



## Some Probabilistic Aspects of Set Partitions

Jim Pitman

*The American Mathematical Monthly*, Volume 104, Issue 3 (Mar., 1997), 201-209.

Stable URL:

<http://links.jstor.org/sici?sici=0002-9890%28199703%29104%3A3%3C201%3ASPAOSP%3E2.0.CO%3B2-9>

---

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/about/terms.html>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

*The American Mathematical Monthly* is published by Mathematical Association of America. Please contact the publisher for further permissions regarding the use of this work. Publisher contact information may be obtained at <http://www.jstor.org/journals/maa.html>.

---

*The American Mathematical Monthly*  
©1997 Mathematical Association of America

JSTOR and the JSTOR logo are trademarks of JSTOR, and are Registered in the U.S. Patent and Trademark Office. For more information on JSTOR contact [jstor-info@umich.edu](mailto:jstor-info@umich.edu).

©2003 JSTOR

---

# Some Probabilistic Aspects of Set Partitions

---

Jim Pitman

---

**1. INTRODUCTION.** A *partition* of the set  $\mathbb{N}_n := \{1, 2, \dots, n\}$  is an unordered collection of non-empty subsets of  $\mathbb{N}_n$ . Let  $\mathbb{P}_n$  denote the set of all such partitions, and let  $B_n = \#(\mathbb{P}_n)$ , the number of partitions of  $\mathbb{N}_n$ . The numbers  $B_n$  are known as *Bell numbers* after E.T. Bell [3, 4, 45]. See Rota [50] and Gardner [24, Chapter 2] for surveys of their properties and applications. The remarkable *Dobiński formula* [18]

$$B_n = e^{-1} \sum_{m=1}^{\infty} \frac{m^n}{m!} \quad (n = 1, 2, \dots) \quad (1)$$

leads [36, 1.9] to the asymptotic evaluation

$$B_n \sim \frac{1}{\sqrt{n}} \lambda(n)^{n+1/2} e^{\lambda(n)-n-1} \quad \text{as } n \rightarrow \infty, \quad (2)$$

where  $\lambda(n) \log(\lambda(n)) = n$ . As noted by Comtet [11], for each  $n$  the infinite sum in (1) can be evaluated as the least integer greater than the sum of the first  $2n$  terms.

From a probabilistic perspective, the series on the right side of Dobiński's formula represents the  $n$ th moment of the Poisson distribution with mean 1. So the initially surprising fact that this series yields an integer for all  $n$  amounts to the fact that all positive integer moments of the Poisson(1) distribution are integers. As explained in Section 2, Dobiński's formula reduces to the fact that the factorial moments of the Poisson(1) distribution are identically equal to 1, and this identity can be understood probabilistically with essentially no calculation.

While such probabilistic interpretations of identities related to set partitions are the main theme of this paper, Section 1.2 recalls an elementary combinatorial proof of Dobiński's formula.

**1.1 Notation.** Following the notation of [27], let  $\left\{ \begin{smallmatrix} n \\ k \end{smallmatrix} \right\}$  denote the number of partitions of  $\mathbb{N}_n$  into exactly  $k$  distinct non-empty subsets, so that

$$B_n = \sum_{k=1}^n \left\{ \begin{smallmatrix} n \\ k \end{smallmatrix} \right\}. \quad (3)$$

The  $\left\{ \begin{smallmatrix} n \\ k \end{smallmatrix} \right\}$  are known as the *Stirling numbers of the second kind*. Let  $m^{\underline{k}}$  denote the falling factorial with  $k$  factors

$$m^{\underline{k}} = m(m-1) \cdots (m-k+1), \quad (4)$$

which, for positive integers  $m$  and  $k$ , is the number of permutations of length  $k$  of

$m$  distinct symbols. The formula

$$m^n = \sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} m^k \quad (5)$$

decomposes the number  $m^n$  of sequences of  $m$  distinct symbols of length  $n$  as the sum over  $k$  of the number of such sequences that contain exactly  $k$  distinct symbols [54, p. 35]. As an identity of polynomials in  $m$  of degree  $n$ , this identity provides an alternative definition of the coefficients  $\left\{ \begin{matrix} n \\ k \end{matrix} \right\}$  for  $1 \leq k \leq n$ . See [11, 47, 48, 54] for background and a wealth of further information about Stirling numbers.

**1.2 A quick proof of Dobiński's formula.** This argument is attributed to Schützenberger by Foata [22, p. 73]. Divide (5) by  $m!$  to obtain for positive integers  $m$  and  $n$

$$\frac{m^n}{m!} = \sum_{k=1}^m \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \frac{1}{(m-k)!}. \quad (6)$$

This is the identity of coefficients of  $\lambda^m$  in the power series identity

$$\sum_{m=1}^{\infty} \frac{m^n}{m!} \lambda^m = \left( \sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \lambda^k \right) \left( \sum_{j=0}^{\infty} \frac{\lambda^j}{j!} \right), \quad (7)$$

which, upon rearrangement, gives the following *horizontal generating function* for the Stirling numbers of the second kind:

$$\sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \lambda^k = e^{-\lambda} \sum_{m=1}^{\infty} \frac{m^n}{m!} \lambda^m. \quad (8)$$

Now take  $\lambda = 1$  and use (3) to obtain Dobiński's formula (1). The polynomial appearing in (8) is known as an *exponential polynomial*. Many other proofs of the generalization (8) of Dobiński's formula are known. See for instance Roman [49, p. 66] and Wilf [58, p. 106]. Closely related arguments appear in Rota [50], Berge [5, p. 44], Comtet [11, p. 211], Lupas [37], and Chen-Yeh [10].

**2. MOMENTS.** For a non-negative integer-valued random variable  $X$  with

$$P(X = m) = p_m \quad (m = 0, 1, \dots) \quad (9)$$

and a non-negative function  $f$ , let

$$E[f(X)] := \sum_m p_m f(m), \quad (10)$$

which is the *expected value* of  $f(X)$  for  $X$  with distribution (9). See [20, 43] for background. From (5) and linearity of the expectation operator  $E$ , we obtain the following well-known formula for  $E[X^n]$ , the  $n$ th *moment* of  $X$ , in terms of  $E[X^k]$ , the  $k$ th *factorial moment* of  $X$  for  $1 \leq k \leq n$  [47, 14]:

$$E[X^n] = \sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} E[X^k]. \quad (11)$$

For  $\lambda > 0$ , let  $X_\lambda$  denote a random variable with the Poisson distribution

$$P(X_\lambda = m) = e^{-\lambda} \frac{\lambda^m}{m!} \quad (m = 0, 1, \dots) \quad (12)$$

so that

$$E[f(X_\lambda)] = e^{-\lambda} \sum_{m=0}^{\infty} f(m) \frac{\lambda^m}{m!}. \quad (13)$$

Take  $f(m) = m^n$  to see that the right side of (8) equals  $E[X_\lambda^n]$ , so the identity (8) amounts to the formula

$$E[X_\lambda^n] = \sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \lambda^k \quad (n = 1, 2, \dots) \quad (14)$$

for the moments of the  $\text{Poisson}(\lambda)$  distribution [46, 42]. This formula is the particular case of (11) for  $X$  with  $\text{Poisson}(\lambda)$  distribution, for it is known [46, 14] that

$$E[X_\lambda^k] = \lambda^k \quad (k = 1, 2, \dots). \quad (15)$$

Formula (15) follows easily from (13) with  $f(m) = m^k$  by change of summation variable from  $m$  to  $j = m - k$ . In particular, for  $\lambda = 1$  the factorial moments of the  $\text{Poisson}(1)$  distribution are identically equal to 1. So Dobiński's formula (1) can be read from (14) for  $\lambda = 1$ , which follows as indicated above from (11) and (15). In essence, this is Rota's [50] proof of Dobiński's formula cast in probabilistic notation. This argument differs from the proof in Section 1.2 in that it involves checking (15) for  $\lambda = 1$ .

Formula (15) has the following interpretation in terms of a *Poisson process* [33, 43]. Let

$$0 < U_{(1)} < \dots < U_{(X_\lambda)} < 1 \quad (16)$$

denote the random locations in  $(0, 1)$  of the points of a homogeneous Poisson process on  $(0, 1)$  with mean intensity measure  $\lambda du$  for  $0 < u < 1$ . For each  $k = 1, 2, \dots$  define an associated *k-tuple point process*, with points in  $(0, 1)^k$ , to have a point at each of the locations  $(U_{(\sigma_1)}, \dots, U_{(\sigma_k)})$  as  $\sigma$  ranges over the  $X_\lambda^k$  different permutations of  $\{1, \dots, X_\lambda\}$  of length  $k$ . For distinct  $u_i \in (0, 1)$ , independence properties of the basic Poisson process on  $(0, 1)$  imply that the mean intensity of the *k-tuple point process* at  $(u_1, \dots, u_k) \in (0, 1)^k$  is

$$\frac{P(\text{some } U_{(\sigma_i)} \in du_i \text{ for each } 1 \leq i \leq k)}{du_1 \cdots du_k} = \frac{(\lambda du_1) \cdots (\lambda du_k)}{du_1 \cdots du_k} = \lambda^k, \quad (17)$$

so the expected number of points in the *k-tuple point process* is

$$E[X_\lambda^k] = \lambda^k \int_0^1 du_1 \cdots \int_0^1 du_k = \lambda^k. \quad (18)$$

Constantine and Savits [12] derive a generalization of Dobiński's formula by consideration of compound nonhomogeneous Poisson processes. See also Stam [52] and Di Bucchianico [8] for related results. For various applications of Stirling numbers and their generalizations to the computation of moments of probability distributions, see [47, 9]. Moments of the normal distribution also have interesting combinatorial interpretations [19, 25]. More generally, the idea of representing combinatorially defined numbers by an infinite sum or an integral, typically with a probabilistic interpretation, has proved to be a very fruitful one. Other examples are the representation of  $n!$  as a gamma integral, which leads to Stirling's formula [7, 16, 38], and Laplace's representation of  $k$ th differences of powers [35, 14, 30], which yields an asymptotic formula for the Stirling numbers of the second kind. See [41] for a recent survey of asymptotic enumeration methods.

**3. VARIATIONS OF DOBIŃSKI'S FORMULA.** The derivation of Dobiński's formula given in the previous section yields the following proposition:

**Proposition 1.** *Let  $X$  be a random variable with values in  $\{0, 1, 2, \dots\}$  and let  $n$  be a positive integer. The following two conditions are equivalent:*

- (i) *the first  $n$  factorial moments of  $X$  are identically equal to 1;*
- (ii) *the  $k$ th moment of  $X$  equals  $B_k$  for every  $1 \leq k \leq n$ .*

It is well known that for each  $\lambda > 0$  the Poisson( $\lambda$ ) distribution is uniquely determined by its moments; see for instance [6, Section 30]. The Poisson(1) distribution is therefore the unique probability distribution whose  $n$ th moment equals  $B_n$  for every  $n$ . But for each fixed  $n$  there are many probability distributions on  $\{0, 1, 2, \dots\}$  that have the same first  $n$  moments as Poisson(1). It is obvious that there can be at most one such distribution of  $X$  with  $P(X \leq n) = 1$ , because the moment conditions amount to a system of  $n$  linearly independent equations in  $n$  unknowns  $p_1, \dots, p_n$ . Less obvious is the fact that the unique solution of these equations is such that  $p_i \geq 0$  for  $1 \leq i \leq n$  and  $\sum_{i=1}^n p_i \leq 1$ , so that  $(p_1, \dots, p_n)$  is the restriction to  $\{1, \dots, n\}$  of a unique probability distribution on  $\{0, 1, \dots, n\}$ . But this probability distribution on  $\{0, 1, 2, \dots, n\}$ , whose first  $n$  factorial moments are identically equal to one, is known to arise in the setting of the classical matching problem [31, 14, 20, 56]. If  $M_n$  is the number of fixed points of a uniformly distributed random permutation of  $\mathbb{N}_n$ , then it is easy to show by the method of indicators that the first  $n$  factorial moments of  $M_n$  are identically equal to 1; see [14]. The distribution of a random variable  $X$  with range  $\{0, 1, \dots, n\}$  is recovered from its factorial moments by the classical sieve formula [14]

$$P(X = m) = \frac{1}{m!} \sum_{k=m}^n \frac{(-1)^{m-k} E[X^k]}{(m-k)!} \quad (m = 0, 1, \dots, n). \quad (19)$$

For  $X = M_n$  with  $E[M_n^k] \equiv 1$  for  $0 \leq k \leq n$ , this simplifies to

$$P(M_n = m) = \frac{1}{m!} \sum_{s=0}^{n-m} \frac{(-1)^s}{s!} \quad (m = 0, 1, \dots, n). \quad (20)$$

See [20, Section IV.4] for further discussion. According to Proposition 1, the  $k$ th moment of  $M_n$  equals  $B_k$  for every  $1 \leq k \leq n$ . That is to say,

$$B_k = \sum_{m=1}^n \frac{m^k}{m!} \sum_{s=0}^{n-m} \frac{(-1)^s}{s!} \quad (1 \leq k \leq n). \quad (21)$$

This variation of Dobiński's formula is derived in quite a different way by Wilf [58, p. 22] by substituting the classical formula

$$\left\{ \begin{matrix} n \\ k \end{matrix} \right\} = \frac{1}{k!} \sum_{j=1}^k (-1)^{k-j} \binom{k}{j} j^n \quad (22)$$

into (3). As observed by Wilf, Dobiński's formula (1) follows easily from (21) by letting  $n \rightarrow \infty$ . See also Lovász [36, 1.9] for a similar argument, James and Kerber [32, pp. 227–237] for connections with the representation theory of the symmetric group, and Diaconis and Shashahani [17] for various generalizations. In Dale and Skau [13] the Bell numbers appear as the factorial moments of a probability distribution on the non-negative integers.

**4. THE MOMENT GENERATING FUNCTION.** Consider now the *moment generating function* (m.g.f.) of the Poisson( $\lambda$ ) distribution:

$$E[\exp(\theta X_\lambda)] = E\left[\sum_{n=0}^{\infty} \frac{\theta^n X_\lambda^n}{n!}\right] = \sum_{n=0}^{\infty} E[X_\lambda^n] \frac{\theta^n}{n!}, \quad (23)$$

where the series converge for all real  $\theta$  and the interchange of  $E$  and  $\sum$  is easily justified. See [6] for a modern treatment of m.g.f.'s. From (13) with  $f(m) = e^{\theta m}$  there is the standard formula

$$E[\exp(\theta X_\lambda)] = e^{-\lambda} \sum_{m=0}^{\infty} \frac{(\lambda e^\theta)^m}{m!} = \exp(\lambda(e^\theta - 1)). \quad (24)$$

This combines with (8) to yield the following *double generating function* of the Stirling numbers of the second kind. This classical formula [11, p. 206] is an identity between two different expressions for the m.g.f. in  $\theta$  of the Poisson( $\lambda$ ) distribution:

$$1 + \sum_{n=1}^{\infty} \sum_{k=1}^n \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \frac{\lambda^k \theta^n}{n!} = \exp(\lambda(e^\theta - 1)). \quad (25)$$

In particular, for  $\lambda = 1$  this reduces by (3) to Bell's [3, 4] formula

$$1 + \sum_{n=1}^{\infty} B_n \frac{\theta^n}{n!} = \exp(e^\theta - 1), \quad (26)$$

which gives two expressions for the m.g.f. in  $\theta$  of the Poisson(1) distribution. Equating coefficients of  $\lambda^k$  in (25) yields the *vertical generating function* of the Stirling numbers of the second kind:

$$\sum_{n \geq k} \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \frac{\theta^n}{n!} = \frac{1}{k!} (e^\theta - 1)^k \quad (k = 1, 2, \dots). \quad (27)$$

See [11, 47, 54] for alternative derivations of these identities. There are similar identities for many other arrays of combinatorial numbers, such as the binomial coefficients and Stirling numbers of the first kind [11, 58], [27, p. 351], most of which admit probabilistic interpretations. Formulae with binomial coefficients typically involve independent trials, while those with Stirling numbers of the first kind typically involve the cycle structure of random permutations [1]. See also [2] for probabilistic analysis of more general combinatorial structures and further references.

**5. RANDOM PARTITIONS.** A *random partition* of  $\mathbb{N}_n$  is a random variable  $\Pi$  with values in the set  $\mathbb{P}_n$  of partitions of  $\mathbb{N}_n$ . The *distribution* of  $\Pi$  then refers to the collection of probabilities  $P(\Pi = \pi)$  as  $\pi$  ranges over  $\mathbb{P}_n$ . Questions about enumeration of partitions of  $\mathbb{N}_n$  of various kinds can be phrased probabilistically in terms of a *uniform random partition*, that is, a random partition  $\Pi$  with the uniform distribution  $P(\Pi = \pi) = 1/B_n$  for each partition  $\pi \in \mathbb{P}_n$ . For developments of this idea see [29, 28, 51, 23]. Random partitions with non-uniform distribution also arise naturally in various contexts, so it is useful to have models for random partitions, both uniform and non-uniform.

The following *random allocation scheme* provides a basic method of generating a random partition of  $\mathbb{N}_n$ . See [14, 34, 57] for extensive study of this and related schemes, and further references. Throw  $n$  balls labelled by  $\mathbb{N}_n$  into  $m$  boxes

labelled by  $\mathbb{N}_m$ , and assume that all  $m^n$  possible allocations of balls into boxes are equally likely. Let  $\Pi_{nm}$  be the partition of balls by boxes. More formally, let  $X_i$  be the number of the box containing the  $i$ th ball for  $1 \leq i \leq n$ . Then the  $X_i$  are independent and uniformly distributed on  $\mathbb{N}_m$ , and  $\Pi_{nm}$  is the partition of  $\mathbb{N}_n$  induced by the random equivalence relation  $i \sim j$  if and only if  $X_i = X_j$ . Formally, the  $X_i$  can be regarded as coordinate maps defined on  $(\mathbb{N}_n)^m$ , and  $\Pi_{nm}$  is then defined as a map from  $(\mathbb{N}_n)^m$  to  $\mathbb{P}_n$ , the set of partitions of  $\mathbb{N}_n$ . Let  $\#(\pi)$  denote the number of subsets in a partition  $\pi \in \mathbb{P}_n$ . The distribution of  $\Pi_{nm}$  induced by the uniform distribution  $P$  on  $\mathbb{N}_m$  can be read from formula (5):

$$P(\Pi_{nm} = \pi) = \frac{m^k}{m^n} \quad \text{if } \#(\pi) = k. \quad (28)$$

The distribution of  $\#(\Pi_{nm})$ , the number of occupied boxes when  $n$  balls are thrown into  $m$  boxes, is given by the following probabilistic equivalent of (5):

$$P[\#(\Pi_{nm}) = k] = \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \frac{m^k}{m^n} \quad (1 \leq k \leq n). \quad (29)$$

Because the probability displayed in (28) depends on the number of occupied boxes  $k$ , for  $n \geq 3$  this random partition  $\Pi$  of  $\mathbb{N}_n$  does not have uniform distribution on  $\mathbb{P}_n$  for any  $m$ . However, as observed by Stam [53], for each fixed  $n$  it is possible to generate a uniformly distributed random element of  $\mathbb{P}_n$  by a suitable randomization of  $m$ . The following proposition was suggested by Stam's construction, which is described in Corollary 3.

**Proposition 2.** *Let  $M$  be a random variable with values in  $\{1, 2, \dots\}$ , and suppose given  $M = m$  that  $n$  balls labelled by  $\mathbb{N}_n$  are thrown independently and uniformly at random into  $m$  boxes. Let  $\Pi_{nM}$  denote the random partition of  $\mathbb{N}_n$  so generated. The following two conditions are equivalent:*

- (i)  $\Pi_{nM}$  has uniform distribution over the set  $\mathbb{P}_n$  of all partitions of  $\mathbb{N}_n$ ;
- (ii) the distribution of  $M$  is of the form

$$P(M = m) = \frac{m^n p_m}{B_n} \quad (m = 1, 2, \dots) \quad (30)$$

for some probability distribution  $(p_m)$  on  $\{0, 1, 2, \dots\}$  whose first  $n$  factorial moments are identically equal to 1.

Before the proof, here are two corollaries which follow immediately from the Proposition and the discussion in Sections 2 and 3:

**Corollary 3.** [53] *If  $M$  has the distribution (30) for  $p_m = e^{-1}/m!$ , then  $\Pi_{nM}$  has uniform distribution on  $\mathbb{P}_n$ .*

**Corollary 4.** *For each  $n$  there is a unique distribution of  $M$  such that*

$$P(M \leq n) = 1 \text{ and } \Pi_{nM} \text{ has uniform distribution on } \mathbb{P}_n.$$

*This distribution of  $M$  is defined by (30) for  $p_m = P(M_n = m)$  as in (20) with  $M_n$  the number of fixed points of a uniform random permutation of  $\mathbb{N}_n$ .*

*Proof of Proposition 2.* By conditioning on  $M$  and using (28),

$$P(\Pi_{nM} = \pi) = \sum_{m=1}^{\infty} \frac{m^k}{m^n} P(M = m) \quad \text{if } \#(\pi) = k, \quad (31)$$

so the distribution of  $\Pi_{nM}$  is uniform on  $\mathbb{P}_n$  if and only if

$$\sum_{m=1}^{\infty} \frac{m^k}{m^n} P(M = m) = \frac{1}{B_n} \quad (1 \leq k \leq n). \quad (32)$$

Define

$$p_m = B_n m^{-n} P(M = m) \quad (m = 1, 2, \dots), \quad (33)$$

so that (32) becomes

$$\sum_{m=1}^{\infty} m^k p_m = 1 \quad (1 \leq k \leq n), \quad (34)$$

which for  $k = 1$  implies that  $\sum_{m=1}^{\infty} p_m \leq \sum_{m=1}^{\infty} m p_m = 1$ . It follows that  $\Pi_{nM}$  is uniform if and only if  $(p_m)$  derived from the distribution of  $M$  via (33) is the restriction to  $\{1, 2, \dots\}$  of a probability distribution on  $\{0, 1, 2, \dots\}$  whose first  $n$  factorial moments are equal to 1. This is condition (ii). ■

As shown by Stam, Corollary 3 allows numerous results regarding the asymptotic distribution for large  $n$  of a uniform random partition of  $\mathbb{N}_n$  to be deduced from corresponding results for the classical occupancy problem defined by random allocations of balls in boxes, for which see [34, 57]. See also [2, 15, 23, 26, 28, 29, 51] for a more detailed account of the asymptotics of uniform random partitions of  $\mathbb{N}_n$ .

As a variation, the following corollary is easily obtained by a similar argument:

**Corollary 5.** *Suppose that  $M$  has the distribution*

$$P(M = m) = \frac{m^n P(X_\lambda = m)}{\mu_n(\lambda)} \quad (m = 1, 2, \dots), \quad (35)$$

where  $X_\lambda$  has the *Poisson*( $\lambda$ ) distribution (12), and  $\mu_n(\lambda) = E(X_\lambda^n)$ . Then the distribution of  $\Pi_{nM}$  is given by

$$P(\Pi_{nM} = \pi) = \frac{\lambda^k}{\mu_n(\lambda)} \quad \text{if } \#(\pi) = k. \quad (36)$$

As a check, (36) implies

$$P[\#(\Pi_{nM}) = k] = \left\{ \begin{matrix} n \\ k \end{matrix} \right\} \frac{\lambda^k}{\mu_n(\lambda)} \quad (1 \leq k \leq n). \quad (37)$$

The fact that these probabilities sum to 1 amounts to formula (14) for  $\mu_n(\lambda)$ . The distribution of  $\Pi_{nM}$  defined by formula (36) defines a *Gibbs distribution* on partitions of  $\mathbb{N}_n$ . See [55, 44] for further discussion of such Gibbs distributions on sets of combinatorial objects. See Nijenhuis and Wilf [39] for a recursive algorithm to construct a uniform random partition of  $\mathbb{N}_n$  based on the recurrence

$$B_n = 1 + \sum_{k=1}^{n-1} \binom{n-1}{k} B_k, \quad (38)$$

where the right side counts the number of partitions  $\pi$  of  $\mathbb{N}_n$  according to the size  $k$  of the subset in  $\pi$  that contains  $n$  [36, Problem 1.10]. See [40] for related



combinatorial algorithms, and [21] for a recent systematic approach to the random generation of labelled combinatorial structures and further references on this topic.

**ACKNOWLEDGMENTS.** Thanks to Persi Diaconis, Hsien-Kuei Hwang, and the referee for providing some references.

## REFERENCES

1. R. Arratia and S. Tavaré. The cycle structure of random permutations, *Ann. Prob.*, 20:1567–1591, 1992.
2. R. Arratia and S. Tavaré. Independent process approximations for random combinatorial structures, *Adv. Math.*, 104:90–154, 1994.
3. E. T. Bell. Exponential numbers, *Amer. Math. Monthly*, 41:411–419, 1934.
4. E. T. Bell. Exponential polynomials, *Annals of Mathematics*, 35:258–277, 1934.
5. C. Berge. *Principles of Combinatorics*. Academic Press, New York and London, 1971.
6. P. Billingsley. *Probability and Measure*, 2nd ed. Wiley, New York, 1986.
7. C. R. Blyth and P. K. Pathak. A note on easy proofs of Stirling's theorem, *Amer. Math. Monthly*, 93:376–379, 1986.
8. A. Di Bucchianico. Representations of Sheffer polynomials, *Studies in Applied Math.*, 93:1–14, 1994.
9. Ch. A. Charalambides and J. Singh. A review of the Stirling numbers, their generalizations and statistical applications, *Commun. Statist.-Theory Meth.*, 17:2533–2595, 1988.
10. B. Chen and Y.-N. Yeh. Some explanations of Dobinski's formula, *Studies in Applied Math.*, 92:191–199, 1994.
11. L. Comtet. *Advanced Combinatorics*. D. Reidel Pub. Co., Boston, 1974. (translated from French).
12. G. M. Constantine and T. H. Savits. A stochastic representation of partition identities, *SIAM J. Discrete Math.*, 7:194–202, 1994.
13. K. Dale and I. Skau. The (generalized) secretary's packet problem and the Bell numbers, *Discrete Math.*, 137:357–360, 1995.
14. F. N. David and D. E. Barton. *Combinatorial Chance*. Griffins, London, 1962.
15. J. M. DeLaurentis and B. G. Pittel. Counting subsets of the random partition and the 'Brownian bridge' process, *Stochastic Processes and their Applications*, 15:155–167, 1983.
16. P. Diaconis and D. Freedman. An elementary proof of Stirling's formula, *Amer. Math. Monthly*, 93:123–125, 1986.
17. P. Diaconis and M. Shahshahani. On the eigenvalues of random matrices, *J. Applied Probability*, Special vol. 31A:49–62, 1994.
18. G. Dobiński. Summirung der Reihe  $\Sigma n^m/n!$  für  $m = 1, 2, 3, 4, 5, \dots$ , *Grunert Archiv (Arch. für Mat. und Physik)*, 61:333–336, 1877.
19. E. B. Dynkin. Gaussian and non-Gaussian random fields associated with Markov processes, *J. Funct. Anal.*, 55:344–376, 1984.
20. W. Feller. *An Introduction to Probability Theory and its Applications*, Vol. 1, 3rd ed. Wiley, New York, 1968.
21. Ph. Flajolet, P. Zimmerman, and B. V. Cutsem. A calculus for the random generation of labelled combinatorial structures, *Theoretical Computer Science*, 132:1–35, 1994.
22. D. Foata. *La série génératrice exponentielle dans les problèmes d'énumération*, volume 54 of *Séminaire de Mathématiques supérieures*. Presses de l'Université de Montréal, 1974.
23. B. Fristedt. The structure of partitions of large sets, Technical Report 86-154, University of Minnesota Mathematics Dept., Minneapolis, Minnesota, 1987.
24. M. Gardner. *Fractal music, hypercards and more— : mathematical recreations from Scientific American magazine*. W.H. Freeman, New York, 1992.
25. C. D. Godsil. *Algebraic Combinatorics*. Chapman & Hall, New York, 1993.
26. W. M. Y. Goh and E. Schmutz. Random set partitions, *SIAM J. Discrete Math.*, 7:419–436, 1994.
27. R. L. Graham, D. E. Knuth, and O. Patashnik. *Concrete Mathematics: a foundation for computer science*, 2nd ed. Addison-Wesley, Reading, Mass., 1989.
28. J. Haigh. Random equivalence relations, *Journal of Combinatorial Theory*, 13:287–295, 1972.
29. L. H. Harper. Stirling behavior is asymptotically normal, *Ann. Math. Stat.*, 38:410–414, 1966.
30. L. Holst. On numbers related to partitions of unlike objects and occupancy problems, *Europ. J. Combinatorics*, 2:231–237, 1981.

31. J. O. Irwin. A unified derivation of some well-known frequency distribution of interest in biometry and statistics, *J.R. Statist. Soc.*, 118:389–404, 1955.
32. G. D. James and A. Kerber. *The representation theory of the symmetric group*, volume 16 of *Encyclopedia of mathematics and its applications*. Addison-Wesley, Reading, Mass., 1981.
33. J. F. C. Kingman. *Poisson Processes*. Clarendon Press, Oxford, 1993.
34. V. F. Kolchin, B. A. Sevastyanov, and V. P. Christyakov. *Random Allocations*. V. H. Winston & Sons, Washington, D. C., 1978.
35. P. S. Laplace. *Théorie Analytique des Probabilités*, 2nd ed.. Paris, 1814.
36. L. Lovász. *Combinatorial Problems and Exercises*, 2nd ed. North-Holland, Amsterdam, 1993.
37. A. Lupas. Dobiński-type formula for binomial polynomials, *Stud. Univ. Babes-Bolyai Math.*, 33(2):40–44, 1988.
38. V. Namias. A simple derivation of Stirling’s asymptotic series, *Amer. Math. Monthly*, 93:25–29, 1986.
39. A. Nijenhuis and H. S. Wilf. A method and two algorithms on the theory of partitions, *J. Combin. Theory A*, 18:219–222, 1975.
40. A. Nijenhuis and H. S. Wilf. *Combinatorial algorithms for computers and calculators*, 2nd ed. Academic Press, New York, 1978.
41. A. M. Odlyzko. Asymptotic enumeration methods, in R. L. Graham, M. Grötschel, and L. Lovász, editors, *Handbook of Combinatorics Vol. II*, pp. 1063–1229. Elsevier, New York, 1995.
42. C. Philipson. A note on the moments of a Poisson probability distribution, *Skand. Aktuarietidskrift*, 46:243–4, 1963.
43. J. Pitman. *Probability*. Springer-Verlag, New York, 1993.
44. J. Pitman. Probabilistic bounds on the coefficients of polynomials with only real zeros, Technical Report 453, Dept. Statistics, U.C. Berkeley, 1996. To appear in *J. Comb. Theory A*.
45. C. Reid. *The search for E. T. Bell: also known as John Taine*. MAA Spectrum. Mathematical Association of America, Washington, DC, 1993.
46. J. Riordan. Moment recurrence relations for the binomial Poisson and hypergeometric probability distributions, *Ann. Math. Stat.*, 8:103–111, 1937.
47. J. Riordan. *An Introduction to Combinatorial Analysis*. Wiley, New York, 1958.
48. J. Riordan. *Combinatorial Identities*. Wiley, New York, 1968.
49. S. Roman. *The Umbral Calculus*. Academic Press, New York, 1984.
50. G.-C. Rota. The number of partitions of a set, *Amer. Math. Monthly*, 71:498–504, 1964.
51. V. N. Sachkov. Random partitions of sets, *Theory Probab. Appl.*, 19:184–190, 1973.
52. A. J. Stam. Polynomials of binomial type and compound Poisson processes, *Journal of Mathematical Analysis and Applications*, 130:151, 1988.
53. A. J. Stam. Generation of a random partition of a set by an urn model, *J. Combin. Theory A*, 35:231–240, 1983.
54. R. P. Stanley. *Enumerative Combinatorics*, Vol I. Wadsworth & Brooks/Cole, Monterey, California, 1986.
55. J. M. Steele. Gibbs’ measures on combinatorial objects and the central limit theorem for an exponential family of random trees, *Probability in the Engineering and Informational Sciences*, 1:47–59, 1987.
56. L. Takács. The problem of coincidences, *Arch. Hist. Exact. Sci.*, 21:229–244, 1980.
57. V. A. Vatutin and V. G. Mikhailov. Limit theorems for the number of empty cells in an equiprobable scheme for group allocation of particles, *Theory of Probability and its Applications (Transl. of Teorija Veroyatnosti i ee Primenenija)*, 27:734–743, 1982.
58. H. Wilf. *Generatingfunctionology*. Academic Press, San Diego, 1990.

*Department of Statistics*  
*University of California*  
*367 Evans Hall # 3860*  
*Berkeley, CA 94720-3860*  
*pitman@stat.Berkeley.EDU*