Smartphone Depth of Field (DoF) With a Full Frame Camera

From DP Review [Apple's iPhone 14 and 14 Pro: Imaging tech examined]:

iPhone 14 Pro (Max) cameras vs iPhone 13 Pro (Max) cameras

iPhone 14 Pro / Pro Max				
Focal length	**Pixel count**	**Sensor size**	**f/number**	**Crop factor**
24mm equiv.	48MP / 12MP	Type 1/1.28 (9.8x7.3mm)	F1.78	~3.5x
13mm equiv	12MP	Type 1/2.55 (5.6x4.2mm)	F2.2	~6.2x
77mm equiv	12MP	Type 1/3.5 (4x3mm)	F2.8	~8.7x
iPhone 13 Pro / Pro Max				
Focal length	**Pixel count**	**Sensor size**	**f/number**	**Crop factor**
26mm equiv.	12MP	Type 1/1.7 (7.6x5.7mm)	F1.5	~4.6x
13mm equiv	12MP	Type 1/3.5 (4x3mm)	F1.8	~8.7x
77mm equiv	12MP	Type 1/3.5 (4x3mm)	F2.8	~8.7x

The iPhone's crop factors are based on the size of its sensor compared to full frame. The aspect ratio for full frame is 3:2 while the iPhone sensors are normally 4:3.

Each of the iPhone cameras has a fixed focal length sated as a full frame (24x36mm) equivalent. Divide the diagonal measurement for full frame by the diagonal of the iPhone sensor to get the crop factor.

Each of the iPhone cameras has a fixed aperture. A corresponding full frame aperture can also be found by multiplying the iPhone's aperture by the crop factor. Both physical apertures are the same.

The result is the same hyperfocal distance (HD) for both cameras. At any focus distance closer to the camera than the HD will produce almost exactly the same near and far limit and DoF although the far limits may differ depending on how close the focus distance is to HD.

Common DoF calculators do not let us set aperture settings between the common click stops. The iPhone's cameras may have a sensor dimension that is not recognized by some of the available DoF calculators.

DoF calculators don't always calculate the Circle of Confusion (CoC) the same way. We might expect CoC to be calculated as the length of the format diagonal divided by 1500. This would lead to a CoC of 0.0288444mm for the 24x36mm full frame sensor. But the DoF calculators might use 0.025, 0.029, 0.03 or some other value. To account for differences in visual acuity the 1500 constant might (for viewing an 8x10" image from 25cm) not be the same in all calculators.

To address all of these issues we need to create a DoF calculator from scratch.

A Basic DoF calculator

	A	B	C	D	E	F	G	H
1	Focal length	50	mm					
2	Aperture f/	8						
3	Subject Distance	3.05	meters	10.0	feet			
4	Height	24	mm					
5	Width	36	mm					
6	COC	0.029	mm			=SQRT(B4^2+B5^2)/1500		
7								
8	Hyperfocal	10.88	meters	35.7	feet	=(B1+(B1^2)/(B2*B6))/1000		
9								
10	Near Limit	**2.4**	meters	7.8	feet	=B8*B3/(B8+B3)		
11	Far Limit	**4.2**	meters	13.9	feet	=IF(B8>B3,B8*B3/(B8-B3),"INF")		
12								
13	DOF	**1.9**	meters	6.1	feet	=IF(B3<B8,B11-B10,"INF")		
14								

Using the formulas are from Circle of confusion, Hyperfocal distance and Depth of field, the hyperfocal distance is calculated first then the near and far limits and finally the DoF.

The formulas are based on assumption that CoC=[format diagonal]/1500 is the correct value to produce an 8x10” print from 25cm (about 10 inches) to be viewed by someone with normal visual acuity. Other DoF calculators probably use the same basic formulas but a constant slightly different from 1500.

iPhones Compared to Full Frame

Using the information from the DP Review article we can compare the DoF values for each of the iPhone cameras to a comparable full frame camera even though the iPhone images have an aspect ratio of 3:4 where the full frame ratio is 2:3.

	A	B	C	D	E	F	G	H	I	J	K
1	**To achieve the same field of view**										
2											
3		Full Frame (FF)		iPhone		Red values copied from Source below					
4	Focal length mm	26	->	*5.652*		D4=B4/D5					
5	Crop factor	1.00		4.6							
6	f/ Aperture	*6.9*	<-	1.5		B6=D6*D5					
7	Subject Distance m	3.05	->	*3.05*		B7 is entered by user			D7=B7		
8	COC mm	*0.029*	->	*0.0063*		B8=SQRT(24^2+36^2)/1500			D8=B8/D5		
9	Physical aperture mm	*3.768*		*3.768*		B9=B4/B6	D9=D4/D6				
10											
11	**Hyperfocal, meters**	***3.42***		***3.40***							
12											
13	**Near Limit**	***1.61***		***1.61***							
14	**Far Limit**	***28.02***		***29.46***							
15											
16	DOF	***26.41***		***27.86***							
17											
18	iPhone 14 *	Equivalent focal length	crop factor	max f/		Height	Width	CoC		FF HD	iPhone HD
19		24	3.5	1.78		7.3	9.8	*0.0081*		*3.23*	*3.21*
20		13	6.2	2.2		4.2	5.6	*0.0047*		*0.44*	*0.43*
21		77	8.7	2.8		3	4	*0.0033*		*8.52*	*8.45*
22											
23	iPhone 13 *	Equivalent focal length	crop factor	max f/		Height	Width	CoC		Full Frame HD	iPhone HD
24		26	4.6	1.5		5.7	7.6	*0.0063*		*3.42*	*3.40*
25		13	8.7	1.8		3	4	*0.0033*		*0.39*	*0.38*
26		77	8.7	2.8		3	4	*0.0033*		*8.52*	*8.45*

Download: DoF calculator spreadsheet

A small sensor makes it easy to capture a lot of sharp detail because of the inherent DoF.

A larger sensor, a longer focal length and a wide aperture can produce a close-up of a flower with a shallow DoF and a nicely blurred background.

If you want to photograph wildlife or portraits you might fall somewhere in between those extremes. You don't actually need to do the calculations. Just understanding the principles will suffice.