

M3PM16/M4PM16 PROBLEMS 4. 9.2.2012

Q1 (Euler totient function ϕ). Recall that $\phi(n)$ is defined to be the number of positive integers $\leq n$ coprime to n . Show that:

(i)

$$\sum_{d|n} \phi(d) = n;$$

(ii) ϕ is multiplicative;

(iii)

$$\phi(n) = n \prod_{p|n} \left(1 - \frac{1}{p}\right);$$

(iv)

$$\phi(n) = n \sum_{k|n} \mu(k)/k.$$

Q2 (Principle of Inclusion and Exclusion). (i) Let A be a finite set of N elements ($|A| = N$), A_1, \dots, A_r be subsets of N_1, \dots, N_r elements (so $|A_i| = N_i$). Write $N_{ij} := |A_i \cap A_j|$, $N_{ijk} := |A_i \cap A_j \cap A_k|$, etc.,

$$S_1 := \sum_i N_i, \quad S_2 := \sum_{ij} N_{ij}, \quad S_3 := \sum_{ijk} N_{ijk}, \quad \text{etc.}$$

Show that the number of elements of A not in any of A_1, \dots, A_r is

$$S = S_1 - S_2 + S_3 - \dots$$

(ii) Deduce that (as in Q1(iii))

$$\phi(n) = n \prod_{p|n} \left(1 - \frac{1}{p}\right).$$

Q3 (Euler's formula $\zeta(2) = \pi^2/6$ by Fourier rather than Complex Analysis). Find the Fourier series of x on $[0, \pi]$ as

$$x = \frac{\pi}{2} - \frac{4}{\pi} \frac{\cos(2n-1)x}{(2n-1)^2}.$$

By taking $x = 0$, deduce Euler's formula (see e.g. M2PM3 III.7 L31)

$$\zeta(2) := \sum_{n=1}^{\infty} 1/n^2 = \pi^2/6.$$

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