The Lengths of the Rods

Appendix A examines the actual lengths of the flexible rods (note that these are not the published official lengths, most of which are understated – see the Know Your Pieces – Rods (Non-flexible) tip). You will notice that some of the rods have varying lengths, unlike the non--flexible ones.

Here is a summary of the lengths based on Ted's samples:

Flexible Rod Lengths (mm)		
Colour	**Length**	**Average**
Short Purple	32	32
Blue	53 - 53½	53¼
Orange	83½ - 85	84½
Translucent Orange	84 - 85	
Translucent Red	84½	
Long Purple	186½ - 188	187¾
Mottled Dark Grey	188 - 189	
Translucent White	188 - 188½	
Light Green	187 - 188½	
Fluorescent Green	187 - 188½	
Pale Blue	189	

Making a Wheel with Eight Radii

Occasionally the flexible rods come in very handy, especially for the rims of large wheels.

But which set of same-length rods can be used to exactly form a circumference? In one of the standard Ferris wheel models, the rim has to be clumsily augmented by two short purple flexible rods because the other flexible rods in the rim are not quite the right length!

The hub of a simple wheel is usually an 8-way connector. A rod, or rods, will be attached to each of the eight slots in the connector to create the radii of the wheel. A 5-way connector will then be attached to the end of each radius, eight flexible rods being used to join these to form the rim.

The question is, "What should the lengths of the radii (including any connectors) be so that the circumference can be formed from eight identical flexible rods?"

First of all, it should be remembered that the actual lengths of the rods differ from the official lengths, and secondly, that the length of a rod is increased by 20mm if there is a connector on each end.

The Non-flexible Radii Rods

The effective lengths of the non-flexible rods, which will be used to form the radii, are therefore as follows:

Non-flexible Rod Lengths (mm)		
Colour	Actual Length	Length with Connectors
Green	17¼	37¼
White	33	53
Blue	55	75
Yellow	86	106
Red	130	150
Grey	192	212

The Flexible Circumference Rods

If the radius of a wheel is r, then the circumference is $2\pi r$. This circumference is to be formed from eight flexible rods of the same length and eight connectors. The radius is to be formed from one or more non-flexible rods.

Let the length of each flexible rod (including the connectors) forming the rim be f. Ignoring the fact that the connectors on the rim are straight rather that curved (the error is insignificant), we have:

$$8f = 2\pi r$$

or

$$r = 4f/\pi$$

For various effective flexible rod lengths, f, we have the following values for r (all measurements are in millimetres, and the rod lengths include the length of the connector on each end):

Rim Rod (Average) f	Length of Required Radial Rod(s) $r\ (=4f/\pi)$
73¼	93¼
104½	133
207¾	264½

Finding the Compatible Rods

The question now is, “Which of these values of r can be formed with using non-flexible rods?”

Including the connector on each end, the available rod lengths are 37¼, 53, 75, 106, 150 and 212.

The radial rods can be formed as follows:

Length of Required Radial Rod(s)	How to Produce
93¼	Not possible
133	Not possible
264½	212 + 53 = 265

So we have just one flexible rod length which can be used to exactly form the rim of a wheel — we can use the long flexible rods which have an average length of 187¾mm. The radii will be made from a grey rod and a white one, or from two yellow rods with a white one (there are other combinations, but the letter is the most likely to be used because the white rod can be used to separate the two yellow ones, thus creating a pleasing design).

When Ted made the reels for his fruit machine, he used two yellow rods separated by the white one.

Making a Wheel with 16 Radii

If two 8-way connectors are used for the hub of a wheel, they can be staggered so that there are effectively slots for 16 radii.

Let's see whether a wheel can be constructed where the rim consists of 16 similar flexible rods.

Using the same notation as before, we have:

$$16f = 2\pi r, \textit{ ie } r = 8f/\pi$$

Rim Rod (Average) f	Length of Required Radial Rod(s) $r\ (= 4f/\pi)$	How to Produce
73¼	186½	Not possible
104½	266	212 + 53 = 265 [1]
207¾	529	212 + 212 + 106 = 530 [2]

[1] This would only work if the flexible rods are sorted through so that their average length is 84 (*ie* 104 including the connectors). The radii would look nicer as 106 + 53 + 106.

[2] This too would only work if the flexible rods are carefully selected, but this wheel would be quite flimsy owing to the long lengths of the rods.

In practice a slight error doesn't matter, because the flexible rods would be slightly stretched, or would slightly bulge. Indeed, in one Ferris wheel model, the rim rods bulge slightly because they are too long!

Appendix A

The following tables show the distribution of the lengths of samples of used flexible rods (Ted suspects that as these rods are used, their properties change, thus causing a change in size):

	Blue
Length	**Frequency**
53	9
53½	20
54	1
54½	-
55	-
Average	**53¼**

	Orange	Translucent Orange
Length	**Frequency**	**Frequency**
83	1	-
83½	12	-
84	6	6
84½	7	13
85	4	11
Average	**84**	**84½**

The lengths of Ted's eight short purple rods (the ones used as fillers for one of the official Ferris wheels) are 32mm, and all of Ted's translucent red rods are 84½mm long.

	Long Purple	Mottled Dark Grey	Translucent White	Light Green	Fluorescent Green
Length	**Frequency**	**Frequency**	**Frequency**	**Frequency**	**Frequency**
186½	3	-	-	-	-
187	14	-	-	8	2
187½	9	-	-	12	8
188	4	11	4	8	5
188½	-	16	2	2	2
189	-	3	-	-	-
Average	**187¼**	**188¼**	**188¼**	**187½**	**187¾**

Ted also has 12 pale blue rods with a consistent length of 189mm and just four yellow rods with a consistent length of 188½mm.