

1. Suppose you are given a magic black box that somehow answers the following decision problem in *polynomial time*:

- INPUT: A CNF formula φ with n variables x_1, x_2, \dots, x_n .
- OUTPUT: TRUE if there is an assignment of TRUE or FALSE to each variable that satisfies φ .

Using this black box as a subroutine, describe an algorithm that solves the following related search problem in *polynomial time*:

- INPUT: A CNF formula φ with n variables x_1, \dots, x_n .
- OUTPUT: A truth assignment to the variables that satisfies φ , or NONE if there is no satisfying assignment.

[Hint: You can use the magic box more than once.]

2. An **independent set** in a graph G is a subset S of the vertices of G , such that no two vertices in S are connected by an edge in G . Suppose you are given a magic black box that somehow answers the following decision problem in *polynomial time*:

- INPUT: An undirected graph G and an integer k .
- OUTPUT: TRUE if G has an independent set of size k , and FALSE otherwise.

- (a) Using this black box as a subroutine, describe algorithms that solves the following optimization problem in *polynomial time*:

- INPUT: An undirected graph G .
- OUTPUT: The size of the largest independent set in G .

[Hint: You've seen this problem before.]

- (b) Using this black box as a subroutine, describe algorithms that solves the following search problem in *polynomial time*:

- INPUT: An undirected graph G .
- OUTPUT: An independent set in G of maximum size.

To think about later:

3. Formally, a **proper coloring** of a graph $G = (V, E)$ is a function $c: V \rightarrow \{1, 2, \dots, k\}$, for some integer k , such that $c(u) \neq c(v)$ for all $uv \in E$. Less formally, a valid coloring assigns each vertex of G a color, such that every edge in G has endpoints with different colors. The **chromatic number** of a graph is the minimum number of colors in a proper coloring of G .

Suppose you are given a magic black box that somehow answers the following decision problem *in polynomial time*:

- INPUT: An undirected graph G and an integer k .
- OUTPUT: TRUE if G has a proper coloring with k colors, and FALSE otherwise.

Using this black box as a subroutine, describe an algorithm that solves the following **coloring problem** *in polynomial time*:

- INPUT: An undirected graph G .
- OUTPUT: A valid coloring of G using the minimum possible number of colors.

[Hint: You can use the magic box more than once. The input to the magic box is a graph and **only** a graph, meaning **only** vertices and edges.]