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## 2. Preliminaries

2.1. **Notation.** As is usual, we write  $\mu$  for the Moebius function,  $\Lambda$  for the von Mangoldt function. We let  $\tau(n)$  be the number of divisors of an integer n and  $\omega(n)$  the number of prime divisors. For p prime, n a non-zero integer, we define  $v_p(n)$  to be the largest non-negative integer  $\alpha$  such that  $p^{\alpha}|n$ .

We write (a, b) for the greatest common divisor of a and b. If there is any risk of confusion with the pair (a, b), we write gcd(a, b). Denote by  $(a, b^{\infty})$  the divisor  $\prod_{p|b} p^{v_p(a)}$  of a. (Thus,  $a/(a, b^{\infty})$  is coprime to b, and is in fact the maximal divisor of a with this property.)

As is customary, we write e(x) for  $e^{2\pi ix}$ . We write  $|f|_r$  for the  $L_r$  norm of a function f.

We write  $O^*(R)$  to mean a quantity at most R in absolute value.

2.2. Dirichlet characters and L functions. A Dirichlet character  $\chi: \mathbb{Z} \to \mathbb{C}$  of modulus q is a character  $\chi$  of  $(\mathbb{Z}/q\mathbb{Z})^*$  lifted to  $\mathbb{Z}$  with the convention that  $\chi(n) = 0$  when  $(n,q) \neq 1$ . Again by convention, there is a Dirichlet character of modulus q = 1, namely, the trivial character  $\chi_T : \mathbb{Z} \to \mathbb{C}$  defined by  $\chi_T(n) = 1$  for every  $n \in \mathbb{Z}$ .

If  $\chi$  is a character modulo q and  $\chi'$  is a character modulo q'|q such that  $\chi(n) = \chi'(n)$  for all n coprime to q, we say that  $\chi'$  induces  $\chi$ . A character is primitive if

it is not induced by any character of smaller modulus. Given a character  $\chi$ , we write  $\chi^*$  for the (uniquely defined) primitive character inducing  $\chi$ . If a character  $\chi$  mod q is induced by the trivial character  $\chi_T$ , we say that  $\chi$  is *principal* and write  $\chi_0$  for  $\chi$  (provided the modulus q is clear from the context). In other words,  $\chi_0(n) = 1$  when (n, q) = 1 and  $\chi_0(n) = 0$  when (n, q) = 0.

A Dirichlet L-function  $L(s,\chi)$  ( $\chi$  a Dirichlet character) is defined as the analytic continuation of  $\sum_n \chi(n) n^{-s}$  to the entire complex plane; there is a pole at s=1 if  $\chi$  is principal.

A non-trivial zero of  $L(s,\chi)$  is any  $s\in\mathbb{C}$  such that  $L(s,\chi)=0$  and  $0<\Re(s)<1$ . (In particular, a zero at s=0 is called "trivial", even though its contribution can be a little tricky to work out. The same would go for the other zeros with  $\Re(s)=0$  occurring for  $\chi$  non-primitive, though we will avoid this issue by working mainly with  $\chi$  primitive.) The zeros that occur at (some) negative integers are called trivial zeros.

The critical line is the line  $\Re(s) = 1/2$  in the complex plane. Thus, the generalized Riemann hypothesis for Dirichlet L-functions reads: for every Dirichlet character  $\chi$ , all non-trivial zeros of  $L(s,\chi)$  lie on the critical line. Verifiable finite versions of the generalized Riemann hypothesis generally read: for every Dirichlet character  $\chi$  of modulus  $q \leq Q$ , all non-trivial zeros of  $L(s,\chi)$  with  $|\Im(s)| \leq f(q)$  lie on the critical line (where  $f: \mathbb{Z} \to \mathbb{R}^+$  is some given function).

## 2.3. Fourier transforms. The Fourier transform on $\mathbb{R}$ is normalized as follows:

$$\widehat{f}(t) = \int_{-\infty}^{\infty} e(-xt)f(x)dx$$

for  $f: \mathbb{R} \to \mathbb{C}$ .

The trivial bound is  $|\widehat{f}|_{\infty} \leq |f|_1$ . Integration by parts gives that, if f is differentiable k times outside finitely many points, then

$$\widehat{f}(t) = O^* \left( \frac{|\widehat{f^{(k)}}|_{\infty}}{2\pi t} \right) = O^* \left( \frac{|f^{(k)}|_1}{(2\pi t)^k} \right).$$

It could happen that  $|f^{(k)}|_1 = \infty$ , in which case (2.1) is trivial (but not false). In practice, we require  $f^{(k)} \in L_1$ . In a typical situation, f is differentiable k times except at  $x_1, x_2, \ldots, x_k$ , where it is differentiable only (k-2) times; the contribution of  $x_i$  (say) to  $|f^{(k)}|_1$  is then  $|\lim_{x\to x_i^+} f^{(k-1)}(x) - \lim_{x\to x_i^-} f^{(k-1)}(x)|$ .

## 2.4. **Mellin transforms.** The Mellin transform of a function $\phi:(0,\infty)\to\mathbb{C}$ is

(2.2) 
$$M\phi(s) := \int_0^\infty \phi(x) x^{s-1} dx.$$

In general,  $M(f *_M g) = Mf \cdot Mg$  and

(2.3) 
$$M(f \cdot g)(s) = \frac{1}{2\pi i} \int_{\sigma - i\infty}^{\sigma + i\infty} Mf(z) Mg(s - z) dz$$
 [GR00, §17.32]

provided that z and s-z are within the strips on which Mf and Mg (respectively) are well-defined.

The Mellin transform is an isometry, in the sense that

(2.4) 
$$\int_0^\infty |f(t)|^2 t^{2\sigma} \frac{dt}{t} = \frac{1}{2\pi} \int_{-\infty}^\infty |Mf(\sigma + it)|^2 dt.$$

Table 22. Number and percent distribution of emergency department visits resulting in hospital admission, with corresponding standard errors, by selected characteristics: United States, 2006

Selected characteristic	Number of visits in thousands	Standard error in thousands	Percent distribution	Standard error of percent
All admissions	15,263	896		
Age				
Under 15 years	947	99	6.2	0.5
5–24 years	828	73	5.4	0.4
5–24 years	2,698	222	17.7	0.8
5–64 years	4,683	314	30.7	0.9
5–74 years	2,223	191	14.6	0.7
5 years and over	3,884	234	25.4	1.1
Unit to which admitted				
Other bed or unit	10,566	742	69.2	2.2
Critical care unit	2,255	227	14.8	1.3
Operating room or catheterization lab	479	71	3.1	0.5
Jnknown	1,964	323	12.9	2.0
Hospital discharge status				
slive	12,745	777	83.5	2.2
Died	312	40	2.0	0.3
Inknown	2,205	389	14.4	2.3
Length of stay <sup>1</sup>				
–2 days	3,236	262	21.2	1.2
–4 days	4,627	309	30.3	1.2
–6 days	2,483	180	16.3	0.9
–8 days	1,247	117	8.2	0.6
–10 days	652	77	4.3	0.4
fore than 10 days	1,139	105	7.5	0.5
Inknown	1,878	381	12.3	2.3
Mode of arrival				
mbulance	6,155	447	40.3	1.2
Other	9,108	515	59.7	1.2
Immediacy with which patient should be seen				
mmediate or emergent <sup>2</sup>	5,238	473	34.3	2.3
Other	10,025	667	65.7	2.3
Patient seen in this ED within the last 72 hours <sup>3</sup>				
es	545	68	3.6	0.4
lo	14,718	865	96.4	0.4
Patient discharged from any hospital within the last 7 days				
/es	738	106	4.8	0.6
No or unknown	14,525	844	95.2	0.6

NOTE: Numbers may not add to totals because of rounding.

<sup>...</sup> Category not applicable.

<sup>1</sup>The mean length of stay was 5.3 days (standard error = 0.1).

<sup>&</sup>lt;sup>2</sup>Emergent is 1 to 14 minutes.

<sup>&</sup>lt;sup>3</sup>ED is emergency department.

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Figure 10. 2006 Emergency Department Patient Record