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1. DENSITY AND VISCOSITY OF FRESH WATER AND SEA WATER

1.1 Formulae Used by 1978 ITTC Performance Prediction Method:

Density of fresh water

$$\rho = 1000 \text{ kg / m}^3$$

Viscosity of fresh water:

$$\nu_0 = ((0.585 \cdot 10^{-3} \cdot (T - 12.0) - 0.03361) \cdot (T - 12.0) + 1.2350) \cdot 10^{-6}$$

Density of sea water

$$\rho = 1025 \text{ kg / m}^3$$

Viscosity of sea water:

$$\nu_s = ((0.659 \cdot 10^{-3} \cdot (T - 1.0) - 0.05076) \cdot (T - 1.0) + 1.7688) \cdot 10^{-6}$$


With T water temperature in °C.

1.2 Formula Given in 1963:

Formula by Hardy for viscosity of salt water

$$\mu_s = \frac{K}{1 + 0.03338T + 0.00018325T^2} \cdot \mu_0 \quad \text{Where}$$

$K = 1.052$, μ_s is the viscosity of seawater at $T^\circ \text{C}$ and $\mu_0 = 0.01787$ poise that of fresh water at 0°C

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1.3 Tables Given In 1963

TABLE 1

Values of Mass Density for Fresh Water

Temperature in degrees Centigrade

$$\rho \text{ in metric units of } \frac{\text{kg} \cdot \text{s}^2}{\text{m}^4}$$

| °C | ρ | °C | ρ |
|----|--------|----|--------|
| 0 | 101.95 | 16 | 101.86 |
| 1 | 101.95 | 17 | 101.84 |
| 2 | 101.96 | 18 | 101.82 |
| 3 | 101.96 | 19 | 101.80 |
| 4 | 101.96 | 20 | 101.78 |
| 5 | 101.96 | 21 | 101.76 |
| 6 | 101.96 | 22 | 101.74 |
| 7 | 101.95 | 23 | 101.71 |
| 8 | 101.95 | 24 | 101.69 |
| 9 | 101.94 | 25 | 101.66 |
| 10 | 101.93 | 26 | 101.64 |
| 11 | 101.92 | 27 | 101.61 |
| 12 | 101.91 | 28 | 101.58 |
| 13 | 101.90 | 29 | 101.55 |
| 14 | 101.88 | 30 | 101.52 |
| 15 | 101.87 | | |


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TABLE 2

Values of Mass Density for Salt Water

Temperature in degrees Centigrade

ρ in metric units of $\frac{kgs^2}{m^4}$

Salinity 3.5%

| $^{\circ}C$ | ρ | $^{\circ}C$ | ρ |
|-------------|--------|-------------|--------|
| 0 | 104.83 | 16 | 104.59 |
| 1 | 104.82 | 17 | 104.56 |
| 2 | 104.81 | 18 | 104.54 |
| 3 | 104.81 | 19 | 104.52 |
| 4 | 104.80 | 20 | 104.49 |
| 5 | 104.79 | 21 | 104.46 |
| 6 | 104.77 | 22 | 104.43 |
| 7 | 104.76 | 23 | 104.40 |
| 8 | 104.74 | 24 | 104.37 |
| 9 | 104.73 | 25 | 104.34 |
| 10 | 104.71 | 26 | 104.31 |
| 11 | 104.69 | 27 | 104.28 |
| 12 | 104.68 | 28 | 104.24 |
| 13 | 104.65 | 29 | 104.21 |
| 14 | 104.63 | 30 | 104.18 |
| 15 | 104.61 | | |


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TABLE 3

Values of Kinematic Viscosity for Fresh Water

Temperature in degrees Centigrade

ν in metric units of $\frac{m^2}{s} 10^6$

| °C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|-----|----------|---------|---------|---------|---------|---------|---------|---------|---------|----------|
| 0. | 1.78661 | 1.18056 | 1.77450 | 1.76846 | 1.76246 | 1.75648 | 1.75054 | 1.74461 | 1.73871 | 1.73285 |
| 1. | 1.72701 | 1.72121 | 1.71545 | 1.70972 | 1.70403 | 1.69836 | 1.69272 | 68710 | 1.68151 | 1.67594 |
| 2. | 1.67040 | 1.66489 | 1.65940 | 1.65396 | 1.64855 | 1.64316 | 1.63780 | 1.63247 | 1.62717 | 1.62190 |
| 3. | 1.61665 | 1.61142 | 1.60622 | 1.60105 | 1.59591 | 1.59079 | 1.58570 | 1.58063 | 1.57558 | 1.57057 |
| 4. | 1.56557 | 1.56060 | 1.55566 | 1.55074 | 1.54585 | 1.54098 | 1.53613 | 1.53131 | 1.52651 | 1.52173 |
| 5. | 1.51698 | 1.51225 | 1.50754 | 1.50286 | 1.49820 | 1.49356 | 1.48894 | 1.48435 | 1.47978 | 1.47523 |
| 6. | 1.47070 | 1.46619 | 1.46172 | 1.45727 | 1.45285 | 1.44844 | 1.44405 | 1.43968 | 1.43533 | 1.43099 |
| 7. | 1.42667 | 1.42238 | 1.41810 | 1.41386 | 1.40964 | 1.40543 | 1.40125 | 1.39709 | 1.39294 | 1.38882 |
| 8. | 1.38471 | 1.38063 | 1.37656 | 1.37251 | 1.36848 | 1.36445 | 1.36045 | 1.35646 | 1.35249 | 1.34855 |
| 9. | 1.34463 | 1.34073 | 1.33684 | 1.33298 | 1.32913 | 1.32530 | 1.32149 | 1.31769 | 1.31391 | 1.31015 |
| 10. | 1.30641 | 1.30268 | 1.29897 | 1.29528 | 1.29160 | 1.28794 | 1.28430 | 1.28067 | 1.27706 | 1.27346 |
| 11. | 1.26988 | 1.26612 | 1.26277 | 1.25924 | 1.25573 | 1.25223 | 1.24874 | 1.24527 | 1.24182 | 1.23838 |
| 12. | 1.23495 | 1.23154 | 1.22815 | 1.22478 | 1.22143 | 1.21809 | 1.21477 | 1.21146 | 1.20816 | 1.20487 |
| 13. | 1.20159 | 1.19832 | 1.19508 | 1.19184 | 1.18863 | 1.18543 | 1.18225 | 1.7908 | 1.17592 | 1.17278 |
| 14. | 1.16964 | 1.16651 | 1.16340 | 1.16030 | 1.15721 | 1.15414 | 1.15109 | 1.14806 | 1.14503 | 1.14202 |
| 15. | 1.13902 | 1.13603 | 1.13304 | 1.13007 | 1.12711 | 1.12417 | 1.12124 | 1.11832 | 1.11542 | 1.11254 |
| 16. | 1.10966 | 1.10680 | 1.10395 | 1.10110 | 1.09828 | 1.09546 | 1.09265 | 1.08986 | 1.08708 | 1.08431 |
| 17. | 1.08155 | 1.01880 | 1.07606 | 1.07334 | 1.07062 | 1.06792 | 1.06523 | 1.06254 | 1.05987 | 1.05721 |
| 18. | 1.05456 | 1.05193 | 1.04930 | 1.04668 | 1.04407 | 1.04148 | 1.03889 | 1.03631 | 1.03315 | 1.03119 |
| 19. | 1.02865 | 1.02611 | 1.02359 | 1.02107 | 1.01857 | 1.01607 | 1.01359 | 1.01111 | 1.00865 | 1.00619 |
| 20. | 1.00374 | 1.00131 | 0.99888 | 0.99646 | 0.99405 | 0.99165 | 0.98927 | 0.98690 | 0.98454 | 0.98218 |
| 21. | 0.97984 | 0.97750 | 0.97517 | 0.97285 | 0.97053 | 0.96822 | 0.96592 | 0.96363 | 0.96135 | 0.95908 |
| 22. | 0.95682 | 0.95456 | 0.95231 | 0.95008 | 0.94786 | 0.94565 | 0.94345 | 0.94125 | 0.93906 | 0.93688 |
| 23. | 0.93471 | 0.93255 | 0.93040 | 0.92825 | 0.92611 | 0.92397 | 0.92184 | 0.91971 | 0.91760 | 0.915149 |
| 24. | 0.91340 | 0.91132 | 0.90924 | 0.90718 | 0.90512 | 0.90306 | 0.90102 | 0.89898 | 0.89695 | 0.89493 |
| 25. | 0.89292 | 0.89090 | 0.88889 | 0.88689 | 0.88490 | 0.88291 | 0.88094 | 0.87697 | 0.87702 | 0.87507 |
| 26. | 0.87313 | 0.87119 | 0.86926 | 0.86734 | 0.86543 | 0.86352 | 0.86162 | 0.85973 | 0.85784 | 0.85596 |
| 27. | 0.854091 | 0.85222 | 0.85036 | 0.84851 | 0.84666 | 0.84482 | 0.84298 | 0.84116 | 0.83934 | 0.83752 |
| 28. | 0.83572 | 0.83391 | 0.83212 | 0.83033 | 0.82855 | 0.82677 | 0.82500 | 0.82324 | 0.82148 | 0.81973 |
| 29. | 0.81798 | 0.81625 | 0.81451 | 0.81279 | 0.81106 | 0.80935 | 0.80765 | 0.80596 | 0.80427 | 0.80258 |
| 30. | 0.80091 | 0.79923 | 0.79755 | 0.79588 | 0.79422 | 0.79256 | 0.79090 | 0.78924 | 0.78757 | 0.78592 |


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TABLE 4

Values of Kinematic Viscosity for Salt Water

Temperature in degrees Centigrade

ν in metric units of $\frac{m^2}{s} 10^6$

Salinity 3.5%

| °C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0. | 1.82844 | 1.82237 | 1.81633 | 1.81055 | 1.80436 | 1.79842 | 1.79251 | 1.78662 | 1.78077 | 1.77494 |
| 1. | 1.76915 | 1.76339 | 1.75767 | 1.75199 | 1.74634 | 1.74072 | 1.73513 | 1.72956 | 1.72403 | 1.71853 |
| 2. | 1.71306 | 1.70761 | 1.70220 | 1.69681 | 1.69145 | 1.68612 | 1.68082 | 1.67554 | 1.67030 | 1.66508 |
| 3. | 1.65988 | 1.65472 | 1.64958 | 1.64446 | 1.63938 | 1.53432 | 1.62928 | 1.62427 | 1.61929 | 1.61433 |
| 4. | 1.60940 | 1.60449 | 1.59961 | 1.59475 | 1.58992 | 1.58511 | 1.58032 | 1.57556 | 1.57082 | 1.56611 |
| 5. | 1.56142 | 1.55676 | 1.55213 | 1.54752 | 1.54294 | 1.53838 | 1.53383 | 1.52930 | 1.52479 | 1.52030 |
| 6. | 1.51584 | 1.51139 | 1.50692 | 1.50259 | 1.49823 | 1.49388 | 1.48956 | 1.48525 | 1.48095 | 1.47667 |
| 7. | 1.47242 | 1.46818 | 1.46397 | 1.45918 | 1.45562 | 1.45147 | 1.44735 | 1.44325 | 1.43916 | 1.43508 |
| 8. | 1.43102 | 1.42698 | 1.42296 | 1.41895 | 1.41498 | 1.41102 | 1.40709 | 1.40317 | 1.39927 | 1.39539 |
| 9. | 1.39152 | 1.38767 | 1.38385 | 1.38003 | 1.37624 | 1.37246 | 1.36870 | 1.36496 | 1.36123 | 1.35752 |
| 10. | 1.35383 | 1.35014 | 1.34647 | 1.34281 | 1.33917 | 1.33555 | 1.33195 | 1.32837 | 1.32481 | 1.32126 |
| 11. | 1.31773 | 1.31421 | 1.31011 | 1.30722 | 1.30375 | 1.30030 | 1.29685 | 1.29343 | 1.29002 | 1.28662 |
| 12. | 1.28324 | 1.27987 | 1.27652 | 1.27319 | 1.26988 | 1.26658 | 1.26360 | 1.26003 | 1.25671 | 1.25352 |
| 13. | 1.25028 | 1.24705 | 1.24384 | 1.24064 | 1.23745 | 1.23428 | 1.23112 | 1.22798 | 1.22484 | 1.22172 |
| 14. | 1.21862 | 1.21552 | 1.21244 | 1.20938 | 1.20632 | 1.20328 | 1.20027 | 1.19726 | 1.19426 | 1.19128 |
| 15. | 1.18431 | 1.18534 | 1.18239 | 1.17944 | 1.17651 | 1.17359 | 1.11068 | 1.16778 | 1.16490 | 1.16202 |
| 16. | 1.15916 | 1.15631 | 1.15348 | 1.15066 | 1.14786 | 1.14506 | 1.14228 | 1.13951 | 1.13674 | 1.13399 |
| 17. | 1.13125 | 1.12852 | 1.12581 | 1.12309 | 1.12038 | 1.11769 | 1.11500 | 1.11232 | 1.10966 | 1.10702 |
| 18. | 1.10438 | 1.10176 | 1.09914 | 1.09654 | 1.09394 | 1.09135 | 1.08876 | 1.09619 | 1.08363 | 1.08107 |
| 19. | 1.07854 | 1.07601 | 1.073b0 | 1.07099 | 1.06850 | 1.06601 | 1.06353 | 1.06106 | 1.05861 | 1.05616 |
| 20. | 1.05372 | 1.05129 | 1.04886 | 1.04645 | 1.04405 | 1.04165 | 1.03927 | 1.03699 | 1.03452 | 1.03216 |
| 21. | 1.02781 | 1.02747 | 1.02514 | 1.02281 | 1.02050 | 1.01819 | 1.01589 | 1.01360 | 1.01132 | 1.00904 |
| 22. | 1.0067 | 1.00452 | 1.00227 | 1.00003 | 0.99780 | 0.99557 | 0.99336 | 0.99115 | 0.98895 | 0.98676 |
| 23. | 0.98457 | 0.98239 | 0.98023 | 0.9780b | 0.97591 | 0.97376 | 0.97163 | 0.96950 | 0.96737 | 0.96526 |
| 24. | 0.96315 | 0.96105 | 0.95896 | 0.95687 | 0.95479 | 0.95272 | 0.95067 | 0.94862 | 0.94658 | 0.94455 |
| 25. | 0.94252 | 0.94049 | 0.93847 | 0.93646 | 0.93445 | 0.93245 | 0.93046 | 0.92847 | 0.92649 | 0.92452 |
| 26. | 0.92255 | 0.92059 | 0.91865 | 0.91671 | 0.91478 | 0.91286 | 0.91094 | 0.90903 | 0.90711 | 0.90521 |
| 27. | 0.90331 | 0.90141 | 0.89953 | 0.89765 | 0.89579 | 0.89393 | 0.89207 | 0.89023 | 0.88838 | 0.88654 |
| 28. | 0.88470 | 0.88287 | 0.88105 | 0.87923 | 0.87742 | 0.87562 | 0.87383 | 0.87205 | 0.87927 | 0.86849 |
| 29. | 0.86671 | 0.86494 | 0.86318 | 0.86142 | 0.85966 | 0.85792 | 0.85619 | 0.85446 | 0.85274 | 0.85102 |
| 30. | 0.84931 | 0.84159 | 0.84588 | 0.84418 | 0.84248 | 0.84079 | 0.83910 | 0.83739 | 0.83570 | 0.83400 |