

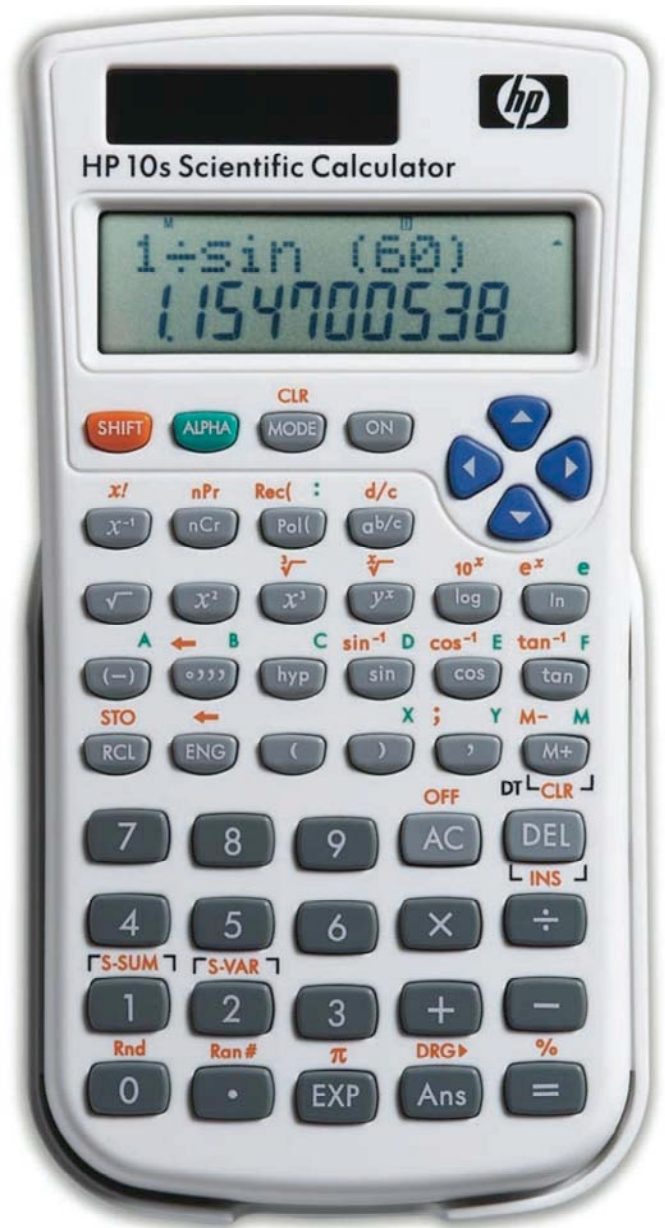


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HP 10s Probability – Rearranging Items

Rearranging Items

Practice Solving Problems Involving Factorials, Permutations, and Combinations



Rearranging items

The calculation of probabilities often involves counting the ways in which items can be rearranged. We have three functions at our disposal for this purpose: factorial, permutations and combinations.

If n is a *positive integer*, its factorial (whose symbol is $n!$) is the product of all the positive integers up to and including n :

$$n! = n \times (n-1) \times (n-2) \times \dots \times 2 \times 1$$

$0!$ is defined as 1.

A permutation of r from n is a way in which a set of r elements may be chosen in order from a set of n elements. In other words, it's an *ordered* subset of a set of distinct objects. The number of possible permutations, each containing r objects, that can be formed from a collection of n distinct objects is given by:

$${}^n P_r = P_r^n = {}_n P_r = P(n, r) = (n)_r = \frac{n!}{(n-r)!}$$

The above expression also shows the multiple ways of symbolizing permutations. When a permutation involves all the elements of a set (i.e. $r = n$) then it is called a *rearrangement*, and also as *shuffle* especially when cards are used. Notice that in this case:

$$P_r^n = P_n^n = \frac{n!}{0!} = n!$$

A combination is a selection of one or more of a set of distinct objects without regard to order. These are the different ways of denoting combinations, and the number of possible combinations, each containing r objects, that can be formed from a collection of n distinct objects:

$${}^n C_r = C_r^n = {}_n C_r = C(n, r) = \binom{n}{r} = \frac{n!}{(n-r)!r!}$$

As far as rearranging items is concerned, whether order is important or not is the *only* difference between combinations and permutations.

One of the most important theorems on combinations is Vandermonde's theorem, which states that:

$$C_r^n = C_{r-1}^{n-1} + C_r^{n-1}$$

The factorial function was traditionally used for calculating permutations and combinations, which show up in many discrete probability distribution calculations, such as the binomial and hypergeometric distributions.

On the HP 10s all these functions are executed using the $\frac{x!}{}$, $\binom{n}{r}$ and $\frac{nPr}{}$ keys. The HP 10s errors for factorials of integers greater than 69, but this covers most of the problems you will probably find, although numbers larger than 69 can be used for combinations and permutations, if the result does not cause an overflow.

Practice solving problems involving factorials, permutations, and combinations

Example 1: Calculate the number of combinations and permutations of 15 objects taken 5 at a time.

Solution: The number of combinations is calculated by first keying in the value of n (it can be the result of a calculation) then pressing \boxed{nCr} and finally keying the value of r. $\boxed{=}$ displays the result:

$$\boxed{1} \boxed{5} \boxed{nCr} \boxed{5} \boxed{=}$$

Likewise, the number of permutations is calculated by pressing:

$$\boxed{1} \boxed{5} \boxed{SHIFT} \boxed{nPr} \boxed{5} \boxed{=}$$

Answer: 3003 and 360360.

Example 2: Calculate the number of ways that six people can line up for a photograph.

Solution: Since the order does matter in this example, the problem is solved as a permutation: P_6^6 . Press:

$$\boxed{6} \boxed{SHIFT} \boxed{nPr} \boxed{6} \boxed{=}$$

Note that $P_6^6 = 6! = 6 \times 5 \times 4 \times 3 \times 2 \times 1$, so this example can be solved using the factorial function, which is a postfix function on the HP 10s:

$$\boxed{6} \boxed{SHIFT} \boxed{x!}$$

The $\boxed{=}$ key is not required now, because the result of a postfix function is automatically displayed as soon as its key is pressed.

Answer: 720

Example 3: In how many different ways can five seats be filled by a group of ten persons?

Solution: Again, the order is important, so the answer is P_5^{10} . Press

$$\boxed{1} \boxed{0} \boxed{SHIFT} \boxed{nPr} \boxed{5} \boxed{=}$$

Answer: 30,240

Example 4: How many different hands of 5 cards could be dealt from a standard deck of 52 cards? Assume the order of the cards in the hand does not matter.

Solution: Since the order of the cards in the hand does not matter, the problem is solved as a combination: C_5^{52}

$$\boxed{5} \boxed{2} \boxed{nCr} \boxed{5} \boxed{=}$$

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Answer: 2,598,960 different hands.

Example 5: If five cards are dealt from a standard deck of 52 cards, calculate the probability of these five cards containing four-of-a-kind.

Solution: The probability is the number of favorable events divided by the number of possible events. There are 13 ranks of four-of-a-kind, the fifth card being any of the remaining 48 cards. The number of possible five-card hands has been calculated in the previous example: it is given by the combination C_5^{52} . Therefore, the probability of being dealt four-of-a-kind is:

$$P = \frac{\text{possible four - of - a - kind hands}}{\text{possible five - card hands}} = \frac{13 \times 48}{\binom{52}{5}}$$

The keystroke sequence is:

1 3 × 4 8 ÷ 5 2 nCr 5 =

Answer: 0.000240096. Approximately, 1 out of 4165 hands (which is calculated by inverting the result).

Example 6: Find the probability that at least two of 23 people have the same birthday.

Solution: The probability that at least two of n persons have the same birthday is given by: $1 - \frac{P_n^{365}}{365^n}$. In this example $n = 23$:

1 - 3 6 5 nPr 2 3 ÷ 3 6 5 yx 2 3 =

Answer: 0.507297234. The probability is greater than 50%. You can easily verify that for $n \leq 22$, the probability is smaller than 50%, so 23 is the smallest number of persons such that the probability of at least two of them having the same birthday is greater than 50%!

Example 7: Evaluate the binomial density function $f(x)$ at $x=4$ for a constant probability of success (p) of 0.49 and 6 Bernoulli trials (n).

Solution: $f(x) = \binom{n}{x} \cdot p^x \cdot (1 - p)^{n-x}$. In our case: $f(4) = \binom{6}{4} \cdot 0.49^4 \cdot (1 - 0.49)^{6-4}$

6 nCr 4 × . 4 9 yx 4 × (1 - . 4 9) yx (4 - 2) =

Answer: $f(4) = 0.224913711$

Example 8: If you flip a coin 10 times, what is the probability that it comes up tails exactly 4 times?

Solution: It is an application of the previous example. In this case, $n = 10$, $x = 4$ and $p = 0.5$:

1 0 nCr 4 × . 5 yx 4 × . 5 yx (1 0 - 4) =

Answer: 0.205078125. If you flip a coin 10 times, there is a 20.51% chance of seeing heads 4 times.