Problem 1: By the functional equation for

\[ \xi(s) = \pi^{-\frac{s}{2}} \Gamma\left(\frac{s}{2}\right) \zeta(s), \]

the function \( s(1-s)\xi(s) \) can be regarded as an entire function of \( s^2 - s \); what is the order of this function? Use this to obtain the alternative infinite product

\[ \xi(s) = \frac{\xi(1/2)}{4(s-s^2)} \prod_{\rho} \left(1 - \left(\frac{s - \frac{1}{2}}{\rho - \frac{1}{2}}\right)^2\right) \]

the product extending over zeros \( \rho \) of \( \xi(s) \) whose imaginary part is positive. [This symmetrical form eliminates the exponential factors \( e^{A+Bs} \) and \( e^{s/\rho} \) occurring in the usual Hadamard factorization of \( \xi(s) \).]

Problem 2: Calculate the mean value

\[ \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} \left| \zeta(\sigma + it) \right|^2 dt \]

provided \( \sigma > 1 \).

Problem 3: Explicitly construct all Dirichlet characters \((\text{mod } 15)\). Each such character is a completely multiplicative function \( \chi : \mathbb{Z} \to \mathbb{C} \) satisfying \( \chi(n + 15) = \chi(n) \) for all \( n \in \mathbb{Z} \).

Problem 4: Let \( q \) be an integer which has the property that every Dirichlet character \( \chi \ (\text{mod } q) \) is real valued (takes on only the values 0, \( \pm 1 \)). Show that \( q \) must divide 24.