Course #: NAME 324
Assignment # B.3: **Approximate Calculation of Ship Resistance**

Hotrop and Mennen's Method

The total resistance of a ship can be subdivided into:

$R_T=R_F(1+k_1)+R_{APP}+R_W+R_B+R_{TR}+R_A$
Where,

R_F	Frictional resistance according to the ITTC 1957 friction formula $= 0.5.\rho V^2SC_F$.
C_F	$= 0.075/(Log_{10}Re-2)^2$
Re	Reynold's No.= $\rho VL/\mu$
$1+k_1$	Form factor describing the viscous resistance of the hull form in relation to R_F
R_{APP}	Appendage resistance
R_W	Wave-making and wave-breaking resistance
R_B	Additional pressure resistance due to bulbous bow near the water surface
R_{TR}	Additional pressure resistance of immersed transom stern
R_A	Model-ship correlation resistance

The form factor of the hull can be predicted by:

$$1+k_1 = c_{13}\{0.93+c_{12}(B/L_R)^{0.92497}$$
$$(0.95-C_P)^{-0.521448}(1-C_P+0.0225\,lcb)^{0.6906}\}$$

In this formula, C_P is the prismatic coefficient based on the waterline length, L and lcb is the longitudinal centre of buoyancy forward of 0.5L as a percentage of L. Here, L_R is a parameter reflecting the length of the run according to:

$L_R/L=1-C_P+0.06C_Plcb(4C_P-1)$

$C_{12}=(T/L)^{0.2228446}$ if $T/L > 0.05$
$=48.20(T/L-0.02)^{2.078}+0.479948$ if $0.02<T/L<0.05$
$=0.479948$ if $T/L<0.02$

Where T is the average moulded draught.

$C_{13}=1+0.003C_{stern}$
C_{stern} will be -10, 0 and +10 if the afterbody form is of V-shaped, Normal and U shaped sections respectively.

The wetted area of the hull can be approximated by:

$$S = L(2T+B)\sqrt{C_M}\,(0.453+0.4425\,C_B$$
$$-0.2862\,C_M - 0.003467\;B/T + 0.3696\,C_{WP})$$
$$+2.38\,A_{BT}/C_B$$

where A_{BT} is the transverse sectional area of the bulb at the position where the still-water surface intersects the stem.

The appendage resistance can be determined from

$R_{APP}=0.5\rho V^2S_{APP}(1+k_2)_{eq}C_F$

Where S_{APP} the wetted area of the appendages, $1+k_2$ the appendage resistance factor

Approximate $1+k_2$ values

Rudder behind skeg	1.5~2.0
Rudder behind stern	1.3~1.5
Twin-screw balance rudders	2.8
Shaft brackets	3.0
Skeg	1.5~2.0
Strut bossings	3.0
Hull bossings	2.0
Shafts	2.0~4.0
Stabilizer fins	2.8
Dome	2.7
Bilge keels	1.4

The equivalent $1+k_2$ value for a combination of appendages is determined from:

$$(1+k_2)_{eq} = \frac{\sum(1+k_2)S_{APP}}{\sum S_{APP}}$$

The wave resistance is determined from:

$$R_W = c_1c_2c_5\nabla\rho g\exp\{m_1F_n^d + m_2\cos(\lambda F_n^{-2})\}$$

with

$$c_1 = 2223105c_7^{3.78613}(T/B)^{1.07961}(90-i_E)^{-1.37565}$$

$c_7 = 0.229577(B/L)^{0.33333}$ if $B/L<0.11$
$= B/L$ if $0.11<B/L<0.25$
$= 0.5-0.0625\;L/B$ if $B/L>0.25$

$$c_2 = \exp(-1.89\sqrt{c_3}$$

$c_5 = 1-0.48A_T/(BTC_M)$

$\lambda = 1.446C_P-0.03\;L/B$ if $L/B < 12$
$= 1.446C_P-0.36$ if $L/B>12$

$$m_1 = 0.0140407L/T - 1.75254\nabla^{1/3}/L - 4.79323B/L - c_{16}$$

$$c_{16} = 8.07981C_P - 13.8673C_P^2 + 6.984388C_P^3$$ if C_P<0.8

= *1.73014-0.7067*C_P *if* $C_P > 0.8$

$$m_2 = c_{15}C_P^2 \exp(-0.1F_n^{-2})$$

c_{15} = *-1.69385 for* $L^3/\nabla < 512$

= *0* *for* $L^3/\nabla > 1727$

=*-1.69385+*$(L/\nabla^{1/3}-8.0)/2.36$ *if* $512 < L^3/\nabla < 1727$

d=-0.9

$$i_E = 1 + 89\exp\{-(L/B)^{0.80856}(1-C_{WP})^{0.30484}(1-C_P-0.0225lcb)^{0.6367}(L_R/B)^{0.34574}(100\nabla/L^3)^{0.16302}\}$$

$$c_3 = 0.56A_{BT}^{1.5}/\{BT(0.31\sqrt{A_{BT}} + T_F - h_B)\}$$

where h_B is the position of the centre of the transverse area A_{BT} above the keel line and T_F is the forward draught of the ship.

$$R_B = 0.11\exp(-3P_B^{-2})F_{ni}^3A_{BT}^{1.5}\rho g/(1+F_{ni}^2)$$

$$P_B = 0.56\sqrt{A_{BT}}/(T_F - 1.5h_B)$$

$$F_{ni} = V/\sqrt{g(T_F - h_B - 0.25\sqrt{A_{BT}}) + 0.15V^2}$$

$$R_{TR} = 0.5\rho V^2 A_T c_6$$

$$c_6 = 0.2(1-0.2F_{nT})$$ if F_{nT}<5

= 0 if $F_{nT} \geq 5$

$$F_{nT} = V/\sqrt{2gA_T/(B+BC_{WP})}$$

$$R_A = \tfrac{1}{2}\rho V^2 S C_A$$

$$C_A = 0.006(L+100)^{-0.16} - 0.00205 + 0.003\sqrt{L/7.5}C_B^4 c_2(0.04 - c_4)$$

$c_4 = T_F/L$ *when* $T_F/L \leq 0.04$

$c_4 = 0.04$ *when* $T_F/L > 0.04$

Problem: The characteristics of a ship is as follows:

L.O.W L=205.00 m

L.B.P. L_{PP} = 200.00 m

Breadth moulded B = 32.00 m

Draught moulded on F.P, T_F=10.00 m

Draught moulded on A. P. T_A=10.00 m

Displacement volume moulded, ∇=37500 m^3

Longitudinal centre of buoyancy 2.02% aft of 1/2L_{PP}

Transverse bulb area A_{BT} = 20.0 m^2

Centre of bulb area above keel line h_B = 4.0 m

Midship section coefficient C_M = 0.98

Waterplane area coefficient C_{WP} = 0.75

Transom area A_T = 16.0 m^2

Wetted area appendages S_{APP} = 50.0 m^2

Stern shape parameter, C_{stern} = 10.0

Propeller diameter, D = 8.0 m

Number of propeller blades Z = 4

Clearance of propeller with keel line 0.20 m

Ship speed V=25.0 knos

Density, ρ = 1025.87

Kinematic Viscosity, υ = 1.18831e-006

Find R_F, R_{APP}, R_W, R_B, R_{TR}, R_A, R_{total}.

Reference: J. Holtrop and G.G. J. Mennen, 1982: **An Approximate Power Prediction Method**, International Shipbuilding Progress, Vol. 29, No. 335.