

# Vote Counting

Your team is going to celebrate their successful software release with an outing. To keep things as fair as possible they have agreed to vote on their choice of outing, and use a preferential vote counting scheme. Write an application that helps people enter their votes on to a virtual ballot paper, then counts the votes to select a winner.

## *Domain Background*

In a preferential vote counting system, voters are allowed to vote for more than one item so that they can also express a second, third, etc. preference in the event that their first preference is unelectable. In a paper based system, the votes (also called preferences) are written on a ballot paper by the voter. A voter is given an empty ballot paper with a list of the candidates (also called options) like this:

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	
C. Movie night	
D. Museum visit	

The voter can then fill out the empty ballot paper with their choices by putting consecutive numbers against the candidates they wish to be elected in their order of preference. In our situation, we will allow users to nominate as many or as few choices as they wish.

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	2
C. Movie night	
D. Museum visit	1

In the above example, the voter has selected a museum visit as their first preference, then ten pin bowling as their second preference. They have not expressed a third or fourth preference because they're not interested in any of the remaining options or don't care which of them wins the election if they can't have their first or second choice.

In our election, we are only selecting one winner. The rule we will apply is that the winner is the candidate that has more than half of the available votes. To start out the counting, we allocate ballot papers to each candidate according to the first preference written on it. At this point it is possible that no candidate has more than half the number of available votes (called the quota) yet. To resolve this, we find the candidate (or candidates if there are more than one with the same number of votes) with the least number of votes and eliminate them from the election. When a candidate is eliminated, all the ballot papers that have been assigned to them are re-allocated to the next

available preference on each of those ballot papers. This process repeats in rounds until one candidate has more than half of the available votes.

There are a few special rules and edge cases to be aware of:

- 1) A ballot paper can become ‘exhausted’ if it has already been assigned to all of the candidates for which a preference has been provided or if all of the preferences voted for on the ballot paper have already been eliminated. When a ballot paper is exhausted, it can no longer be assigned to anyone, so the number of votes that are required to win the election (the quota) must be re-calculated.
- 2) If there is a tie between two or more leading candidates and there are no other candidates that can be eliminated, one candidate should be chosen at random for elimination.

### Example

Suppose that we have four candidates to choose from. The (empty) ballot paper might look like:

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	
C. Movie night	
D. Museum visit	

After all the ballot papers have been filled out by voters, we might have the following:

Candidate	Vote
A. Winery tour	1
B. Ten pin bowling	2
C. Movie night	4
D. Museum visit	3

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	
D. Museum visit	3

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	3
C. Movie night	1
D. Museum visit	4

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	4
C. Movie night	1
D. Museum visit	2

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	2
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	3
D. Museum visit	

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	2
C. Movie night	1
D. Museum visit	4

### Round 1

First we allocate every ballot to the first preference expressed by the voter. To make the situation clear in this example there is one column per candidate, with the ballots currently assigned to the candidate in that column. Also, we'll grey out each preference as it is allocated. In a real manual counting process we wouldn't bother with this, but we'll do it here to make things more obvious.

#### *Winery Tour*

Candidate	Vote
A. Winery tour	1
B. Ten pin bowling	2
C. Movie night	4
D. Museum visit	3

#### *Ten Pin Bowling*

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	
D. Museum visit	3

#### *Movie Night*

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	3
C. Movie night	1
D. Museum visit	4

#### *Museum Visit*

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	3
D. Museum visit	

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	4
C. Movie night	1
D. Museum visit	2

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	2
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	2
C. Movie night	1
D. Museum visit	4

As there are 8 votes in the system the quota required to win is 5 votes, so there is no winner yet.

## Round 2

The candidate with the least number of votes is “Winery tour”, so all of the ballots allocated to it are re-assigned to the next available preference indicated by the voter. In this case there is a single ballot that has been moved over to the the “Ten pin bowling” candidate, and we have greyed out that preference to indicate that it has been allocated. In the diagram below, the moved ballot is shown in red. Once again for the purpose of clarity, we’ll grey out all remaining preferences for the “Winery tour” candidate, because it has been eliminated from the election and can no longer have ballots allocated to it.

### Winery Tour

### Ten Pin Bowling

### Movie Night

### Museum Visit

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	
D. Museum visit	3

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	3
C. Movie night	1
D. Museum visit	4

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	3
D. Museum visit	

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	4
C. Movie night	1
D. Museum visit	2

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	2
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	1
B. Ten pin bowling	2
C. Movie night	4
D. Museum visit	3

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	2
C. Movie night	1
D. Museum visit	4

There are still 8 active ballots in the system so the quota remains the same at 5, and there is still no winner.

### Round 3

The candidate with the least number of votes is “Museum visit”, so all the ballots allocated to it are re-allocated. One of the votes in the “Museum visit” column had no more available preferences to which it could be allocated (the only remaining choice that the voter made has been eliminated), so it is now an exhausted ballot and is indicated below in grey. The red ballot is the one that was moved.

#### Winery Tour

#### Ten Pin Bowling

#### Movie Night

#### Museum Visit

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	
D. Museum visit	3

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	3
C. Movie night	1
D. Museum visit	4

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	
C. Movie night	
D. Museum visit	1

Candidate	Vote
A. Winery tour	2
B. Ten pin bowling	1
C. Movie night	3
D. Museum visit	

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	4
C. Movie night	1
D. Museum visit	2

Candidate	Vote
A. Winery tour	1
B. Ten pin bowling	2
C. Movie night	4
D. Museum visit	3

Candidate	Vote
A. Winery tour	3
B. Ten pin bowling	2
C. Movie night	1
D. Museum visit	4

Candidate	Vote
A. Winery tour	
B. Ten pin bowling	2
C. Movie night	
D. Museum visit	1

There are now only 7 votes in the system because one has been exhausted. That means that the new quota is 4, so the “Ten pin bowling” candidate is declared the winner.

## *Application Requirements*

The application will be given a file at start up time that lists the options that the team members can choose from. It will contain one option per line. Any additional white space (at the start or end of a line, or blank lines) should be ignored. For example, the input file might look like:

```
Winery tour
Ten pin bowling
Movie night
Dinner at a restaurant
Art gallery visit
Picnic in the park
Horse riding lessons
Museum visit
Surfing lesson
```

At start up, the list of options are to be displayed on the screen with a unique letter prefix. This should be followed by a prompt to indicate that the system is ready to accept commands. For example:

```
A. Winery tour
B. Ten pin bowling
C. Movie night
D. Dinner at a restaurant
E. Picnic in the park
F. Horse riding lessons
G. Museum visit
>
```

Users can then vote for their choices in preference order by typing in a letter sequence on a single line. A vote line (a ballot) will contain the letter corresponding to the user's first choice, followed by their second choice, etc. The user only needs to vote for as many items as they are interested in. Whitespace can be ignored. A ballot that includes an option twice, or a letter that does not correspond to one of the listed candidates is to be considered an informal vote and discarded.

When the word "tally" is entered at the prompt, the application is to count up the votes, display the results, and exit. Vote counting proceeds in rounds until the flow of preferences has resulted in one option reaching enough votes to meet the quota for selection. The quota is calculated as:

$$(\text{number of non-exhausted ballots} / 2) + 1$$

This is to be calculated at each round whenever needed or whenever the number of non-exhausted votes might change. At each round of voting the votes for each candidate are to be measured against the quota.

If a candidate has at least as many votes as the quota, it is selected as the winner and no more counting is necessary. If no option has enough votes to meet the quota, then the candidate or candidates with the smallest number of votes are eliminated, and all the votes for those options are distributed to their next available (i.e. non eliminated) preference as chosen at voting time. If there are no more preferences expressed for a ballot or the remaining preferences have all been eliminated, the ballot is considered to be exhausted.

At each round of counting, the program should display an explanation of what has happened (e.g. “Candidate X eliminated” or “Candidate selected as winner”), the quota required to win, and the number of votes currently assigned to each candidate.