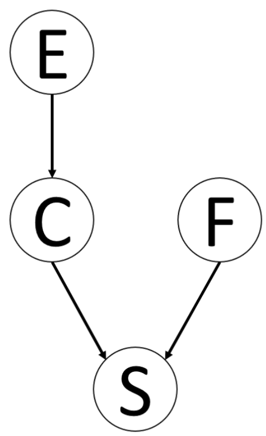
Suppose John can be very sick (S) that can be caused by two different reasons: getting the seasonal flu and catching a cold (F and C). John thinks that he sometimes catches a cold because he works so hard in his final project that he is exhausted (E) and feels sick. The Baye Net and corresponding conditional probability tables are shown below.

For each question, write down the symbolic answer using combinations of P(...) probabilities that are given to you below, e.g., “P(+e) x P(-f)”, where “+e” means “E is True” and “-f” means is False”). You do not need to calculate the numeric answer. You will lose marks if you do not fully develop your answer so that it only uses the probabilities given below.

$P(E)$	
$+e$	0.1
$-e$	0.9

$P(C \mid E)$		
$+e$	$+c$	1.0
$+e$	$-c$	0.0
$-e$	$+c$	0.1
$-e$	$-c$	0.9



$P(F)$	
$+f$	0.4
$-f$	0.6

$P(S \mid C, F)$			
$+c$	$+f$	$+s$	1.0
$+c$	$+f$	$-s$	0.0
$+c$	$-f$	$+s$	0.9
$+c$	$-f$	$-s$	0.1
$-c$	$+f$	$+s$	0.8
$-c$	$+f$	$-s$	0.2
$-c$	$-f$	$+s$	0.1
$-c$	$-f$	$-s$	0.9

(1) [3%] Please write down the joint probability P(+s, +c, +f, +e):

(2) [3%] What is the probability of catching a cold? (Hint: Do not refer to that John feels sick)

(3) [3%] What is the probability that John catches a cold given that he got the seasonal flu?

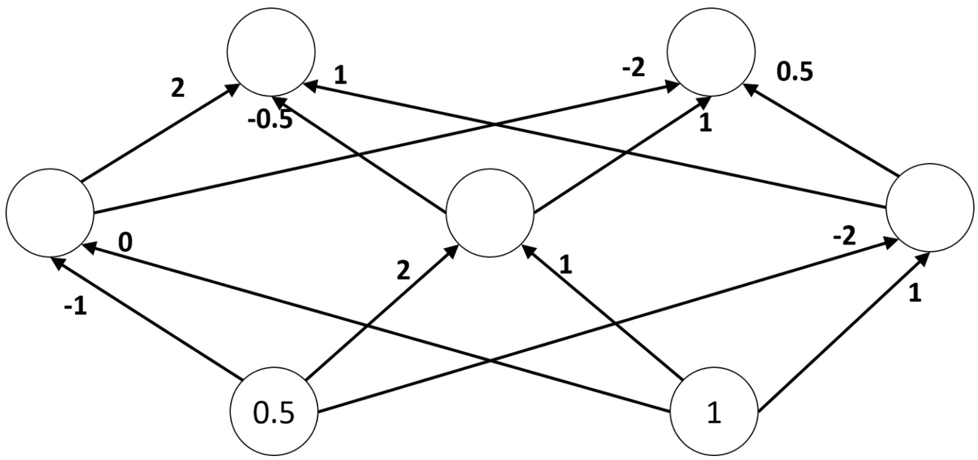
(4) [3%] What is the probability of getting exhausted given a cold, P(+e | +c)?

(5) [3%] What is the probability P(+e | +f)?

(6) [5%] What is the conditional probability P(+c | +s, +f)?

The following is a network of **linear** neurons, that is, neurons whose output is identical to their net input. The numbers in the circles indicate the output of a neuron, and the numbers at connections indicate the value of the corresponding weight.

7.1. [5%] Compute the output of the hidden-layer and the output-layer neurons for the given input (0.5, 1) and **enter those values into the corresponding circles**.



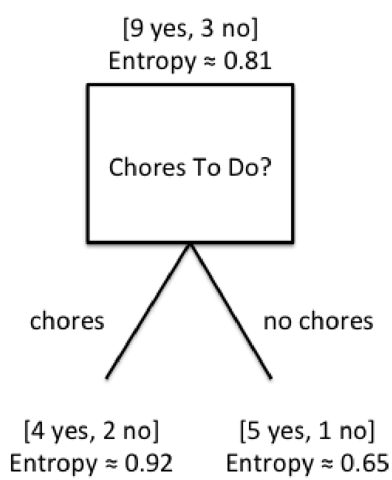
7.2. [3%] What is the output of the network for the input (1, 2), i.e. the left input neuron having the value 1 and the right one having the value 2?

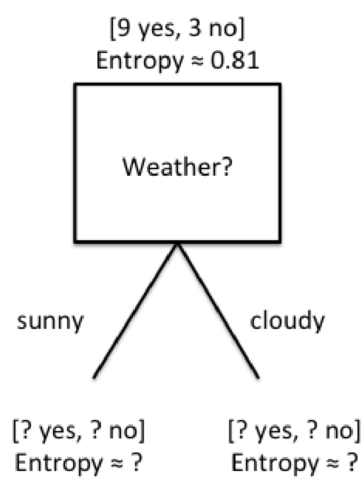
7.3. [2%] To answer 7.2, do you have to do all the network computations once again? Explain why you do or do not have to do this.

2. In trying to decide whether or not to go hiking, some of the factors I consider are the weather and whether or not I have chores to do at home. There are other factors as well of course. Some example decisions are summarized in the table below.

Weather	ChoresToDo	Hike
Sunny	chores	yes
Sunny	chores	yes
Sunny	no chores	yes
Sunny	no chores	yes
Sunny	no chores	yes
Sunny	no chores	yes
Cloudy	chores	no
Cloudy	chores	no
Cloudy	no chores	yes
Cloudy	no chores	no
Cloudy	chores	yes
Cloudy	chores	yes

With 9 positive examples of hiking and 3 negatives, the entropy or information of this decision in bits is 0.81. Consider the following decision trees, reflecting splitting on the attributes of Weather or ChoresToDo:





a) The ChoresToDo tree has been filled out. Complete the values for the Weather tree, including entropy. (Show your work) (6 points)

b) Calculate the information gain *IG* from splitting on ChoresToDo and Weather. Please show formulas used and steps clearly. You do not need to compute a final numerical result. Plug in values to the formulas so that the result could be calculated with a calculator. (4 points)

IG(ChoresToDo) =

IG(Weather) =

c) Which of the two attributes is a better choice in constructing a decision tree? Why? (2 points)

A [5%] You would like to know how useful it is for you to learn to take electric guitar lessons, so you would like to find out what the probability of getting hired by a heavy metal band is given that you took electric guitar lessons. What other probabilities would you need to know? (give a formula to show how these additional probabilities are used).

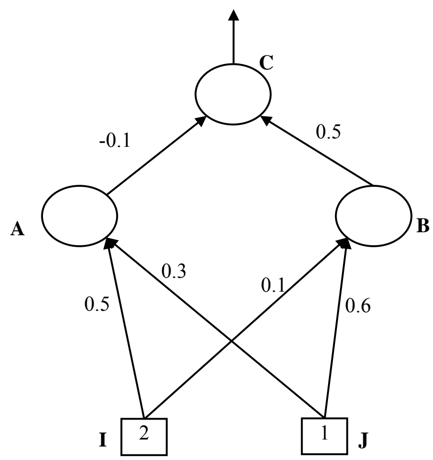
B [5%] (1) We have made a machine to classify whether a room smells fresh or unpleasant based on parts per million (PPM) of methane gas molecules that are in the air. A robot has taken a sample from room which has 100 PPM. From prior sampling, we have derived the following probabilities:

(a) P(100 PPM|Unpleasant) = 0.4
(b) P(100 PPM|Fresh) = 0.3
(c) P(Unpleasant) = 0.2
(d) P(Fresh) = 0.9
(e) P(100 PPM) = 2

Show using a Bayesian classifier whether the room's air should be classified as Fresh or Unpleasant. Be sure to show your work.

5.1 [8%] Consider the neural network shown below, where I, J are inputs and A, B, C are perceptrons. For each perceptron assume it's firing is based on the threshold rule discussed in class with Threshold = 1 i.e.,

$$f(x) = \begin{cases} 1, & if\ x \geq 1 \\ 0, & otherwise \end{cases}$$



a) [3%] Write the ***output*** for each perceptron in the circles in the above figure.

b) [5%] Given the expected output to be 1, find the (a) error value, and the updated weights for (b) AC and (c) BC.

5.2 [12%] You are building a set of perceptrons to mimic logic circuits. For each perceptron assume it's firing is based on the threshold rule discussed in class i.e.

$$f(x) = \begin{cases} 1, & if\ x \geq threshold \\ 0, & otherwise \end{cases}$$

Assume all inputs have value either 0 or 1. Show how perceptrons can be used to mimic the following logic sentences. For each expression, (a) draw the perceptrons, (b) show the weights (c) write the threshold.

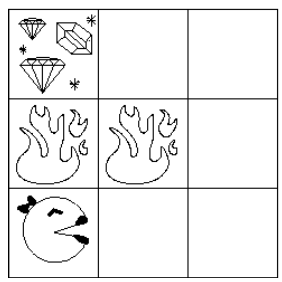
a) **[2%]** $A \wedge B \wedge C$

b) **[2%]** $A \wedge B \vee C$

c) **[3%]** $A \wedge \neg B \wedge C$

d) **[5%]** $A \oplus B \wedge C$

Ms. Pacman takes some time to go treasure hunting in the Gridworld island. Ever prepared, she has a map that shows where all the hazards are, and where the treasure is. From any unmarked square, Ms. Pacman can take the standard actions (N, S, E, W), but she is surefooted enough that her actions always succeed (i.e. there is no movement noise). If she lands in a hazard (H) square or a treasure (T) square, her only action is to call for an airlift (X), which takes her to the terminal 'Done' state; this results in a reward of -64 if she's escaping a hazard, but +128 if she's running off with the treasure. There is no "living reward."



(a) What are the optimal values, V^* of each state in the above grid if $\gamma = 0.5$?

(b) What are the Q-values for the last square on the second row (i.e., the one without fire)?

(c) What's the optimal policy?

It turns out that Ms. Pacman's map is mostly correct, but some of the fire pits may have fizzled out and become regular squares! Thus, when she starts Q-learning, she observes the following episodes:
[(0, 0), N, 0, (0, 1), N, 0, (0, 2), X, 128, Done]
[(0, 0), N, 0, (0, 1), N, 0, (0, 2), X, 128, Done]
[(0, 0), N, 0, (0, 1), E, 0, (1, 1), X, -64, Done]

(f) What are Ms. Pacman's Q-values after observing these episodes? Assume that she initialized her Q-values all to 0 (you only have to write the Q-values that aren't 0) and used a learning rate of 1.0.

(g) In most cases, a learning rate of 1.0 will result in a failure to converge. Why is it safe for Ms. Pacman to use a learning rate of 1.0?

(h) Based on your knowledge about the structure of the maze and the episodes Ms. Pacman observed, what are the *true* optimal values of each state?
