

OI from O on AR , and first suppose the joint A to be clamped. Then, if I is in AR produced, a rotation of the instrument about O with angular velocity ω will give to R the component velocities $OI\omega$ in the direction IR and $IR\omega$ in the direction perpendicular to IR , and will therefore compel the roller to turn with the angular velocity $\frac{RI}{r}\omega$; but, if I is on the other side of R , the angular velocity of the roller will be $-\frac{RI}{r}\omega$. Therefore, keeping A clamped, the roller will turn through an angle $\frac{RI}{r}\theta$ or $-\frac{RI}{r}\theta$, according as I is or is not on the same side of R as A , when the instrument is rotated through an angle θ about O ; but, when I coincides with R , the roller will not turn, and then P describes a circle, called the "zero circle," represented by the middle dotted circular line, of radius

$$\sqrt{(OR^2 + RP^2)} = \sqrt{a^2 - c^2 + (b+c)^2} = \sqrt{a^2 + b^2 + 2bc}.$$

Next unclamp the joint A and clamp the arm OA ; then the roller will turn through an angle $-\frac{c}{r}\phi$, while AP turns through an angle ϕ .

Now suppose P to travel round the finite circuit $PP_1P_2P_3$ by a combination of the preceding motions in the following order. (1) Clamp the joint, and move P to P_1 and A to A_1 , on arcs of circles of centre O ; then the roller will turn through an angle $\frac{RI}{r}\theta$, θ being $\angle AOA_1 = \angle POP_1$. (2) Unclamp the joint and clamp the arm, and move the pointer from P_1 to P_2 on the arc of a circle of centre A_1 ; then the roller will turn through an angle $-\frac{c}{r}\phi$, ϕ being $\angle P_1A_1P_2$. (3) Unclamp the arm and clamp the joint, and move the pointer from P_2 backwards to P_3 and A_1 to A , on arcs of circles of centre O , through an angle θ ; then the roller will turn through an angle $-\frac{RI}{r}\theta$, if OI_1 is the perpendicular from O on P_3A .

SUSA, the Biblical SHUSHAN, capital of Susiana or Elam and from the time of Darius I. the chief residence of the Achæmenian kings, was a very ancient city, which had been the centre of the old monarchy of Elam and undergone many vicissitudes before it fell into the hands of the Persians (see ELAM). The site of the town, which has been fixed by the explorations of Loftus and Churchill, lies in the plain, but within sight of the mountains, between the courses of the Kerkha (Choaspes) and the Dizful, one of the affluents of the Pasitigris. The Shápúr, a small tributary of the Dizful, washes the eastern base of the ruin-mounds of Sús or Shásh. Thus the whole district was fruitful and well watered, fit to support a great city; the surrounding rivers with their canals gave protection and a waterway to the Persian Gulf; while the position of the town between the Semitic and Iranian lands of the empire was convenient for administrative purposes. It is not therefore surprising that Susa became a vast and populous capital; Greek writers assign to it a circuit of 15 or 20 miles,—a statement which is fairly well borne out by the remains. These include three main mounds, of which one is identified with the strong citadel¹ and a second shows the relics of the great palace built by Darius I. and completed by Artaxerxes Mnemon. Susa was still a place of importance under the Sasanians, and after having been razed to the ground in consequence of a revolt seems to have been rebuilt by Shápúr II. under the name of Éranshahr-Shápúr (Nöldeke, *Gesch. d. Perser aus Tabari*, p. 58). The fortifications were destroyed at the time of the Moslem conquest (Mokaddasi, p. 307); but the site, which is now deserted, was inhabited in the Middle Ages, and a seat of sugar-manufacture.

In Daniel viii. 2 the river of Shushan is called Ulai, a name which is identical with Avrai of the Bundelesh and Eulæus of classical writers. What is told of the Eulæus makes it impossible to identify it with the inconsiderable Shápúr; but authorities differ as to whether it is another name for the Choaspes or rather denotes

¹ The Greeks called the citadel the Μεμόνιον (Strabo, xv. 3, 2), and supposed it to have been founded by the Ethiopian Memnon. It was strong enough to withstand Molon in his war with Antiochus the Great (Polyb., v. 48).

(4) Unclamp the joint and clamp the arm, and move the pointer from P_3 to P on the arc of a circle of centre A , and consequently through an angle ϕ ; the roller will turn through an angle $\frac{c}{r}\phi$, which cancels the angle due to motion (2). Thus in completing the finite circuit $PP_1P_2P_3$ the roller will have turned through an angle $(RI - RI_1)\frac{\theta}{r} = (AI - AI_1)\frac{\theta}{r}$. But the area $PP_1P_2P_3 = \text{area } PP_1Q_1Q_2 - \text{sector } OQ_1Q_2 = \frac{1}{2}(OP^2 - OP_1^2)\theta$, $= \frac{1}{2}(OA^2 + AP^2 + 2AI \cdot AP) - (OA^2 + AI_1^2 + 2AI_1 \cdot AP)\theta$, $= (AI - AI_1)AP\theta$, $= br$ times the angle turned through by the roller.

The area $PP_1P_2P_3$ is therefore b times the travel of the circumference of the roller.

Any irregular area, supposed to be built up of infinitesimal elements found in the same manner as $PP_1P_2P_3$, will be accurately measured by the roller when the point P completes a circuit of the perimeter, the arm AP being free to turn on the joint at A and the arm OA on a fixed point O . If, however, O is inside the area, the area of the zero circle must be added to the area deduced from the readings of the roller. When the roller is fixed permanently, this area is constant, and is usually engraved on the arm in units of the adopted length b ; when the roller is held on a slider which also carries the pinion of the arm OA , the length b may be so adjusted that the areas described will be expressed in any desired unit of measure.

Literature and Authorities consulted.—*Accounts of the Operations of the Great Trigonometrical Survey of India; Manual of Survey for India; Col. A. B. Clarke, Geodesy; Methods and Processes of the Ordnance Survey; Col. Waterhouse, On the Application of Photography to Maps and Plans; and Professional Papers of the Royal Engineers.* (J. T. W.)

the Dizful or the Pasitigris. Susa in the days of its greatness must have stretched nearly from river to river. There is a sanctuary of the tomb of Daniel on the banks of the Shápúr, and Arabic geographers relate that this tomb was a frequented shrine before the Moslem conquest and that the Arabs turned the stream over the grave.

SUSA, a city of Italy, in the province of Turin, 33½ miles west of Turin by the railway which passes by the Mont Cenis tunnel into France, is situated on the Dora Riparia (tributary of the Po) at 1625 feet above the sea, and is so protected from the northern winds by the Rocciamelone that it enjoys a milder winter climate than Turin itself. The city walls, 20 to 30 feet broad at the base, were about 50 feet in height, but in 1789 their ruinous condition caused them to be reduced by about half their elevation. Numerous remains of Roman buildings and works of art still show the importance of the ancient town; and the triumphal arch erected by Cottius in honour of Augustus still stands on the old Roman road between Italy and Gaul,—a noble structure, 45 feet high, 39 broad, and 23 deep. The inscription, now illegible, mentioned fourteen "civitates" subject to Cottius. Among the modern buildings of Susa the first place belongs to the church of San Giusto, founded in 1029 by Olderico Manfredi II. and the countess Berta, and in 1772 raised to be the cathedral. The population of the city was 3254 in 1871 and 3305 in 1881 (commune, 4418).

Segusio (also Secusio, Siosium, Scutium, Sencia, &c.) was at a very early period the chief town of this Alpine region, and the Cottian Alps themselves preserve the name of the Segusian chief Cottius, who with the title of præfectus became a tributary and ally of Rome in the reign of Augustus, and left his state strong enough to maintain its independence till the reign of Nero. As a Roman municipium and military post Segusio continued to flourish. After the time of Charlemagne a marquise of Susa was established; and the town became in the 11th century the capital of the famous countess Adelaide, who was mistress of the whole of Piedmont. On his retreat from Legnano, Barbarossa set fire to Susa; but the town became more than ever important when Emanuel Philibert fortified it at great expense in the 16th century.

SUSA (*Sûsa*), a city of Tunis, on the coast of the gulf of Hamâma, 33 miles south of Hamâma. It occupies the side of a hill sloping seawards; and is still, as far as the town proper is concerned, surrounded with heavy white-



washed Oriental-looking walls. The *Kasr al-Ribat*, a square building flanked by seven bastions, was probably either a Roman or Byzantine fortress, and a Byzantine chapel is now transformed into the *Kahwat al-Kubba* or Café of the Dome. Since the French annexation the citadel, built on the highest point within the town, has been entirely restored and serves as the headquarters of the general commanding a division; and a camp of tile-roofed brick buildings has been erected in the neighbourhood. The space within the walls is proving too limited for the growth of the population, and houses already extend along the shore to north and south for about a mile. Susa is the ancient seaport of Kairwan (45 miles inland), with which it is connected by a horse-tramway, and it has a rapidly increasing commerce. In 1864 the port was visited by about 195 vessels, in 1885 by 701, of which 532 were Italian. The exports in 1885 were valued at £1,371,510 (oil, to Genoa and Leghorn, £232,530; grain, largely to Sicily, £397,760; *sansa* or olive refuse, to France, £13,715; esparto, a comparatively recent article for this port, £17,935), and the imports (including building-stone from Sicily and Malta, brick, lime, marble, and timber) amounted to £660,135. The population, which numbered 8000 in 1872 (2000 Jews, 1000 Christians), had increased to upwards of 10,000 in 1886.

Susa is the ancient *HADRUMETUM* (*q.v.*). In 1537 it was besieged by the marquis of Terra Nova, in the service of Charles V., and in 1539 was captured for the emperor by Andrea Doria. But as soon as the imperial forces were withdrawn it became again the seat of Turkish piracy. The town was attacked by the French and the Knights of St John in 1770, and by the Venetians in 1764.

SUSANNA ("Lily"), the heroine of one of the apocryphal additions to the Greek text of the book of Daniel, the others being the *Song of the Three Children* and the story of *Bel and the Dragon*. In the English version the story of the virtuous Susanna—the false accusation brought against her by the elders and her deliverance by the judgment of Daniel—is put as a separate book. Jerome, in his *Preface to Daniel*, points out that it had been observed both by Jews and Christians that this story was certainly written by a Greek, and not translated from Hebrew, since Daniel makes a series of Greek puns on the names of trees.

SUSSEX, a maritime county in the south of England, lying between 50° 43' and 51° 9' N. lat. and 0° 49' E. and 0° 58' W. long. It is 76 miles from Lady Holt Park to Kent Ditch, and 28 miles from Tunbridge Wells to Beachy Head, and adjoins Kent on the N.E., Surrey on the N., Hampshire on the W., and the English Channel on the S. Its total area is 933,269 acres or 1458 square miles.

The range of chalk hills known as the South Downs divides the county into two districts—that of the coast and that of the Wealden—which are of unequal extent and possess very different characteristics. In the western part of the county the South Downs are about 10 miles distant from the sea; they continue eastwards for about 45 miles, and terminate in the bold headland of Beachy Head. Their average height is about 500 feet, though some of the summits reach 700 (Ditchling Beacon, 813 feet; Chanctonbury Ring, 783; Fittle Beacon, 700; and the Devil's Dyke, 697). The Forest Ridge extends through the northern part of the county from Petworth to Crowborough, reaching the coast in Fairlight Down. The principal summits are Crowborough Beacon (796 feet), Brightling Hill (647), and Fairlight Down (528). The county has suffered greatly from incursions of the sea. The site of the ancient cathedral of Selsey is now a mile out at sea. Between 1292 and 1340 upwards of 5500 acres were submerged. In the early part of the 14th century Pagham harbour was formed by a sudden irruption of the sea, devastating 2700 acres. Recently all this and has been reclaimed and again brought under cultivation.

There is considerable reason for believing that the whole coast-line of the county has been slightly raised in the last 800 years (possibly by earthquake shock), as the large estuaries at the river mouths no longer exist, and the archipelago round Pevensey (*eye* signifies "island") has only a slight elevation above the neighbouring marsh land.

The rivers are small and unimportant. The principal are the Rother, the Cuckmere, the Ouse, the Adur, the Arun, and the Lavant. The Rother rises in the Forest Ridge, in the parish of Rotherfield, and enters the sea near Rye, its course having been diverted by a great storm on 12th October 1250, before which date its exit was 12 miles to the east, beyond Dungeness. The Cuckmere also rises in the Forest Ridge, near Heathfield, and empties itself into the sea a little to the east of Seaford. The Ouse rises in St Leonards Forest, to the north-west of Lindfield, and, passing through Isfield and Lewes, enters the sea at Newhaven, now the principal port in the county. The former outlet was at Seaford, but in the reign of Elizabeth the sea broke through the beach bank at some warehouses just below Bishopstone and formed what is now called the old harbour, which was in use until the Newhaven one was made a safer exit. The Adur has three sources, all in the neighbourhood of St Leonards Forest, and flows southwards, entering the sea at Southwick. The mouth of the river formerly shifted from year to year, ranging both east and west over a distance of 2 miles. The Arun rises in St Leonards Forest, in the parish of Slinfold, flows through Amberley and Arundel, and enters the sea at Littlehampton. The Lavant has its source in Charlton Forest and encircles Chichester on all sides except the north, entering the sea through creeks in the extreme south-west corner of the county.

The portion of the county to the north of the South Downs is called the Weald; it formerly formed part of the forest of Andredsweald ("the wood or forest without habitations"), which was 120 miles in length and about 30 in breadth. The total area of forests in 1885 was 113,043 acres, being the greatest of any county in England. About 1660 the total was estimated at over 200,000 acres. The chief remains of the ancient forests are Tilgate, Ashdown, and St Leonards, but the names in many parts indicate their former wooded character, as Hurstpierpoint (*hurst* meaning "wood"), Midhurst, Fernhurst, Billingshurst, Ashurst, and several others. The forests were interspersed with lagoons, and the rainfall being very great caused marshes and the large river estuaries; the rainfall, however, abated in consequence of the cutting down of the Wealden forests for fuel in the extensive ironworks that formerly existed in that district. The wood was exported in the reign of Edward VI.

The greater portion of the county is occupied by the Chalk formation, of which the South Downs are almost entirely composed. Firestone is found in the west, and Steyning is built upon it. At the base of the Downs the Greensand crops up, but is of small extent. The Wealden formations occupy nearly all the inland district of the county, and in these was found the ironstone from which iron was extracted. Sussex was at one time the centre of the English iron manufacture; before 1653 there were 43 iron-forges or mills (reduced to 18 before 1667) and 27 furnaces (reduced to 11 before 1664), which employed 50,000 men¹ and furnished the main supply of ordnance for the national defence. The last forge at Ashburnham was not extinguished until 1809. Between 1872 and 1876 boring was carried on at Netherfield, near Battle, with the object of discovering what beds were below the Wealden and if possible of reaching the Palæozoic rocks, which a

¹ *Suss. Arch. Coll.*, xxxii. pp. 22-25.