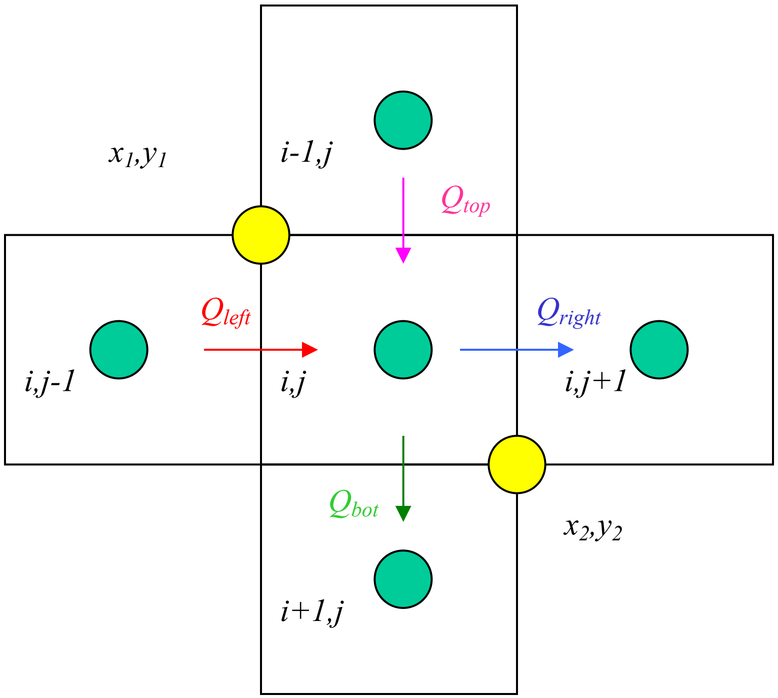
Particle Tracking on a Spreadsheet

- Particle or front tracking is typically performed using special software.
- It can be performed using a spreadsheet.
- The spreadsheet exercise is useful to illustrate the principles involved in particle tracking calculations.
- Particle tracking with reactions is very computationally intensive and is beyond practical application in a spreadsheet.

Velocity Field

- If analytical functions are available for the velocity field then tracking is relatively easy.
- Usually the velocity field is determined numerically at discrete points in space, and this is the situation of interest.
- The interpolation schemes in common use are simple; simple, simple-linear, and multi-linear schemes.
- Only the simple-linear scheme preserves cell-by-cell mass balances.

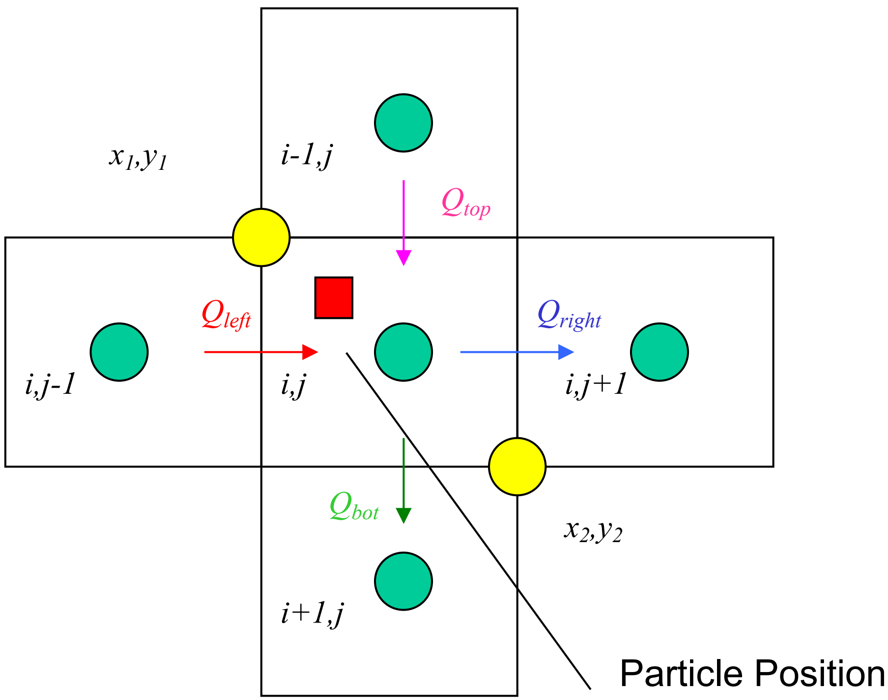
Simple Velocity Scheme



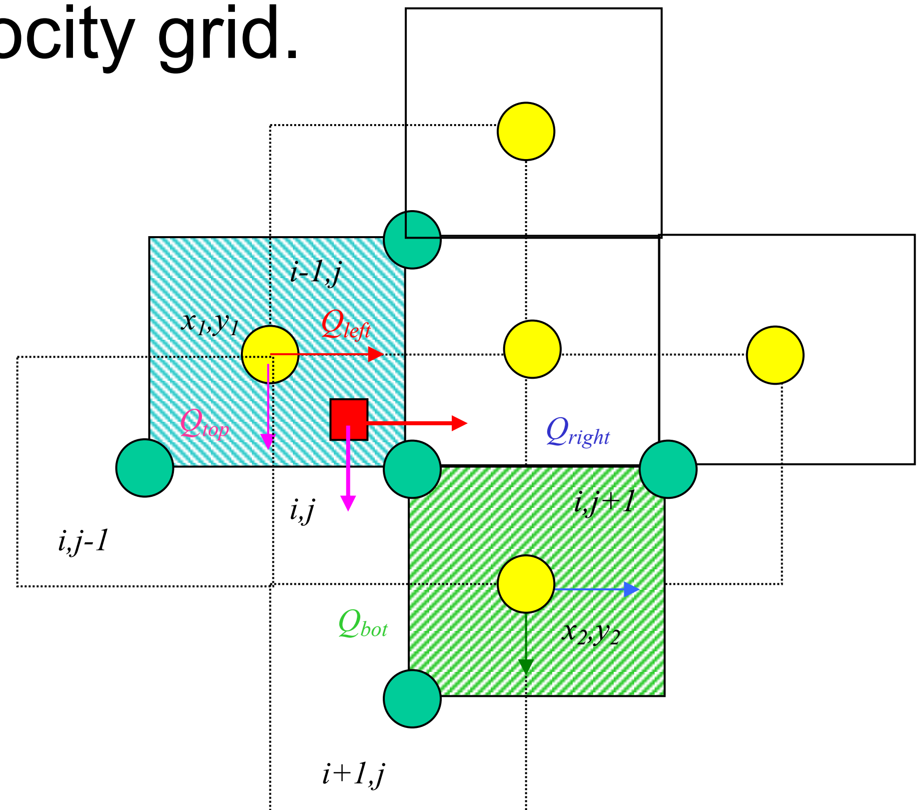
- Typical computational grid for heads.
- Arrows are the interfacial fluxes.
- The simple scheme assigns the top and left flux to (x_1,y_1)
- The simple scheme assgins the right and bottom flux to (x_2,y_2).

Simple Velocity Grid

- The particle velocity is determined by position of the particle relative to the velocity grid.



Grid for Head Distribution



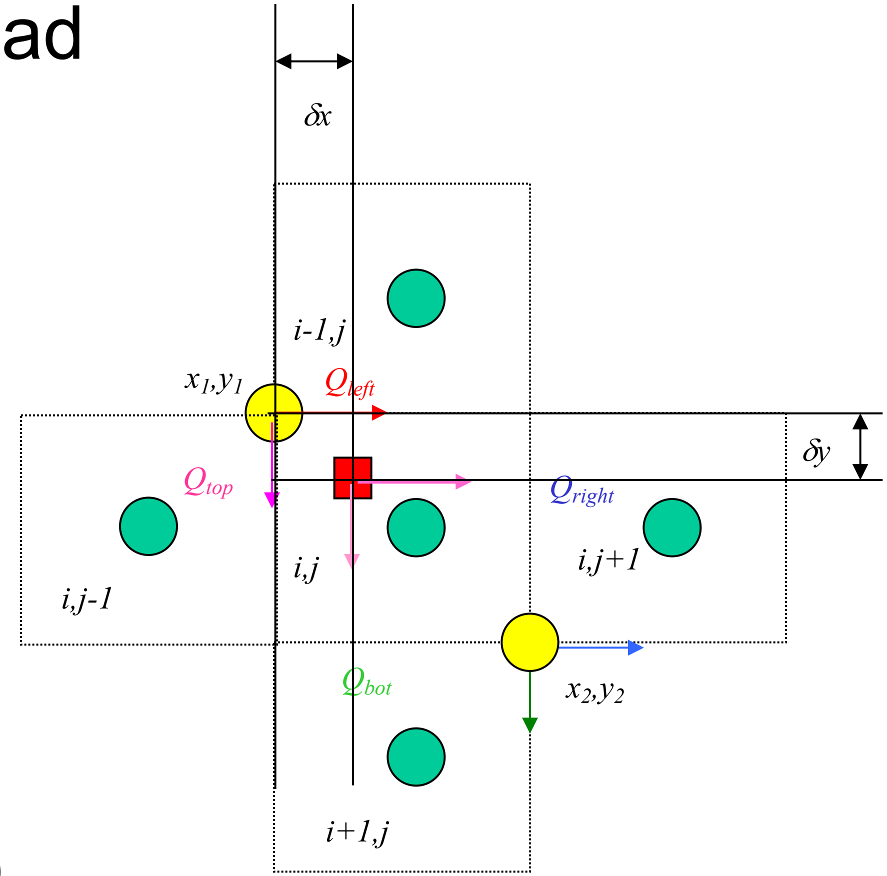
Grid for Velocity Distribution
(Head grid shown as dashed cells)

Linear Interpolation

- Use the same grid as the head scheme.
- Velocity is the distance weighted average of the cell that the particle occupies.

$$u_p = \frac{1-\delta x}{\Delta x} u(x_1, y_1) + \frac{\delta x}{\Delta x} u(x_2, y_2)$$

$$v_p = \frac{1-\delta y}{\Delta y} v(x_1, y_1) + \frac{\delta y}{\Delta y} v(x_2, y_2)$$



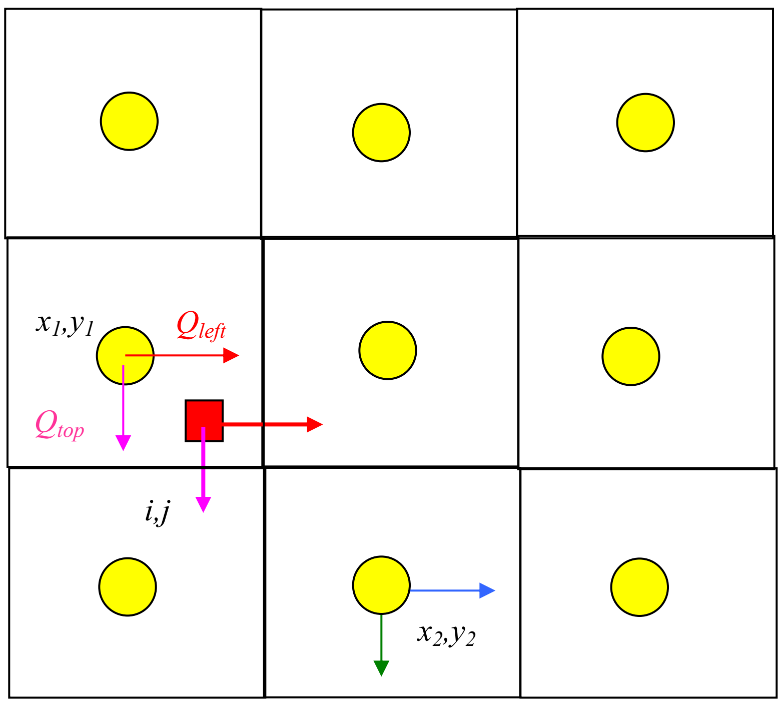
Multi-Linear Interpolation

- Higher order schemes produce smoother velocity fields at the expense of cell mass balances and computational ease.
- The USGS-MOC model uses a bi-linear scheme where the velocities at the four corners of the occupied cell are used.
- When transient flow fields occur, averaging in time is also used.
- The differences in the schemes are hard to detect when the grid spacing is small and the flow field is smoothly varying.

Spreadsheet Approach

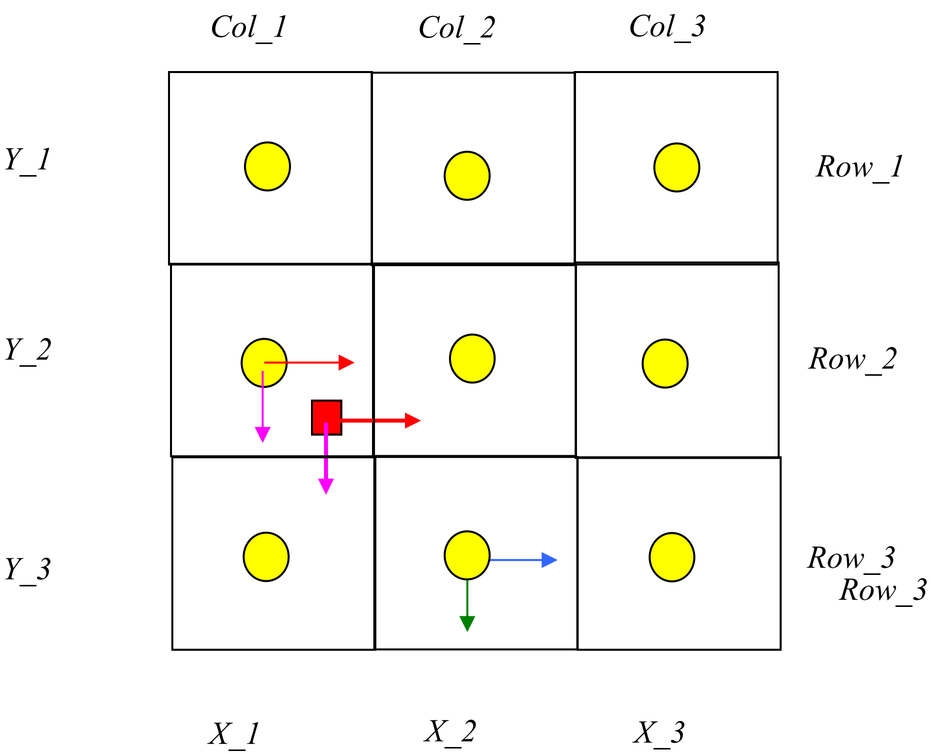
- To illustrate particle tracking the simple velocity scheme is used.
- Extension to higher order schemes is straight forward.

Spreadsheet Approach



- Illustrate with simple scheme.
  - Large rectangles represent the velocity grid.
  - Circles represent the geometric location where velocity is known.
  - Small rectangle represents the particle that we wish to track.

Cell Indexing



- **Each cell represents a grid location in the velocity field. Thus each cell has a unique row and column index.**
- **Each cell centroid also has a unique geomteric (x,y) location.**
- **The particle in the figure is located in cell named: Col_1,Row_2.**
- **The cell is located at position: *(X_1,Y_2).***
- **The particle position is *(XP,YP)*.**

Locating the Particle

- At the start of a time-step
  - particle position is known.
  - cell positions are known.
  - cell that the particle occupies is unknown.
- Construct a distance table
  - The distance from each cell to the particle is calculated and stored in a table.
- Search the table,find the cell nearest the particle.
  - The cell coordinates of the smallest distance inthe table is determined

Locating the Particle in EXCEL

- The spreadsheet function that finds the value in an array (rectangular area of cells), given the position in the array to search is the function ***INDEX(array,row_index,column_index)***
- The spreadsheet function that can find the position in an array where a particular value appears is the function ***MATCH(value,array,type)***

INDEX

- ***INDEX(array,row_index,column_index)***

array is the location of the rectangular area of cells to search (eg. A3:C6).

row_index is number of rows down from the starting row to search.

column_index is the number of columns across from the starting column to search.

MATCH

- ***MATCH(value,array,type)***

value is the numerical value to search for in the array.

array is the location of the rectangular area of cells to search (eg. A3:C6).

type is the type of match to use. type=0 means exact matching.

Using the functions

- The INDEX function allows us to select the correct values of velocity if we know which cell the particle resides in.
- The MATCH function allows us to compare values in an array and determine the position in the array that these values are found. Thus the MATCH function lets us search a distance table, find the cell center nearest the particle, and then use the index to find the correct velocity.

Moving the Particle

- Once the cell containing the particle is identified, the particle is assigned the velocity values for that cell.
- The particle is then “moved” by the simple kinematic calculation:

$$x_p(t+\Delta t) = x_p(t) + u_p(t)\Delta t$$

$$y_p(t+\Delta t) = y_p(t) + v_p(t)\Delta t$$

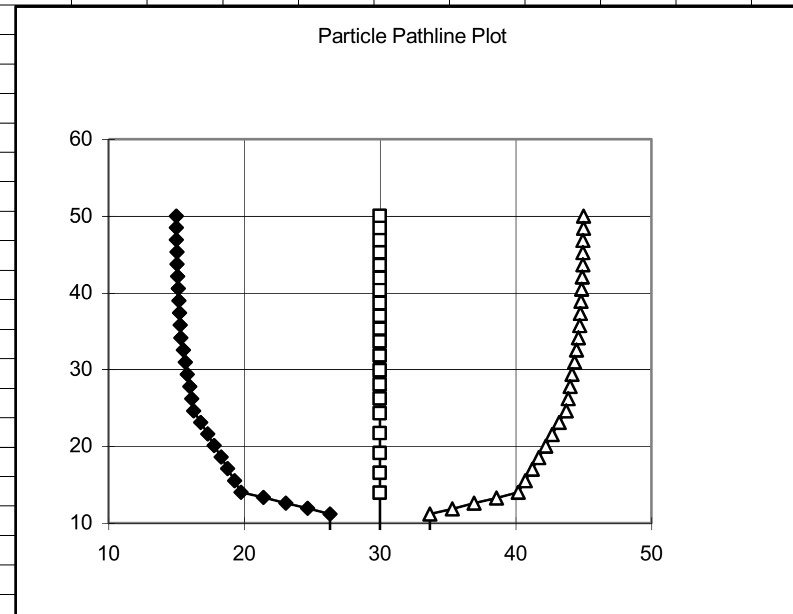
Illustrative Example Spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		Particle Tracking Spreadsheet																					
2																							
3				u(i,j)		10	20	30	40	50													
4																							
5				50		0.009	0.016	8E-14	-0.016	-0.009		1											
6				40		0.03	0.055	2E-13	-0.055	-0.03		2											
7				30		0.087	0.174	2E-13	-0.174	-0.087		3											
8				20		0.231	0.555	2E-13	-0.555	-0.231		4											
9				10		0.511	1.814	2E-13	-1.814	-0.511		5											
10																							
11						1	2	3	4	5													
12																							
13				v(i,j)		10	20	30	40	50													
14																							
15				50		-1.727	-1.758	-1.783	-1.758	-1.727		1											
16				40		-1.688	-1.766	-1.846	-1.766	-1.688		2											
17				30		-1.571	-1.771	-2.07	-1.771	-1.571		3											
18				20		-1.253	-1.677	-2.893	-1.677	-1.253		4											
19				10		-0.511	-0.792	-6.147	-0.792	-0.511		5											
20																							
21						1	2	3	4	5													
22																							
23																							
24					col		1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4
25					row		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2
26					col_dist		10	10	10	10	10	20	20	20	20	20	30	30	30	30	30	40	40
27					row_dist		50	40	30	20	10	50	40	30	20	10	50	40	30	20	10	50	40
28	dt	0.9			u(col,row)		0.009	0.03	0.087	0.231	0.511	0.016	0.055	0.174	0.555	1.814	8E-14	2E-13	2E-13	2E-13	2E-13	-0.016	-0.055
29	Particle # 1				v(col,row)		-1.727	-1.688	-1.571	-1.253	-0.511	-1.758	-1.766	-1.771	-1.677	-0.792	-1.783	-1.846	-2.07	-2.893	-6.147	-1.758	-1.766
30	t	xp	yp	up	vp	Min Dis	Distance Table from Particle to Cell Centers																
31	0	15	50	0.009	-1.727	5	5	11.18	20.62	30.41	40.31	5	11.18	20.62	30.41	40.31	15	18.03	25	33.54	42.72	25	26.93
32	0.9	15.01	48.45	0.016	-1.758	5.228	5.244	9.819	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17.21	23.77	32.15	41.26	25.04	26.38
33	1.8	15.02	46.86	0.016	-1.758	5.883	5.922	8.505	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.47	22.55	30.76	39.79	25.17	25.9
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.64	6.848	7.247	16.07	25.76	35.63	15.69	15.87	21.39	29.38	38.32	25.4	25.52
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.08	8.011	6.178	14.57	24.21	34.06	16.22	15.4	20.28	28.02	36.87	25.73	25.22

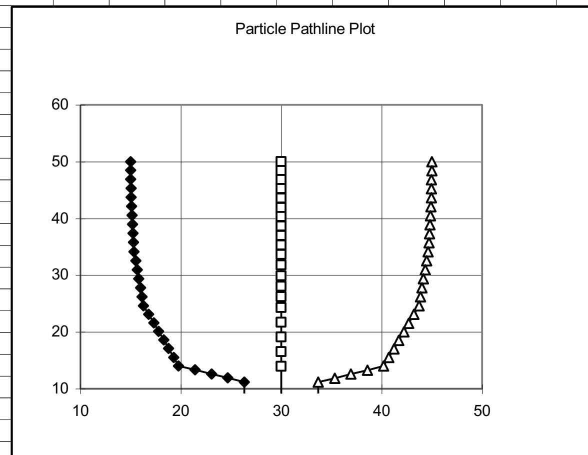
=INDEX($F$5:$J$9,G25,G24)

=SQRT(($B31-G$26)^2+($C31-G$27)^2)

=INDEX($G$28:$AE$28,1,MATCH($F31,$G$31:$AE$31,0))



Segment #1



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1		Particle Tracking Spreadsheet																													
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6				40		0.03	0.055	2E-13	-0.055	-0.03		2																			
7				30		0.087	0.174	2E-13	-0.174	-0.087		3																			
8				20		0.231	0.555	2E-13	-0.555	-0.231		4																			
9				10		0.511	1.814	2E-13	-1.814	-0.511		5																			
10																															
11						1	2	3	4	5																					
12																															
13				v(i,j)		10	20	30	40	50																					
14																															
15				50		-1.727	-1.758	-1.783	-1.758	-1.727		1																			
16				40		-1.688	-1.766	-1.846	-1.766	-1.688		2																			
17				30		-1.571	-1.771	-2.07	-1.771	-1.571		3																			
18				20		-1.253	-1.677	-2.893	-1.677	-1.253		4																			
19				10		-0.511	-0.792	-6.147	-0.792	-0.511		5																			
20																															
21						1	2	3	4	5																					
22																															
23																															
24					col		1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5
25					row		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
26					col_dist		10	10	10	10	10	20	20	20	20	20	30	30	30	30	30	40	40	40	40	40	50	50	50	50	50
27					row_dist		50	40	30	20	10	50	40	30	20	10	50	40	30	20	10	50	40	30	20	10	50	40	30	20	10
28	dt	0.9			u(col,row)		0.009	0.03	0.087	0.231	0.511	0.016	0.055	0.174	0.555	1.814	8E-14	2E-13	2E-13	2E-13	2E-13	-0.016	-0.055	-0.174	-0.555	-1.814	-0.009	-0.03	-0.087	-0.231	-0.511
29	Particle # 1				v(col,row)		-1.727	-1.688	-1.571	-1.253	-0.511	-1.758	-1.766	-1.771	-1.677	-0.792	-1.783	-1.846	-2.07	-2.893	-6.147	-1.758	-1.766	-1.771	-1.677	-0.792	-1.727	-1.688	-1.571	-1.253	-0.511
30	t	xp	yp	up	vp	Min Dis	Distance Table from Particle to Cell Centers																								
31	0	15	50	0.009	-1.727	5	5	11.18	20.62	30.41	40.31	5	11.18	20.62	30.41	40.31	15	18.03	25	33.54	42.72	25	26.93	32.02	39.05	47.17	35	36.4	40.31	46.1	53.15
32	0.9	15.01	48.45	0.016	-1.758	5.228	5.244	9.819	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17.21	23.77	32.15	41.26	25.04	26.38	31.06	37.86	45.85	35.03	36	39.56	45.09	51.99
33	1.8	15.02	46.86	0.016	-1.758	5.883	5.922	8.505	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.47	22.55	30.76	39.79	25.17	25.9	30.14	36.68	44.53	35.12	35.64	38.83	44.1	50.82
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.64	6.848	7.247	16.07	25.76	35.63	15.69	15.87	21.39	29.38	38.32	25.4	25.52	29.27	35.53	43.22	35.28	35.36	38.16	43.15	49.67
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.08	8.011	6.178	14.57	24.21	34.06	16.22	15.4	20.28	28.02	36.87	25.73	25.22	28.46	34.41	41.93	35.51	35.14	37.54	42.23	48.55
36	4.5	15.1	42.11	0.055	-1.766	5.334	9.395	5.521	13.14	22.69	32.51	9.287	5.334	13.06	22.65	32.48	16.86	15.05	19.2	26.66	35.4	26.12	24.99	27.69	33.3	40.63	35.78	34.96	36.94	41.31	47.42
37	5.4	15.15	40.52	0.055	-1.766	4.877	10.79	5.177	11.71	21.16	30.95	10.65	4.877	11.58	21.09	30.9	17.62	14.86	18.2	25.33	33.94	26.6	24.85	26.98	32.23	39.36	36.11	34.85	36.4	40.44	46.32
38	6.3	15.2	38.93	0.055	-1.766	4.917	12.23	5.309	10.34	19.63	29.4	12.06	4.917	10.14	19.53	29.33	18.48	14.84	17.29	24.03	32.5	27.16	24.82	26.36	31.2	38.11	36.52	34.82	35.93	39.62	45.26
39	7.2	15.25	37.34	0.055	-1.766	5.442	13.7	5.884	9.027	18.12	27.84	13.52	5.442	8.745	17.98	27.75	19.44	14.99	16.48	22.77	31.07	27.8	24.89	25.82	30.22	36.88	36.98	34.85	35.52	38.84	44.22
40	8.1	15.3	35.75	0.055	-1.766	6.334	15.2	6.791	7.823	16.62	26.29	15	6.334	7.429	16.44	26.18	20.47	15.3	15.79	21.55	29.65	28.51	25.06	25.36	29.3	35.68	37.51	34.96	35.17	38.11	43.21
41	9	15.35	34.16	0.174	-1.771	6.243	16.71	7.916	6.78	15.14	24.75	16.5	7.462	6.243	14.91	24.61	21.57	15.77	15.23	20.38	28.26	29.3	25.33	25	28.43	34.52	38.1	35.14	34.9	37.43	42.24
42	9.9	15.51	32.57	0.174	-1.771	5.177	18.28	9.247	6.077	13.72	23.23	18	8.682	5.177	13.35	23.01	22.67	16.29	14.72	19.19	26.82	30.06	25.6	24.63	27.53	33.31	38.65	35.28	34.59	36.71	41.22
43	10.8	15.66	30.98	0.174	-1.771	4.445	19.85	10.65	5.747	12.35	21.73	19.51	10.01	4.445	11.8	21.42	23.82	16.94	14.37	18.06	25.41	30.89	25.96	24.36	26.7	32.13	39.25	35.5	34.35	36.05	40.24
44	11.7	15.82	29.38	0.174	-1.771	4.225	21.42	12.11	5.853	11.04	20.24	21.04	11.41	4.225	10.27	19.83	25.02	17.71	14.19	17	24.02	31.78	26.41	24.19	25.94	30.99	39.92	35.79	34.19	35.44	39.29
45	12.6	15.98	27.79	0.174	-1.771	4.59	23	13.59	6.373	9.818	18.77	22.57	12.86	4.59	8.767	18.24	26.27	18.59	14.2	16.04	22.65	32.72	26.95	24.12	25.25	29.89	40.63	36.15	34.09	34.9	38.39

=INDEX($F$5:$J$9,G25,G24)

=SQRT(($B31-G$26)^2+($C31-G$27)^2)

=INDEX($G$28:$AE$28,1,MATCH($F31,$G$31:$AE$31,0))

Segment #2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
46	13.5	16.13	26.2	0.174	-1.771	5.424	24.58	15.11	7.218	8.718	17.32	24.12	14.34	5.424	7.303	16.65	27.55	19.57	14.38	15.19	21.32	33.71	27.57	24.17	24.66	28.84	41.4	36.57	34.08	34.43	37.54
47	14.4	16.29	24.6	0.555	-1.677	5.911	26.17	16.63	8.289	7.794	15.9	25.67	15.84	6.55	5.911	15.07	28.86	20.62	14.73	14.46	20.03	34.74	28.27	24.32	24.15	27.85	42.21	37.06	34.14	34.02	36.74
48	15.3	16.79	23.09	0.555	-1.677	4.457	27.75	18.22	9.686	7.461	14.75	27.1	17.21	7.617	4.457	13.48	29.98	21.46	14.91	13.57	18.6	35.53	28.72	24.22	23.42	26.65	42.74	37.27	33.92	33.35	35.7
49	16.2	17.29	21.58	0.555	-1.677	3.139	29.34	19.81	11.13	7.459	13.69	28.55	18.62	8.843	3.139	11.9	31.13	22.38	15.25	12.81	17.2	36.38	29.24	24.22	22.77	25.49	43.33	37.54	33.78	32.75	34.7
50	17.1	17.79	20.07	0.555	-1.677	2.213	30.92	21.39	12.62	7.789	12.73	30.01	20.05	10.17	2.213	10.31	32.32	23.37	15.74	12.21	15.83	37.27	29.84	24.33	22.21	24.39	43.97	37.88	33.71	32.21	33.75
51	18	18.29	18.56	0.555	-1.677	2.235	32.51	22.98	14.12	8.411	11.92	31.48	21.5	11.56	2.235	8.734	33.55	24.43	16.37	11.8	14.51	38.21	30.51	24.54	21.76	23.34	44.65	38.28	33.71	31.74	32.85
52	18.9	18.79	17.05	0.555	-1.677	3.185	34.1	24.57	15.65	9.267	11.27	32.97	22.98	13	3.185	7.158	34.8	25.54	17.13	11.59	13.25	39.18	31.25	24.85	21.42	22.36	45.38	38.74	33.79	31.35	32
53	19.8	19.29	15.55	0.555	-1.677	4.511	35.68	26.16	17.18	10.3	10.82	34.46	24.47	14.47	4.511	5.591	36.08	26.7	17.99	11.6	12.06	40.2	32.05	25.26	21.19	21.44	46.16	39.26	33.95	31.04	31.21
54	20.7	19.79	14.04	1.814	-0.792	4.042	37.27	27.75	18.72	11.46	10.59	35.96	25.96	15.97	5.968	4.042	37.39	27.9	18.95	11.83	10.98	41.26	32.91	25.76	21.08	20.61	46.97	39.84	34.17	30.8	30.48
55	21.6	21.42	13.32	1.814	-0.792	3.613	38.41	29.02	20.21	13.23	11.89	36.7	26.71	16.74	6.826	3.613	37.67	28.02	18.76	10.87	9.203	41.12	32.51	24.97	19.74	18.88	46.5	39.1	33.09	29.35	28.77
56	22.5	23.05	12.61	1.814	-0.792	4.016	39.6	30.34	21.74	15	13.31	37.51	27.56	17.65	7.994	4.016	38.03	28.26	18.73	10.14	7.423	41.05	32.21	24.28	18.49	17.15	46.09	38.42	32.07	27.94	27.08
57	23.4	24.68	11.9	1.814	-0.792	5.054	40.83	31.71	23.31	16.77	14.81	38.39	28.49	18.7	9.358	5.054	38.47	28.6	18.87	9.69	5.645	41.07	32	23.71	17.33	15.43	45.75	37.82	31.12	26.58	25.39
58	24.3	26.32	11.19	2E-13	-6.147	3.87	42.1	33.11	24.9	18.55	16.36	39.33	29.5	19.85	10.84	6.427	38.99	29.05	19.17	9.553	3.87	41.16	31.9	23.26	16.28	13.73	45.47	37.3	30.25	25.27	23.71
59	25.2	26.32	5.653	2E-13	-6.147	5.698	47.25	38.03	29.31	21.73	16.89	44.79	34.92	25.15	15.68	7.668	44.5	34.54	24.62	14.81	5.698	46.41	36.97	27.93	19.83	14.36	50.27	41.72	33.97	27.69	24.08
60	26.1	26.32	0.121	2E-13	-6.147	10.54	52.48	43.09	34.04	25.72	19.07	50.28	40.38	30.54	20.86	11.73	50.02	40.05	30.11	20.22	10.54	51.72	42.16	32.86	24.13	16.88	55.22	46.38	38.13	30.92	25.66
61	27	26.32	-5.412	2E-13	-6.147	15.85	57.76	48.25	38.99	30.2	22.44	55.77	45.85	35.97	26.19	16.66	55.53	45.56	35.6	25.68	15.85	57.08	47.43	37.96	28.86	20.61	60.26	51.22	42.6	34.74	28.26
62	27.9	26.32	-10.94	2E-13	-6.147	21.27	63.09	53.49	44.08	34.98	26.55	61.27	51.33	41.43	31.58	21.88	61.06	51.08	41.11	31.16	21.27	62.46	52.75	43.17	33.83	25.02	65.38	56.18	47.3	38.97	31.62
63																															
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69	Particle #2																														
70	t	xp	yp	up	vp	Min Dis	Distance Table from Particle to Cell Centers																								
71	0	30	50	8E-14	-1.783	0	20	22.36	28.28	36.06	44.72	10	14.14	22.36	31.62	41.23	0	10	20	30	40	10	14.14	22.36	31.62	41.23	20	22.36	28.28	36.06	44.72
72	0.9	30	48.4	8E-14	-1.783	1.604	20.06	21.69	27.17	34.73	43.29	10.13	13.06	20.94	30.11	39.68	1.604	8.396	18.4	28.4	38.4	10.13	13.06	20.94	30.11	39.68	20.06	21.69	27.17	34.73	43.29
73	1.8	30	46.79	8E-14	-1.783	3.209	20.26	21.12	26.11	33.43	41.88	10.5	12.09	19.54	28.6	38.13	3.209	6.791	16.79	26.79	36.79	10.5	12.09	19.54	28.6	38.13	20.26	21.12	26.11	33.43	41.88
74	2.7	30	45.19	8E-14	-1.783	4.813	20.57	20.66	25.11	32.16	40.47	11.1	11.27	18.18	27.1	36.58	4.813	5.187	15.19	25.19	35.19	11.1	11.27	18.18	27.1	36.58	20.57	20.66	25.11	32.16	40.47
75	3.6	30	43.58	2E-13	-1.846	3.583	21	20.32	24.18	30.92	39.09	11.88	10.62	16.87	25.62	35.04	6.417	3.583	13.58	23.58	33.58	11.88	10.62	16.87	25.62	35.04	21	20.32	24.18	30.92	39.09
76	4.5	30	41.92	2E-13	-1.846	1.921	21.57	20.09	23.28	29.67	37.67	12.86	10.18	15.56	24.09	33.45	8.079	1.921	11.92	21.92	31.92	12.86	10.18	15.56	24.09	33.45	21.57	20.09	23.28	29.67	37.67
77	5.4	30	40.26	2E-13	-1.846	0.26	22.25	20	22.48	28.47	36.27	13.96	10	14.33	22.59	31.87	9.74	0.26	10.26	20.26	30.26	13.96	10	14.33	22.59	31.87	22.25	20	22.48	28.47	36.27
78	6.3	30	38.6	2E-13	-1.846	1.402	23.02	20.05	21.77	27.31	34.9	15.17	10.1	13.19	21.12	30.3	11.4	1.402	8.598	18.6	28.6	15.17	10.1	13.19	21.12	30.3	23.02	20.05	21.77	27.31	34.9
79	7.2	30	36.94	2E-13	-1.846	3.063	23.89	20.23	21.17	26.21	33.55	16.45	10.46	12.17	19.67	28.73	13.06	3.063	6.937	16.94	26.94	16.45	10.46	12.17	19.67	28.73	23.89	20.23	21.17	26.21	33.55
80	8.1	30	35.28	2E-13	-1.846	4.725	24.84	20.55	20.68	25.17	32.23	17.8	11.06	11.31	18.26	27.18	14.72	4.725	5.275	15.28	25.28	17.8	11.06	11.31	18.26	27.18	24.84	20.55	20.68	25.17	32.23
81	9	30	33.61	2E-13	-2.07	3.614	25.86	20.99	20.32	24.19	30.95	19.2	11.87	10.63	16.89	25.64	16.39	6.386	3.614	13.61	23.61	19.2	11.87	10.63	16.89	25.64	25.86	20.99	20.32	24.19	30.95
82	9.9	30	31.75	2E-13	-2.07	1.751	27.07	21.63	20.08	23.2	29.55	20.81	12.96	10.15	15.43	23.94	18.25	8.249	1.751	11.75	21.75	20.81	12.96	10.15	15.43	23.94	27.07	21.63	20.08	23.2	29.55
83	10.8	30	29.89	2E-13	-2.07	0.112	28.36	22.41	20	22.31	28.2	22.46	14.22	10	14.06	22.26	20.11	10.11	0.112	9.888	19.89	22.46	14.22	10	14.06	22.26	28.36	22.41	20	22.31	28.2
84	11.7	30	28.02	2E-13	-2.07	1.976	29.71	23.31	20.1	21.55	26.92	24.14	15.6	10.19	12.82	20.61	21.98	11.98	1.976	8.024	18.02	24.14	15.6	10.19	12.82	20.61	29.71	23.31	20.1	21.55	26.92
85	12.6	30	26.16	2E-13	-2.07	3.839	31.12	24.32	20.37	20.93	25.71	25.85	17.07	10.71	11.75	19	23.84	13.84	3.839	6.161	16.16	25.85	17.07	10.71	11.75	19	31.12	24.32	20.37	20.93	25.71
86	13.5	30	24.3	2E-13	-2.893	4.298	32.57	25.43	20.8	20.46	24.59	27.58	18.62	11.51	10.88	17.45	25.7	15.7	5.702	4.298	14.3	27.58	18.62	11.51	10.88	17.45	32.57	25.43	20.8	20.46	24.59
87	14.4	30	21.69	2E-13	-2.893	1.695	34.66	27.11	21.66	20.07	23.17	30.02	20.86	13	10.14	15.39	28.31	18.31	8.305	1.695	11.69	30.02	20.86	13	10.14	15.39	34.66	27.11	21.66	20.07	23.17
88	15.3	30	19.09	2E-13	-2.893	0.909	36.82	28.93	22.78	20.02	21.97	32.49	23.18	14.8	10.04	13.51	30.91	20.91	10.91	0.909	9.091	32.49	23.18	14.8	10.04	13.51	36.82	28.93	22.78	20.02	21.97
89	16.2	30	16.49	2E-13	-2.893	3.513	39.03	30.87	24.14	20.31	21.03	34.97	25.55	16.81	10.6	11.92	33.51	23.51	13.51	3.513	6.487	34.97	25.55	16.81	10.6	11.92	39.03	30.87	24.14	20.31	21.03
90	17.1	30	13.88	2E-13	-6.147	3.884	41.28	32.89	25.69	20.91	20.37	37.48	27.97	18.97	11.72	10.73	36.12	26.12	16.12	6.116	3.884	37.48	27.97	18.97	11.72	10.73	41.28	32.89	25.69	20.91	20.37

Segment #3

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
91	18	30	8.351	2E-13	-6.147	1.649	46.2	37.44	29.47	23.15	20.07	42.83	33.19	23.85	15.35	10.14	41.65	31.65	21.65	11.65	1.649	42.83	33.19	23.85	15.35	10.14	46.2	37.44	29.47	23.15	20.07
92	18.9	30	2.819	2E-13	-6.147	7.181	51.25	42.22	33.75	26.37	21.25	48.23	38.5	28.96	19.88	12.31	47.18	37.18	27.18	17.18	7.181	48.23	38.5	28.96	19.88	12.31	51.25	42.22	33.75	26.37	21.25
93	19.8	30	-2.714	2E-13	-6.147	12.71	56.38	47.16	38.34	30.26	23.7	53.65	43.87	34.21	24.82	16.18	52.71	42.71	32.71	22.71	12.71	53.65	43.87	34.21	24.82	16.18	56.38	47.16	38.34	30.26	23.7
94	20.7	30	-8.246	2E-13	-6.147	18.25	61.58	52.23	43.16	34.61	27.07	59.1	49.27	39.53	29.96	20.81	58.25	48.25	38.25	28.25	18.25	59.1	49.27	39.53	29.96	20.81	61.58	52.23	43.16	34.61	27.07
95	21.6	30	-13.78	2E-13	-6.147	23.78	66.84	57.38	48.13	39.26	31.07	64.56	54.7	44.91	35.23	25.8	63.78	53.78	43.78	33.78	23.78	64.56	54.7	44.91	35.23	25.8	66.84	57.38	48.13	39.26	31.07
96	22.5	30	-19.31	2E-13	-6.147	29.31	72.14	62.59	53.21	44.11	35.48	70.03	60.15	50.31	40.56	30.97	69.31	59.31	49.31	39.31	29.31	70.03	60.15	50.31	40.56	30.97	72.14	62.59	53.21	44.11	35.48
97	23.4	30	-24.84	2E-13	-6.147	34.84	77.47	67.86	58.38	49.1	40.18	75.51	65.61	55.75	45.95	36.25	74.84	64.84	54.84	44.84	34.84	75.51	65.61	55.75	45.95	36.25	77.47	67.86	58.38	49.1	40.18
98	24.3	30	-30.38	2E-13	-6.147	40.38	82.83	73.16	63.6	54.2	45.06	81	71.08	61.2	51.36	41.6	80.38	70.38	60.38	50.38	40.38	81	71.08	61.2	51.36	41.6	82.83	73.16	63.6	54.2	45.06
99	25.2	30	-35.91	2E-13	-6.147	45.91	88.21	78.5	68.88	59.38	50.08	86.49	76.56	66.66	56.8	46.99	85.91	75.91	65.91	55.91	45.91	86.49	76.56	66.66	56.8	46.99	88.21	78.5	68.88	59.38	50.08
100	26.1	30	-41.44	2E-13	-6.147	51.44	93.6	83.86	74.19	64.61	55.19	91.99	82.05	72.14	62.25	52.4	91.44	81.44	71.44	61.44	51.44	91.99	82.05	72.14	62.25	52.4	93.6	83.86	74.19	64.61	55.19
101	27	30	-46.97	2E-13	-6.147	56.97	99.01	89.24	79.53	69.9	60.38	97.49	87.55	77.62	67.72	57.84	96.97	86.97	76.97	66.97	56.97	97.49	87.55	77.62	67.72	57.84	99.01	89.24	79.53	69.9	60.38
102	27.9	30	-52.51	2E-13	-6.147	62.51	104.4	94.64	84.9	75.21	65.63	103	93.04	83.11	73.19	63.3	102.5	92.51	82.51	72.51	62.51	103	93.04	83.11	73.19	63.3	104.4	94.64	84.9	75.21	65.63
103																															
104																															
105																															
106																															
107																															
108																															
109	Particle #3																														
110	t	xp	yp	up	vp	Min Dis	Distance Table from Particle to Cell Centers																								
111	0	45	50	-0.016	-1.758	5	35	36.4	40.31	46.1	53.15	25	26.93	32.02	39.05	47.17	15	18.03	25	33.54	42.72	5	11.18	20.62	30.41	40.31	5	11.18	20.62	30.41	40.31
112	0.9	44.99	48.42	-0.016	-1.758	5.23	35.02	35.98	39.54	45.07	51.96	25.04	26.37	31.04	37.84	45.83	15.07	17.19	23.74	32.13	41.24	5.23	9.784	19.08	28.85	38.74	5.258	9.798	19.09	28.86	38.74
113	1.8	44.97	46.84	-0.016	-1.758	5.893	35.11	35.63	38.81	44.08	50.79	25.17	25.89	30.12	36.66	44.5	15.3	16.46	22.53	30.73	39.76	5.893	8.452	17.55	27.29	37.17	5.942	8.487	17.57	27.3	37.18
114	2.7	44.96	45.25	-0.016	-1.758	6.862	35.28	35.35	38.14	43.12	49.65	25.4	25.5	29.25	35.5	43.19	15.69	15.85	21.36	29.35	38.3	6.862	7.223	16.04	25.74	35.6	6.925	7.283	16.07	25.75	35.61
115	3.6	44.94	43.67	-0.055	-1.766	6.157	35.51	35.13	37.52	42.21	48.53	25.73	25.21	28.44	34.39	41.9	16.23	15.39	20.25	27.99	36.84	8.029	6.157	14.54	24.18	34.03	8.101	6.25	14.58	24.21	34.05
116	4.5	44.89	42.08	-0.055	-1.766	5.317	35.78	34.95	36.93	41.29	47.4	26.12	24.98	27.67	33.28	40.61	16.87	15.04	19.18	26.64	35.37	9.307	5.317	13.04	22.62	32.45	9.422	5.516	13.12	22.67	32.49
117	5.4	44.84	40.49	-0.055	-1.766	4.868	36.12	34.85	36.39	40.42	46.3	26.6	24.85	26.97	32.2	39.33	17.63	14.85	18.18	25.3	33.91	10.67	4.868	11.56	21.06	30.88	10.82	5.181	11.69	21.13	30.93
118	6.3	44.79	38.9	-0.055	-1.766	4.917	36.52	34.81	35.91	39.6	45.23	27.16	24.82	26.34	31.18	38.08	18.49	14.83	17.27	24	32.47	12.09	4.917	10.11	19.5	29.3	12.26	5.321	10.32	19.61	29.37
119	7.2	44.74	37.32	-0.055	-1.766	5.45	36.99	34.85	35.51	38.82	44.2	27.81	24.89	25.8	30.2	36.86	19.45	14.99	16.46	22.74	31.04	13.54	5.45	8.719	17.95	27.72	13.73	5.902	9.008	18.1	27.82
120	8.1	44.69	35.73	-0.055	-1.766	6.348	37.52	34.96	35.16	38.09	43.19	28.52	25.06	25.35	29.28	35.66	20.49	15.3	15.77	21.52	29.63	15.03	6.348	7.404	16.41	26.15	15.23	6.813	7.807	16.6	26.27
121	9	44.64	34.14	-0.174	-1.771	6.22	38.1	35.14	34.89	37.42	42.22	29.31	25.33	24.99	28.41	34.5	21.59	15.77	15.22	20.35	28.23	16.53	7.479	6.22	14.88	24.58	16.74	7.941	6.768	15.12	24.72
122	9.9	44.49	32.54	-0.174	-1.771	5.158	38.65	35.28	34.58	36.7	41.2	30.07	25.6	24.62	27.51	33.28	22.68	16.29	14.71	19.16	26.8	18.02	8.702	5.158	13.32	22.99	18.31	9.273	6.071	13.7	23.21
123	10.8	44.33	30.95	-0.174	-1.771	4.433	39.26	35.5	34.34	36.03	40.22	30.9	25.96	24.35	26.68	32.11	23.84	16.95	14.36	18.04	25.38	19.54	10.03	4.433	11.78	21.39	19.88	10.68	5.748	12.33	21.7
124	11.7	44.17	29.36	-0.174	-1.771	4.223	39.93	35.79	34.18	35.43	39.27	31.79	26.41	24.18	25.92	30.97	25.04	17.73	14.19	16.98	23.99	21.06	11.43	4.223	10.24	19.8	21.45	12.13	5.862	11.02	20.21
125	12.6	44.02	27.76	-0.174	-1.771	4.598	40.64	36.15	34.09	34.89	38.38	32.73	26.96	24.12	25.24	29.87	26.29	18.61	14.19	16.02	22.63	22.6	12.88	4.598	8.74	18.21	23.03	13.62	6.388	9.801	18.74
126	13.5	43.86	26.17	-0.174	-1.771	5.439	41.41	36.58	34.08	34.42	37.52	33.72	27.58	24.17	24.64	28.82	27.57	19.58	14.38	15.17	21.3	24.14	14.36	5.439	7.277	16.62	24.61	15.13	7.237	8.703	17.3
127	14.4	43.7	24.57	-0.555	-1.677	5.886	42.22	37.07	34.14	34.01	36.72	34.76	28.28	24.32	24.14	27.83	28.88	20.63	14.74	14.45	20.01	25.69	15.86	6.569	5.886	15.04	26.19	16.66	8.312	7.783	15.88
128	15.3	43.2	23.07	-0.555	-1.677	4.434	42.75	37.27	33.92	33.35	35.68	35.55	28.73	24.22	23.41	26.63	30	21.47	14.91	13.56	18.58	27.12	17.24	7.639	4.434	13.45	27.78	18.25	9.71	7.455	14.73
129	16.2	42.7	21.56	-0.555	-1.677	3.12	43.34	37.55	33.78	32.74	34.69	36.39	29.25	24.22	22.76	25.48	31.15	22.4	15.25	12.8	17.17	28.57	18.64	8.867	3.12	11.87	29.36	19.83	11.16	7.459	13.67
130	17.1	42.21	20.05	-0.555	-1.677	2.206	43.98	37.89	33.71	32.21	33.74	37.29	29.85	24.33	22.21	24.37	32.34	23.39	15.75	12.21	15.81	30.03	20.08	10.19	2.206	10.29	30.95	21.42	12.64	7.795	12.72
131	18	41.71	18.54	-0.555	-1.677	2.248	44.67	38.29	33.71	31.74	32.84	38.22	30.53	24.55	21.76	23.32	33.57	24.45	16.38	11.8	14.49	31.51	21.53	11.59	2.248	8.706	32.54	23.01	14.15	8.422	11.9
132	18.9	41.21	17.03	-0.555	-1.677	3.208	45.4	38.75	33.8	31.35	31.99	39.2	31.26	24.86	21.41	22.34	34.82	25.56	17.14	11.59	13.23	32.99	23	13.03	3.208	7.13	34.12	24.6	15.67	9.282	11.26
133	19.8	40.71	15.52	-0.555	-1.677	4.537	46.17	39.27	33.95	31.03	31.2	40.22	32.07	25.27	21.19	21.43	36.11	26.72	18.01	11.61	12.05	34.49	24.49	14.5	4.537	5.563	35.71	26.19	17.21	10.32	10.81
134	20.7	40.21	14.01	-1.814	-0.792	4.014	46.99	39.85	34.18	30.8	30.47	41.28	32.92	25.77	21.08	20.6	37.41	27.92	18.97	11.84	10.97	35.99	25.99	15.99	5.995	4.014	37.3	27.77	18.75	11.48	10.58
135	21.6	38.58	13.3	-1.814	-0.792	3.591	46.52	39.11	33.1	29.35	28.77	41.14	32.53	24.98	19.75	18.87	37.69	28.05	18.78	10.89	9.187	36.73	26.74	16.76	6.854	3.591	38.44	29.05	20.24	13.25	11.89

Summary

- Particle tracking is a tool to determine the position of a fluid particle in a flow field.
- A two-step approach is required:
  - Determine particle velocity
    - Locate the particle relative to known velocity locations.
    - Assign the velocity to the particle based on an interpolation scheme.
  - Move the particle.
- All particle tracking programs use this type of two-step logic.