

## Welcome

# LTL 2

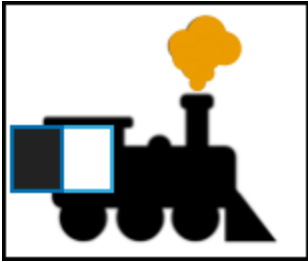
Greetings!

This homework asks about the meaning of LTL formulas and their translation to and from English.

There are three parts, similar to last time:

1. Match traces and formulas (9 questions)
2. Translate formulas to English (5 questions)
3. Translate English to formulas (5 questions)

The questions ask about the state of a robot-driven locomotive (RoboLoc) over time. The RoboLoc has three components, each of which can be ON or OFF at any point: the engine, the door, and the headlight. In the image below, the engine is on, the door is open, and the headlight is off:



= (Engine /\ DoorOpen /\ not Light)

The RoboLoc is a discrete system, not a hybrid system.

## Traces true-false

# Part 1 of 3: Match traces and formulas

The following questions ask whether a trace of the RoboLoc satisfies an LTL formula.

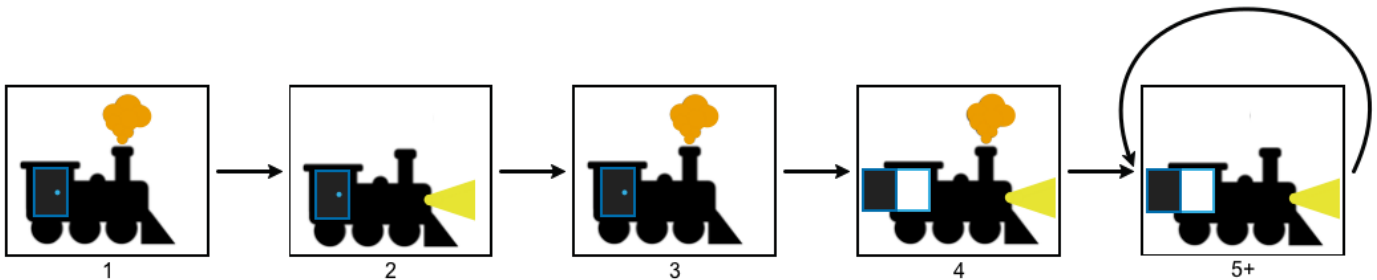
A trace is an infinite sequence of states. We represent traces as five states of the RoboLoc in which the final state repeats forever.

We first give two **Examples** to illustrate the questions and the style of answers that we are expecting.

**Example Question:** Is the formula

$G(\text{Engine} \ \wedge \ \text{Light})$

satisfied by this trace?



**Example Answer:** Yes, because either the engine (smoke) or the headlight is on in each state.

Does the example make sense to you?\*

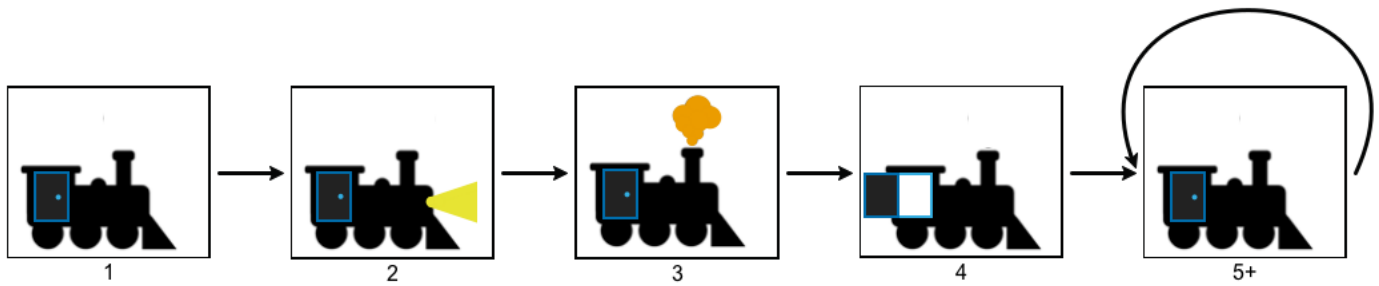
☐ Yes

☐  No (please explain)

**Example Question:** Is the formula

$F(\text{Engine} \ /\ \ \text{DoorOpen})$

satisfied this trace?



**Example Answer:** No, because there is no state in which the engine is on and the door is open.

Does the example make sense to you?\*

☐ Yes

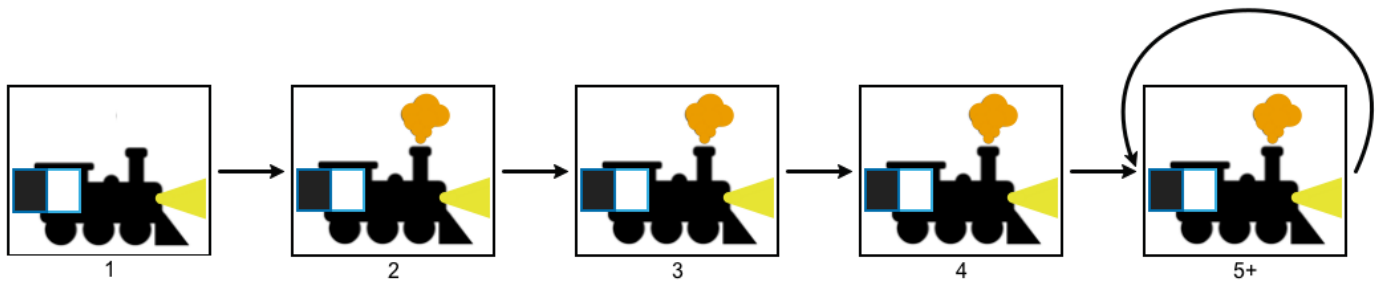
☐  No (please explain)

The actual task begins now.

**Q.** Is the formula

Engine

satisfied by this trace?\*



☐ Yes

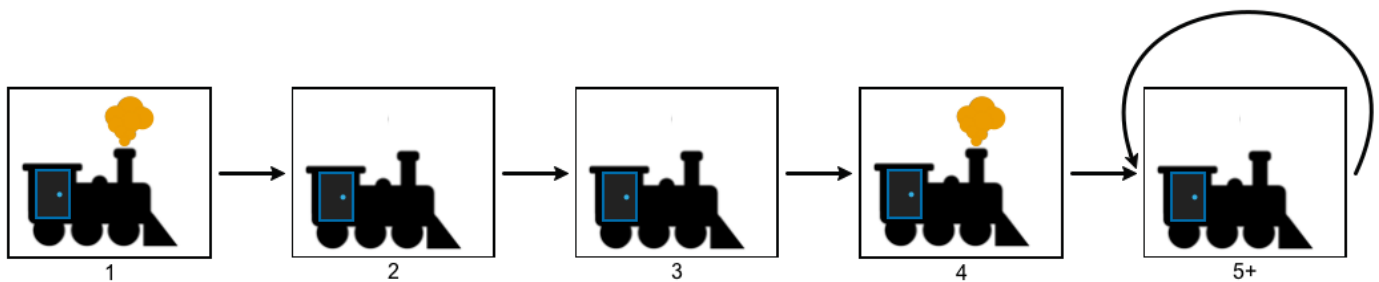
☐ No

(Optional) Feel free to explain your reasoning

**Q.** Is the formula

$X(X(X(\text{Engine})))$

satisfied by this trace?\*



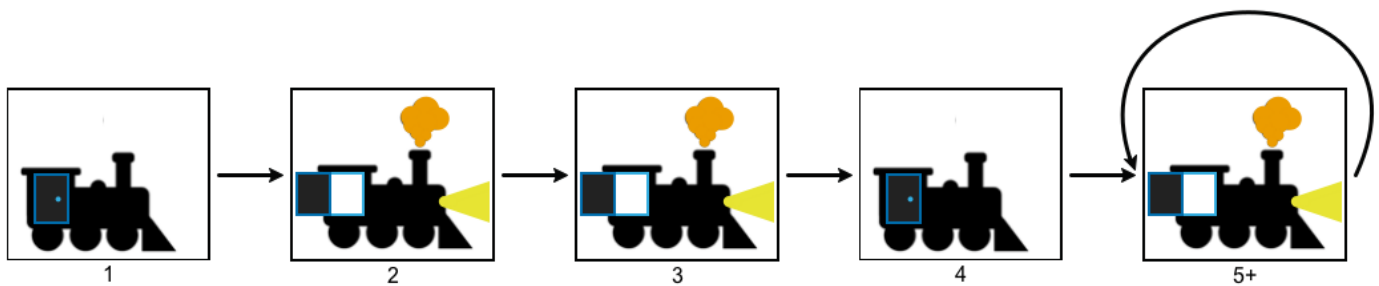
☐ Yes☐ No

(Optional) Feel free to explain your reasoning

**Q.** Is the formula

$G(\text{Engine} \implies X(X(X(\text{Engine}))))$

satisfied by this trace?\*

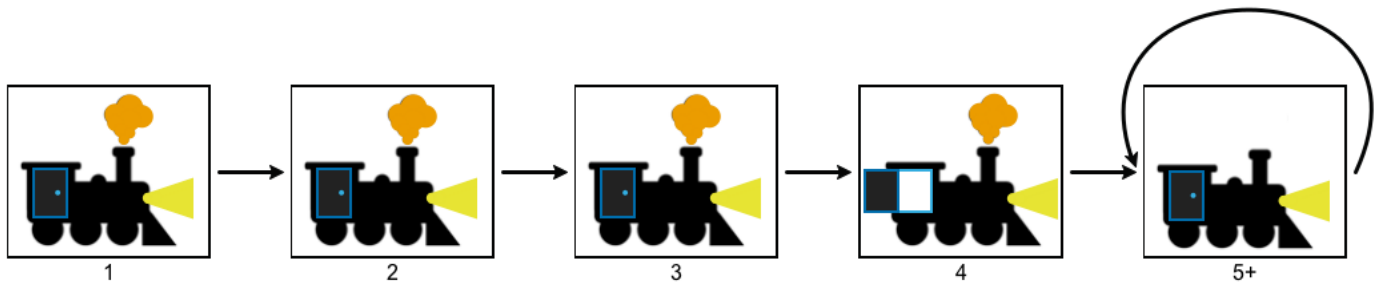
☐ Yes☐ No

(Optional) Feel free to explain your reasoning

**Q.** Is the formula

$X(\text{Engine}) \cup X(\text{DoorOpen})$

satisfied by this trace?\*



☐ Yes

☐ No

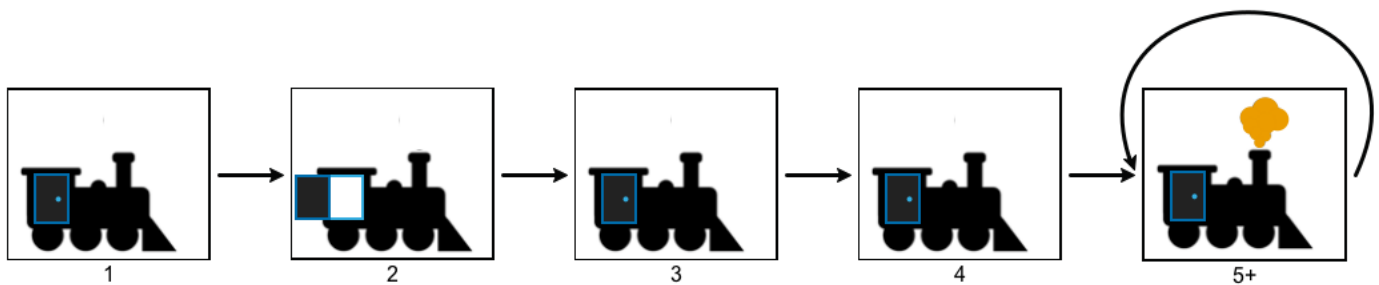
(Optional) Feel free to explain your reasoning



**Q.** Is the formula

$F(\text{Engine}) \wedge \neg F(\text{DoorOpen})$

satisfied by this trace?\*



☐ Yes

☐ No

(Optional) Feel free to explain your reasoning

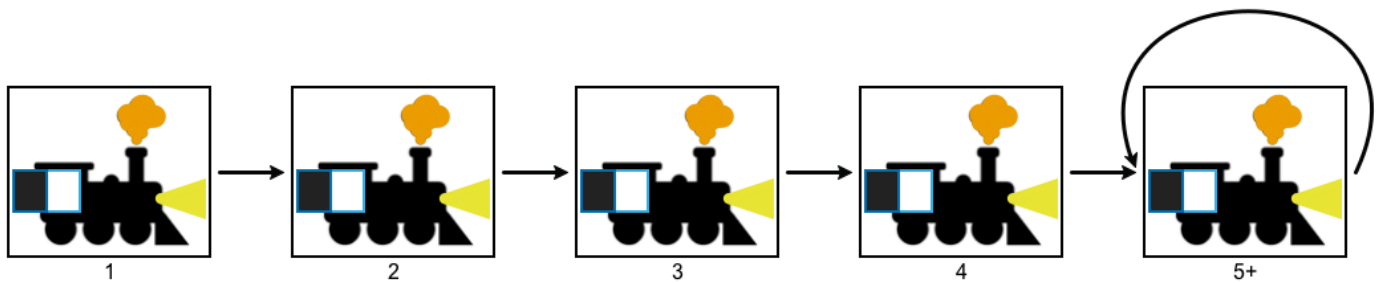




**Q.** Is the formula

$X(X(F(\text{Engine})))$

satisfied by this trace?\*



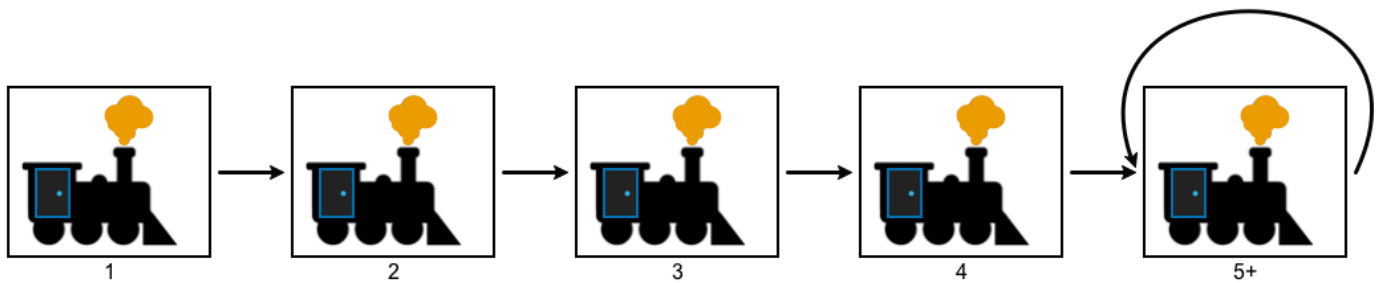
☐ Yes

☐ No

(Optional) Feel free to explain your reasoning



**Q.** Is the formula  
Engine U Light  
satisfied by this trace?\*



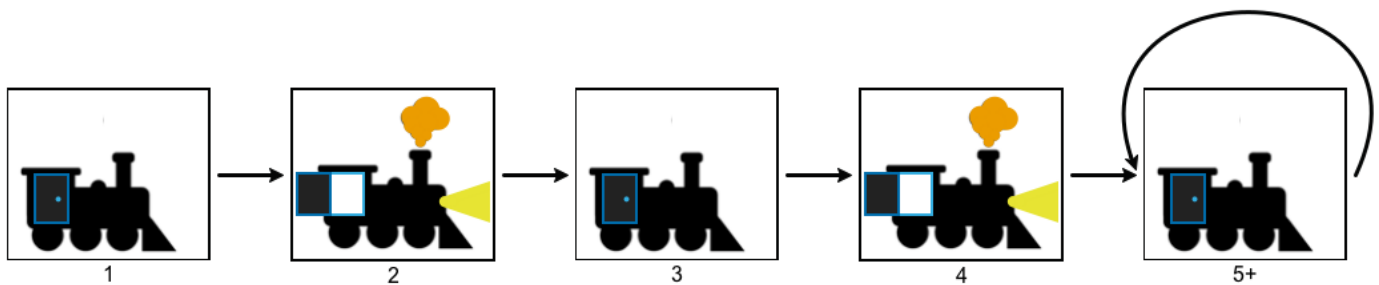
☐ Yes

☐ No

(Optional) Feel free to explain your reasoning



**Q.** Is the formula  
 $F(G(\text{Engine}))$   
satisfied by this trace?\*



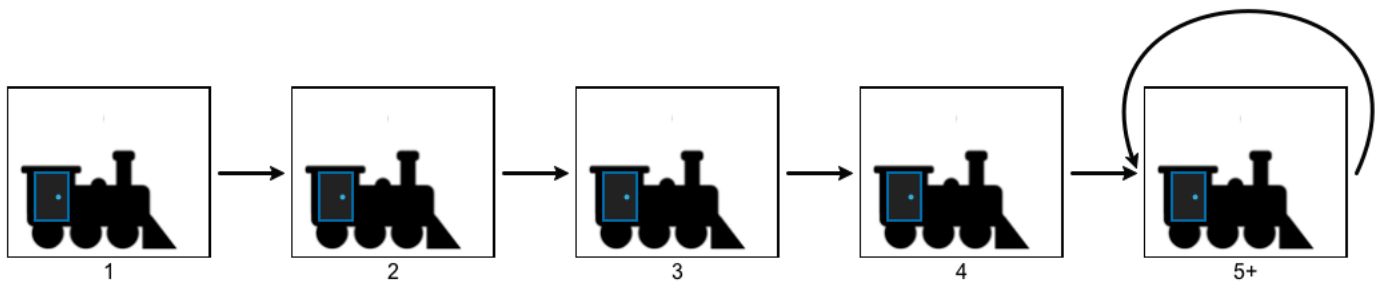
☐ Yes

☐ No

(Optional) Feel free to explain your reasoning



**Q.** Is the formula  
 $G(\text{Engine} \implies \text{Light})$   
satisfied by this trace?\*



- ☐ Yes
- ☐ No

(Optional) Feel free to explain your reasoning

## LTL to English

# Part 2 of 3: Translate formulas to English

Translate the following formulas to English sentences.

If you have do not know how to translate a formula, write "I don't know" below.

We first show two **Examples** to illustrate the questions and the style of answers that we are expecting.

### Example Question:

$G(\text{Engine} \implies X(\text{not}(\text{DoorOpen})))$

**Example Answer:** Whenever the engine is on, the door is closed in the next state.

Does the example make sense to you?\*

☐ Yes

☐  No (please explain)

**Example Question:**

Engine U not (Engine)

**Example Answer:** The engine is on for zero or more states and then turns off.

Does the example make sense to you?\*

☐ Yes

☐  No (please explain)

The actual task begins now.

Engine  $\Rightarrow$  X(X(X(Engine)))



(Optional) Feel free to explain your reasoning



X(X(F(X(Engine))))



(Optional) Feel free to explain your reasoning

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$F(\text{Engine}) \implies G(\text{Light})$

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(Optional) Feel free to explain your reasoning

A large, empty rectangular text box with a thin gray border. In the bottom right corner, there is a small icon consisting of two parallel diagonal lines, indicating a text input field.

$(\text{Engine} \cup \text{Light}) \text{ and } G(\text{Engine})$





(Optional) Feel free to explain your reasoning



$G(\text{Engine} \implies (X(\text{not}(\text{Engine})) \wedge X(X(\text{Engine}))))$



(Optional) Feel free to explain your reasoning

## English to LTL

# Part 3 of 3: Translate English to formulas

Translate the following English sentences to LTL formulas.

- If you do not know how to express an idea in LTL, write "I don't know" below.
- If you believe LTL cannot express a specification, write "inexpressible" and please explain.

As a reminder, here are the LTL connectives and RoboLoc variables:

- `G F X U`
- `/\ \ / ==> not`
- `Engine DoorOpen Light`

We first show one **Example** to illustrate the questions and

the style of answers that we are expecting.

**Example Question:** The door is never closed.

**Example Answer:**

G (DoorOpen)

Does the example make sense to you?\*

☐ Yes

☐  No (please explain)

The actual task begins now.

Whenever the engine is on, it is off in the next state and on again in the state after that.



(Optional) Feel free to explain your reasoning



The engine is on in exactly one state, but not necessarily the first state.



(Optional) Feel free to explain your reasoning

A large, empty rectangular text box with a thin gray border. In the bottom right corner, there is a small icon consisting of two parallel diagonal lines.

The engine cannot stay on for three states in a row.

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(Optional) Feel free to explain your reasoning

A large, empty rectangular text box with a thin gray border. In the bottom right corner, there is a small icon consisting of two parallel diagonal lines.

Whenever the engine is on, the light will be on then or at some point in the future.



(Optional) Feel free to explain your reasoning



The engine is on for zero or more states, and then turns off and remains off in the future.



(Optional) Feel free to explain your reasoning



## Block 4

This is the final page. You have two very important tasks left.

First, copy the response code below:

`${e://Field/ResponseID}`

Use this code to receive credit for this homework on Gradescope.

**DON'T FORGET TO COPY THE RESPONSE CODE!!**

Second, click the right arrow (→) below to submit.