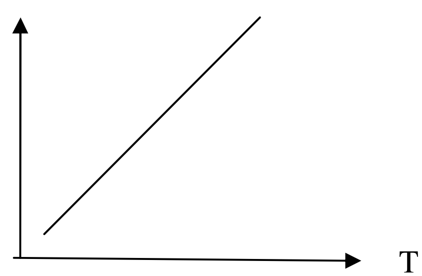
Answer 1:

1) Simulated Annealing is a non-deterministic Algorithm because of the following reasons:
    1. Random nature of next-move selection (i.e. perturb operation is usually random)
    2. Random nature of bad-move acceptance in the high-temperature phase.

   Because of these, it can be said that SA does not make deterministic decisions to approach a solution: the search path of SA is always different for each run, assuming proper randomness.
2) **Metropolis Criterion** is the decision mechanism in SA to determine whether a move that has been made should be accepted or rejected. Good moves are always accepted, while bad move acceptance is a function of the current temperature, as well as the 'badness' of the move (i.e. $-(\Delta h/T)$).
3) **Cooling Schedule** is defined as a set of values for the control variables in SA, i.e. $\{T_0, M, \text{Maxtime}, \alpha, \beta\}$. This set of values determines the behavior of the SA Algorithm. As such they must be finely tuned for each problem type, so as to allow proper approximation of the Annealing Process.
4) Initial Temperature has to be chosen high enough that early in the algorithm probability of bad-move selection is close to 1. M and β (the metropolis runtime variables) have to be chosen such that an appropriate number of moves are made/tested at each temperature level, and as such are related to the size of the problem. β could be slightly greater than 1 (never less) so that more time is spent searching on a lower temperature level than on its preceding higher level. α is set less than 1 to allow temperature decrease with each run of Metropolis. Usually it is set close to 1 (i.e. 0.9, 0.85, etc). MAXTIME can either be a hard constraint of time, i.e. give the best solution found until this time limit, or it could be variable based on a specified quality that must be achieved. Generally, for the first case, MAXTIME, α, and β should be selected that the Annealing behavior is not terminated prematurely. The combination of MAXTME and α should be such that near the end of the algorithmic run, the value of T should have decreased so that the probability of selecting bad moves is negligible.
5) Assuming that the "*random*" numbers exhibit a proper bell-curve of values, the inequality given is used to select bad moves in SA. The right side expression is a function of the difference b/w new and current cost, as well as the current temperature. As temperature decreases or as the difference in costs increases, the probability that the inequality is satisfied also decreases. Thus it is more probable that the inequality is satisfied when the difference in costs is less and temperature is high.
6) The linear function would have a positive gradient with respect to T (temperature). As T increases, the exponential function increases as well, thereby increasing the probability of accepting bad moves. Therefore, the linear function should also exhibit this quality.



7) **SA vs. GA**
   a. Simulated Annealing operates on a single solution at a time, whereas Genetic Algorithms operate on a group of solutions.
   b. Simulated Annealing performs small changes/moves on the solution in attempting to achieve improvements in cost. GAs on the other hand make drastic changes to their set of solutions in their ‘crossover’ operations, attempting to combine the best qualities of multiple solutions.
   c. SA is a memory less process, while GA attempts to refine the search based on previous searches. Future moves in GAs depend upon previous moves, whereas this is not the case in SA.
   d. GAs operate on coded representations of the solutions, whereas SA operates on the solution itself.
   e. GAs have multiple operators that are used to alter the solution (parent selection, crossover, mutation), whereas SA implementations usually have simple perturb functions.
8) “Survival of the fittest” is a concept in evolution that states that organisms that are most adapted to, or ‘fit’ for their environment are most likely to survive and pass on their genes, and hence their characteristics onto future generations. Thus, after several generations, assuming the environment is constant, the characteristics in organisms will approach the optimum characteristics required for survival in that particular environment.
9) The Crossover operation provides a mechanism for transferring the characteristics of parent chromosomes to their offspring. It is hoped that some of the offspring produced through properly selected crossover operations will have the best characteristics of the parents, and these offspring will most likely be retained for producing further generations.
10) The three places in GAs where non-determinism is introduced are:
   a. Parent selection (this is done randomly, but is usually biased towards the solutions with the better characteristics/cost).
   b. Crossover operations (multiple kinds of operations may be tried randomly, or even choosing random cut-points causes randomness)
   c. Mutation (altering alleles in chromosomes and selecting the genotypes for mutation is done probabilistically).

Answer 4:

In designing crossover operators for Polish notation strings, several constraints need to be considered:

- The Balloting property is satisfied
- The polish expression remains normalized (preferably)

In order to do this, we must keep track of the individual operators themselves, as they are binary in nature, as opposed to the operands, that have valid permutations. The following crossovers are proposed:

1. Modified Partially Mapped Crossover: here, PMX is carried out with one adjustment: the number of operands is kept the same as in the parent whose half-string we have copied.

   For example:

   P1 = 53V24|VH1V P2 = 12V3V|4H5H

   For PMX, we take the right hand string of P2, and read from the left half of P1:

   O1 = 13V2V|4H5H

   In the above example, the offspring was generated without any serious concern for the operands. Lets now take the second half of P1:

   O2 = 52V3**?**|VH1V

   Here, the balloting property would be violated if we placed operator V at location 5. also, operand 4 would also be excluded, resulting in an invalid solution. Now, since the number of operators should not exceed 4, and all 4 operators have been used up, any extra operators should be treated as duplicate alleles. Thus, the offspring would be:

   O2 = 52V34|VH1V

2. Independent Crossover operations on operands and operators: Notice that the operators represent a set of binary values: (V, H), where as the operands exist in permutations. Thus we can treat the two separately, performing the simple cut-catenate on the operators, and any other crossover operation on the operands, and then recombining them by maintaining the same locations for the operators as in one of the parents:

   For Example:

   P1 = 53V24VH1V P2 = 12V3V4H5H

   P1 = 532|41 VV|HV

   P2 = 123|45 VV|HH

   Now, applying cut-catenate (simple crossover) on the operators and the order crossover on the operands (copying from P1 the left sub-string for both operations, as well as the ordering of operands and operators):

   O3 = 532|14 VV|HH

   O3 = 53V21VH4H

   This approach however runs the risk of violating the Normalized polish expression property. To avoid this, and additional precaution could be to not cut the operator sequence in the middle of a chain (wrt the parent whose ordering is preserved).

Mutation operations: the mutation operations are similar to the perturb functions in Simulated Annealing. Thus we apply the same functions developed for simulated annealing when applied to the Floorplanning problem:

M1: Adjacent Operator swap.

M2: Operand Chain inversion
M3: Adjacent Operand/Operator swap.

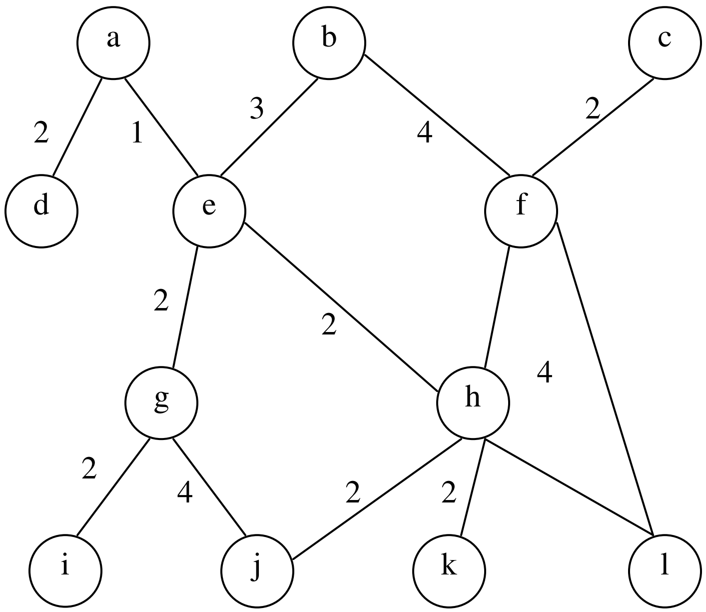
Answer 2:

We use the semi-perimeter method to estimate the length of the interconnect. The maximum coordinates of the bounding box are (0, 0) and (35, 40). Therefore the approximate total interconnection length is 75 micrometers.

Now,

Delay = Base Delay + Load Factor * Capacitance
= 0 + 3 * [(total capacitances at the inputs of the gates) + (length of interconnect * width of interconnect * capacitance per unit area)]
= 0 + 3 * [(0.1*5) + (75 * 3 * 0.01)]
= 3 * 2.75
= 8.25 nano seconds.

Answer 5:



f	j	c	i
k	d	h	b
l	e	a	g

1) Assuming that the clique represented by {f, h, l} is a multi-pin net, the lengths of each of the wire segments has been calculated using semi-perimeter method. The total wire length is = 30 units.

2) P1 = l e a g b| h d k f j c i

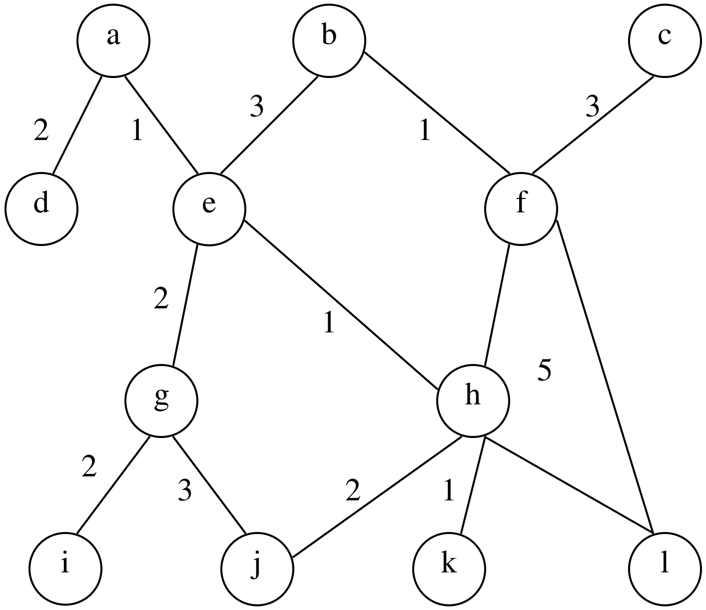
   P2 = i j l c k| a g b f d e h

   Applying the PMX crossover with P2 as root:

   O1 = l c i j k | a g b f d e h

   Applying the Order crossover with P2 as root:

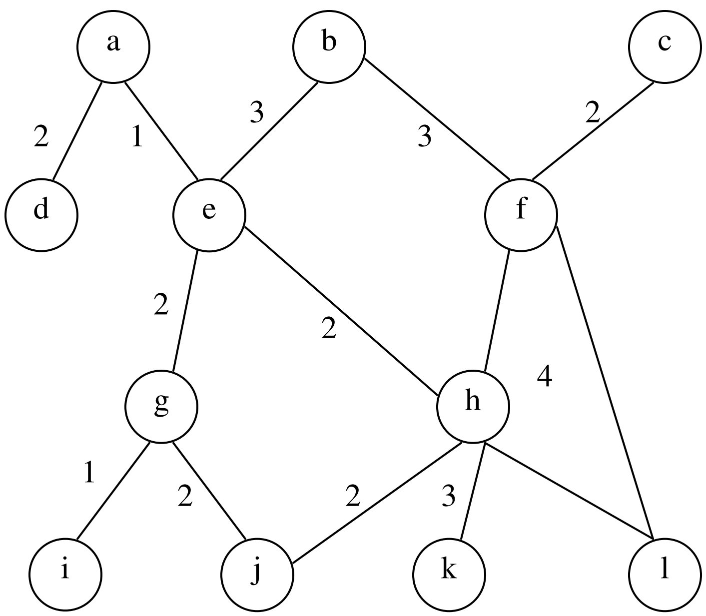
   O2 = i j l c k | e a g b h d f



Wire lengths for O1. Total = 26

f	d	e	h
b	g	a	k
l	c	i	j

Placement for O1
l c i j k a g b f d e h

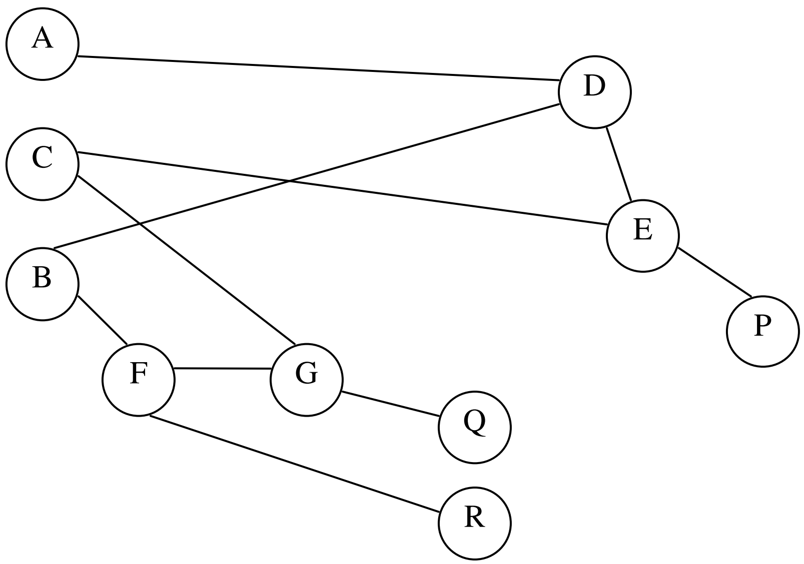


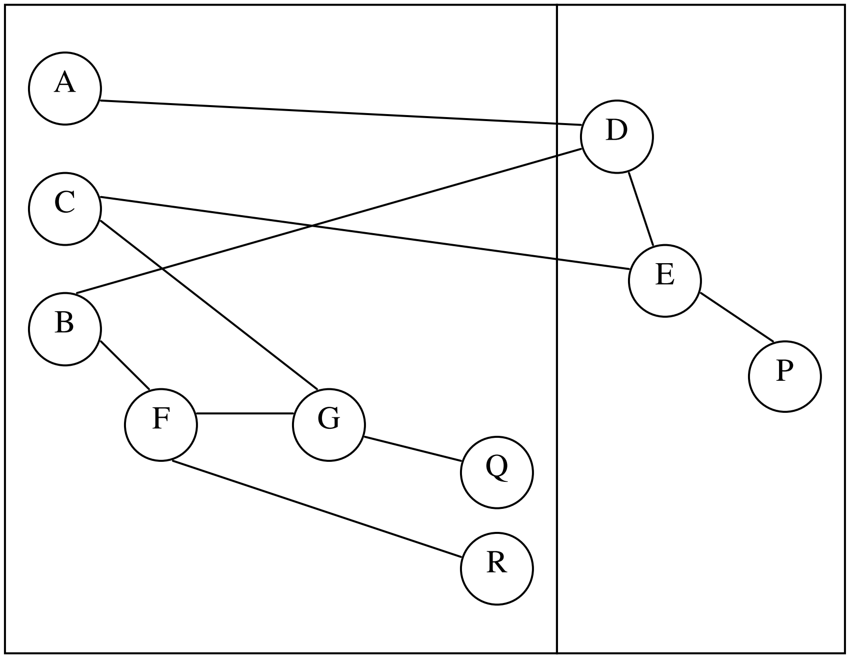
Wire lengths for O1. Total = 27

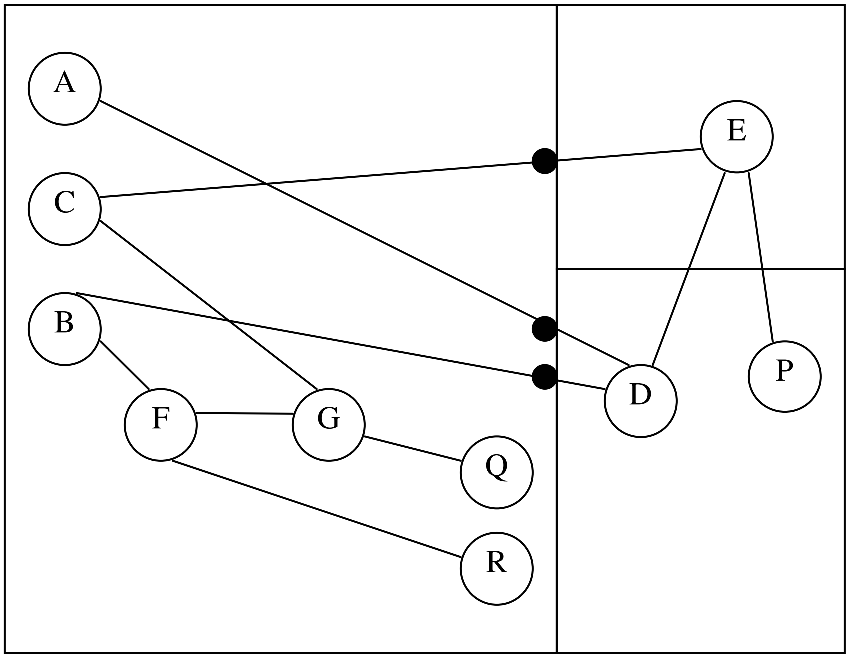
b	h	d	f
g	a	e	k
i	j	l	c

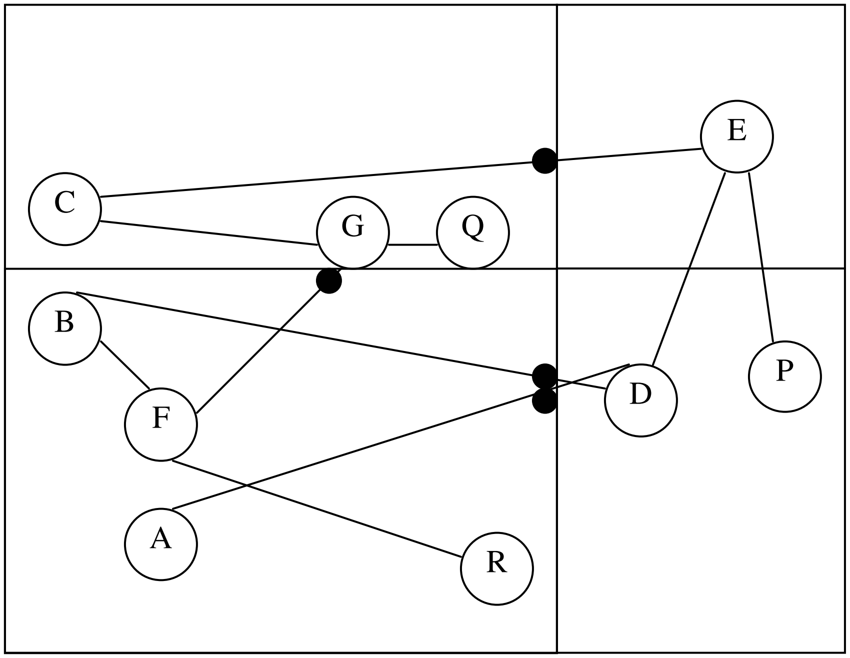
Placement for O2
i j l c k e a g b h d f

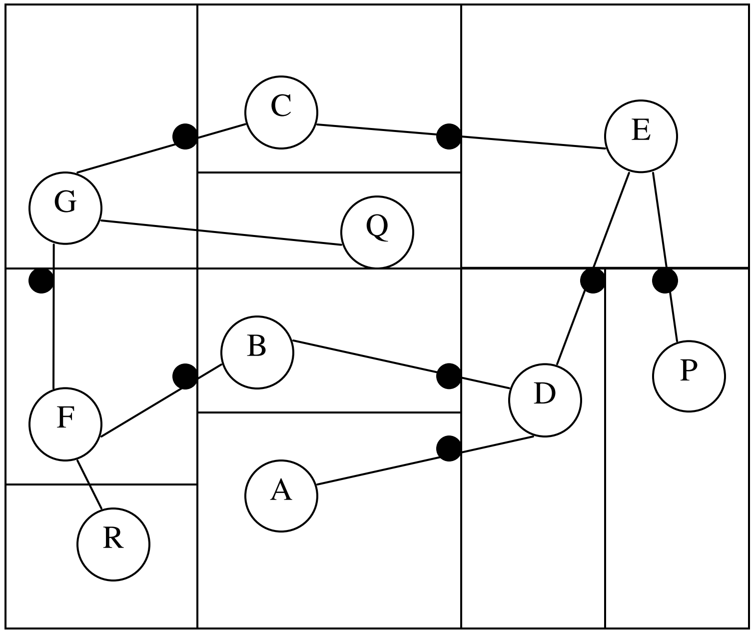
<u>Answer 3:</u> In this exercise, partitioning is done on the basis of equal weight distribution, as well as minimum wires cut.







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