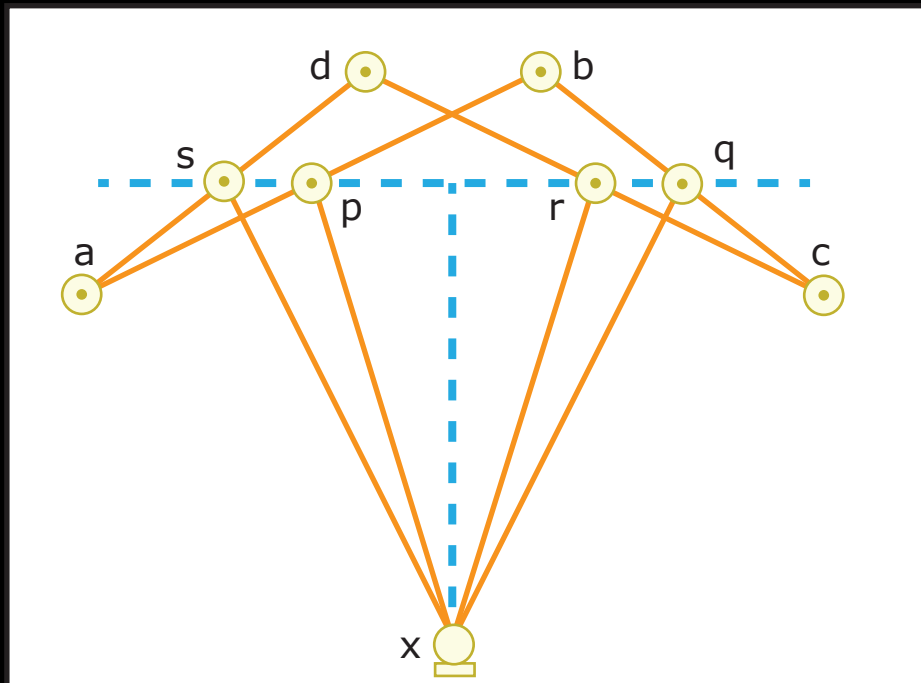

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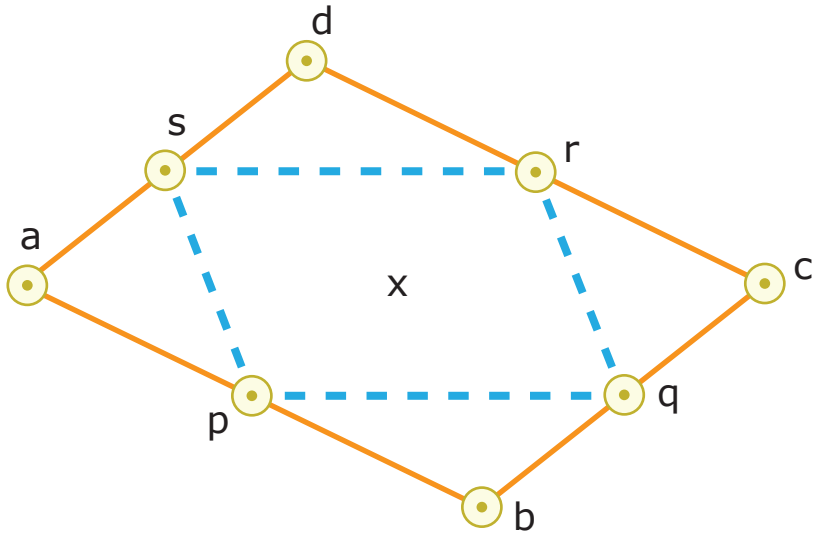

(B)

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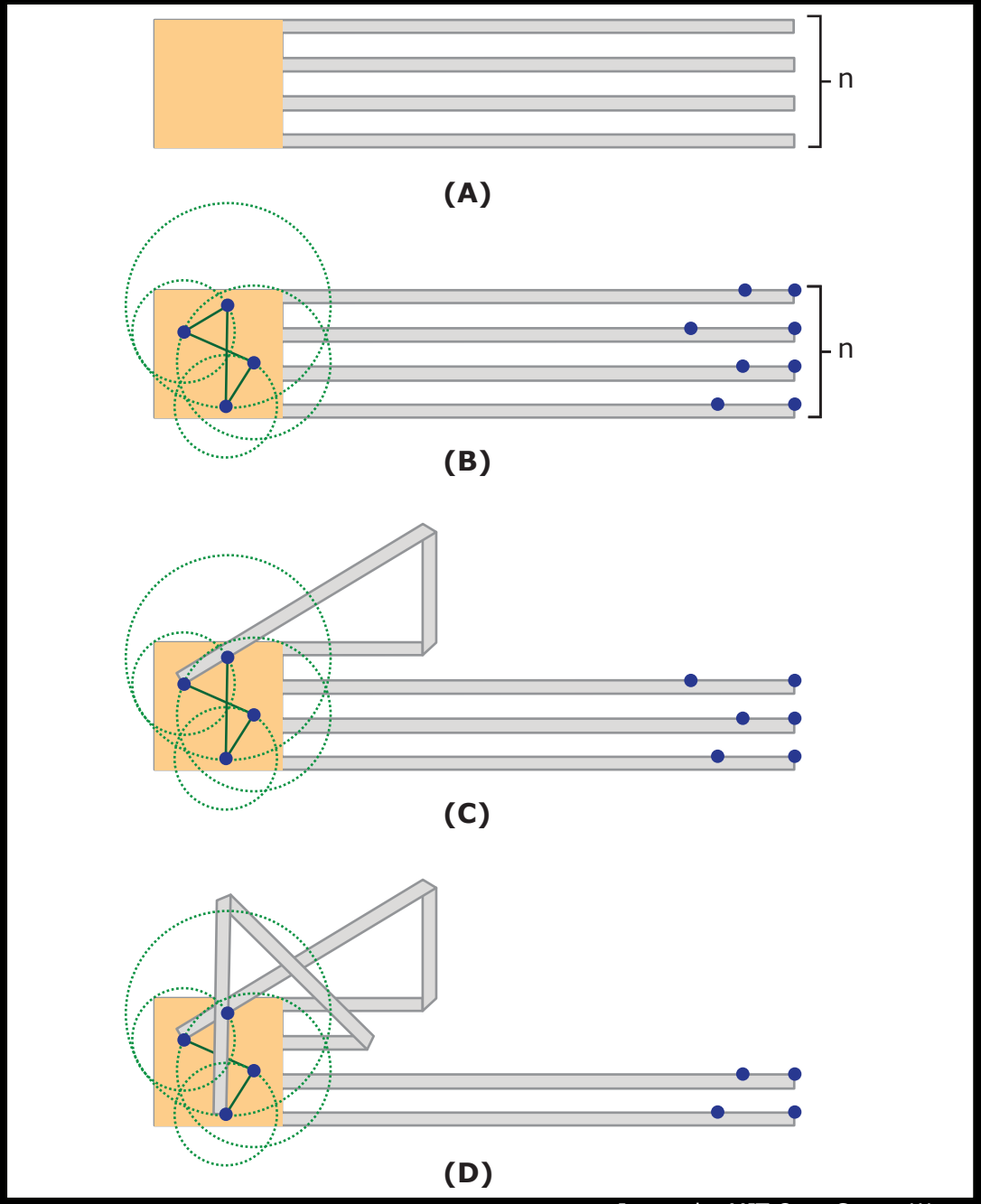

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6.849 Geometric Folding Algorithms: Linkages, Origami, Polyhedra
Fall 2012

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