CMPT 310
Assignment 4
Uncertainty

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Instructions:

- You can do this assignment individually or in a team of two. If you are doing it in a group, only one submission per group is required.
- You may submit multiple times until the deadline. Grade penalties will be imposed for late submissions (see the course outline for the details).
- Always plan before coding.
- For coding questions - Use function-level and inline comments throughout your code. We will not be specifically grading documentation. However, remember that you will not be able to comment on your code unless sufficiently documented. Take the time to document your code as you develop it properly.
- We will carefully analyze the code submitted to look for plagiarism signs, so please do not do it! If you are unsure about what is allowed, please talk to an instructor or a TA.
- Make sure that in your answers, you clearly indicate the <u>exact section</u> you are answering.
- Check A3 rubric available on canvas.
- You will submit one .zip file.
    - For theoretical questions - Your submission must be formatted as a single PDF file; other types of submissions (non-pdf, multiple files, etc.) will not be graded. Your name(s) and student number(s) must appear at the top of the first page of your submission.
    - Make sure that in your answers, you clearly indicate the <u>exact section</u> you are answering.
- Please put all your files (pdf + code) in one folder. Compress these into a single archive named a3.zip and submit it on Canvas before the due date listed there.

Ques 1. [20 marks] - Probabilities

Tom has changed car's oil	Tom speeding	Tom crashes	p

F	F	F	0.18
F	F	T	0.12
F	T	F	0.06
F	T	T	0.24
T	F	F	0.12
T	F	T	0.08
T	T	F	0.04
T	T	T	0.16

Tom is sick today, but he has decided to drive his car. You can see the joint probability distribution for different events and situations in the above table.

a) [5 points] Compute the p(Tom crashes = T| Tom has changed the car's oil = F).

TC = Tom crashes
TCO = Tom has changed car's oil

P(TC = T ^ TCO = F) = 0.12 + 0.24 = 0.36

P(TCO = F) = 0.18 + 0.12 + 0.06 + 0.24 = 0.6

So, P(TC = T | TCO = F) = P(TC = T ^ TCO = F) ÷ P(TCO = F)
i.e. P(TC = T | TCO = F) = 0.36 ÷ 0.6
Therefore, **P(TC = T | TCO = F) = 0.6**

b) [10 points] List all the interdependencies you can find. Prove it using formulas you have learned.

TCO = Tom has changed car's oil
TS = Tom speeding
TC = Tom crashes

Checking if TCO and TS are marginally independent of each other:

- P(TCO = T) = 0.12 + 0.08 + 0.04 + 0.16 = 0.40
- P(TCO = F) = 0.18 + 0.12 + 0.06 + 0.24 = 0.60
  OR P(TCO = F) = 1 - P(TCO = T) = 1 - 0.4 = 0.6
- P(TCO = T | TS = T) = P(TCO = T ^ TS = T) / P(TS = T)
  = (0.04 + 0.16) / (0.06 + 0.24 + 0.04 + 0.16)
  = 0.20 / 0.50
  = 0.40
  So P(TCO = T | TS = T) is the same as above for P(TCO = T)
- P(TCO = T | TS = F) = P(TCO = T ^ TS = F) / P(TS = F)
  = (0.12 + 0.08) / (0.18 + 0.12 + 0.12 + 0.08)
  = 0.20 / 0.5

= 0.40

So P(TCO = T | TS = F) is the same as above for P(TCO = T)

- P(TCO = F | TS = T) = P(TCO = F ^ TS = T) / P(TS = T)
  = (0.06 + 0.24) / (0.06 + 0.24 + 0.04 + 0.16)
  = 0.30 / 0.50
  = 0.60

  So P(TCO = F | TS = T) is the same as above for P(TCO = F)
- P(TCO = F | TS = F) = P(TCO = F ^ TS = F) / P(TS = F)
  = (0.18 + 0.12) / (0.18 + 0.12 + 0.12 + 0.08)
  = 0.30 / 0.5
  = 0.60

  So P(TCO = F | TS = F) is the same as above for P(TCO = F)

  This means that the probability of TCO does not depend on TS.
  Therefore, TCO is marginally independent of TS

Checking if TCO and TC are marginally independent of each other:

- P(TCO = T) = 0.12 + 0.08 + 0.04 + 0.16 = 0.40
- P(TCO = F) = 0.18 + 0.12 + 0.06 + 0.24 = 0.60
  OR P(TCO = F) = 1 - P(TCO = T) = 1 - 0.4 = 0.6
- P(TCO = T | TC = T) = P(TCO = T ^ TC = T) / P(TC = T)
  = (0.08 + 0.16) / (0.12 + 0.24 + 0.08 + 0.16)
  = 0.24 / 0.60
  = 0.40

  So P(TCO = T | TC = T) is the same as above for P(TCO = T)
- P(TCO = T | TC = F) = P(TCO = T ^ TC = F) / P(TC = F)
  = (0.12 + 0.04) / (0.18 + 0.06 + 0.12 + 0.04)
  = 0.16 / 0.4
  = 0.40

  So P(TCO = T | TC = F) is the same as above for P(TCO = T)
- P(TCO = F | TC = T) = P(TCO = F ^ TC = T) / P(TC = T)
  = (0.12 + 0.24) / (0.12 + 0.24 + 0.08 + 0.16)
  = 0.36 / 0.60
  = 0.60

  So P(TCO = F | TC = T) is the same as above for P(TCO = F)
- P(TCO = F | TC = F) = P(TCO = F ^ TC = F) / P(TC = F)
  = (0.18 + 0.06) / (0.18 + 0.06 + 0.12 + 0.04)
  = 0.24 / 0.4
  = 0.60

  So P(TCO = F | TC = F) is the same as above for P(TCO = F)

  This means that the probability of TCO does not depend on TC.
  Therefore, TCO is marginally independent of TC

Checking if TS and TC are marginally independent of each other:

- P(TS = T) = 0.06 + 0.24 + 0.04 + 0.16 = 0.50
- P(TS = F) = 0.18 + 0.12 + 0.12 + 0.08 = 0.50
  OR P(TS = F) = 1 - P(TS = T) = 1 - 0.5 = 0.5

- P(TS = T | TC = T) = P(TS = T ^ TC = T) / P(TC = T)
  = (0.24 + 0.16) / (0.12 + 0.24 + 0.08 + 0.16)
  = 0.40 / 0.60
  = 0.66

  So P(TS = T | TC = T) is not the same as above for P(TS = T)
- P(TS = T | TC = F) = P(TS = T ^ TC = F) / P(TC = F)
  = (0.06 + 0.04) / (0.18 + 0.06 + 0.12 + 0.04)
  = 0.10 / 0.40
  = 0.25

  So P(TS = T | TC = F) is not the same as above for P(TS = T)
- P(TS = F | TC = T) = P(TS = F ^ TC = T) / P(TC = T)
  = (0.12 + 0.08) / (0.12 + 0.24 + 0.08 + 0.16)
  = 0.20 / 0.60
  = 0.33

  So P(TS = F | TC = T) is not the same as above for P(TS = F)
- P(TS = F | TC = F) = P(TS = F ^ TC = F) / P(TC = F)
  = (0.18 + 0.12) / (0.18 + 0.06 + 0.12 + 0.04)
  = 0.30 / 0.4
  = 0.75

  So P(TS = F | TC = F) is not the same as above for P(TS = F)
  This means that the probability of TS depends on TC.
  Therefore, TS is not marginally independent of TC

Checking if TS is conditionally independent of TCO given TC:

- P(TS = T | TCO = T, TC = T) = P(TS = T ^ TCO = T ^ TC = T) / P(TCO = T ^ TC = T)
  = 0.16 / (0.08 + 0.16)
  = 0.16 / 0.24
  = 0.66

  And,
  P(TS = T | TCO = F, TC = T) = P(TS = T ^ TCO = F ^ TC = T) / P(TCO = F ^ TC = T)
  = 0.24 / (0.12 + 0.24)
  = 0.24 / 0.36
  = 0.66

  Also, we know that P(TS = T | TC = T) = 0.66 which is the same as the above values.
- P(TS = T | TCO = T, TC = F) = P(TS = T ^ TCO = T ^ TC = F) / P(TCO = T ^ TC = F)
  = 0.04 / (0.12 + 0.04)
  = 0.04 / 0.16
  = 0.25

  And,
  P(TS = T | TCO = F, TC = F) = P(TS = T ^ TCO = F ^ TC = F) / P(TCO = F ^ TC = F)

= 0.06 / (0.18 + 0.06)
= 0.06 / 0.24
= 0.25

Also, we know that P(TS = T | TC = F) = 0.25 which is the same as the above values.

- P(TS = F | TCO = T, TC = T) = P(TS = F ^ TCO = T ^ TC = T) / P(TCO = T ^ TC = T)
  = 0.08 / (0.08 + 0.16)
  = 0.08 / 0.24
  = 0.33

  And,
  P(TS = F | TCO = F, TC = T) = P(TS = F ^ TCO = F ^ TC = T) / P(TCO = F ^ TC = T)
  = 0.12 / (0.12 + 0.24)
  = 0.12 / 0.36
  = 0.33

  Also, we know that P(TS = F | TC = T) = 0.33 which is the same as the above values.
- P(TS = F | TCO = T, TC = F) = P(TS = F ^ TCO = T ^ TC = F) / P(TCO = T ^ TC = F)
  = 0.12 / (0.12 + 0.04)
  = 0.12 / 0.16
  = 0.75

  And,
  P(TS = F | TCO = F, TC = F) = P(TS = F ^ TCO = F ^ TC = F) / P(TCO = F ^ TC = F)
  = 0.18 / (0.18 + 0.06)
  = 0.18 / 0.24
  = 0.75

  Also, we know that P(TS = F | TC = F) = 0.75 which is the same as the above values.

  Therefore, TS is conditionally independent of TCO given TC

Checking if TCO is conditionally independent of TC given TS:

- P(TCO = T | TC = T, TS = T) = P(TCO = T ^ TC = T ^ TS = T) / P(TC = T ^ TS = T)
  = 0.16 / (0.24 + 0.16)
  = 0.16 / 0.40
  = 0.4

  And,
  P(TCO = T | TC = F, TS = T) = P(TCO = T ^ TC = F ^ TS = T) / P(TC = F ^ TS = T)
  = 0.04 / (0.06 + 0.04)
  = 0.04 / 0.10
  = 0.4

Also, we know that P(TCO = T | TS = T) = 0.40 which is the same as the above values.

- P(TCO = T | TC = T, TS = F) = P(TCO = T ^ TC = T ^ TS = F) / P(TC = T ^ TS = F)
  = 0.08 / (0.12 + 0.08)
  = 0.08 / 0.20
  = 0.4

  And,
  P(TCO = T | TC = F, TS = F) = P(TCO = T ^ TC = F ^ TS = F) / P(TC = F ^ TS = F)
  = 0.12 / (0.18 + 0.12)
  = 0.12 / 0.30
  = 0.4

  Also, we know that P(TCO = T | TS = F) = 0.40 which is the same as the above values.
- P(TCO = F | TC = T, TS = T) = P(TCO = F ^ TC = T ^ TS = T) / P(TC = T ^ TS = T)
  = 0.24 / (0.24 + 0.16)
  = 0.24 / 0.40
  = 0.6

  And,
  P(TCO = F | TC = F, TS = T) = P(TCO = F ^ TC = F ^ TS = T) / P(TC = F ^ TS = T)
  = 0.06 / (0.06 + 0.04)
  = 0.06 / 0.10
  = 0.6

  Also, we know that P(TCO = F | TS = T) = 0.60 which is the same as the above values.
- P(TCO = F | TC = T, TS = F) = P(TCO = F ^ TC = T ^ TS = F) / P(TC = T ^ TS = F)
  = 0.12 / (0.12 + 0.08)
  = 0.12 / 0.20
  = 0.6

  And,
  P(TCO = F | TC = F, TS = F) = P(TCO = F ^ TC = F ^ TS = F) / P(TC = F ^ TS = F)
  = 0.18 / (0.18 + 0.12)
  = 0.18 / 0.30
  = 0.6

  Also, we know that P(TCO = F | TS = F) = 0.60 which is the same as the above values.

  Therefore, TCO is conditionally independent of TC given TS

Checking if TS is conditionally independent of TC given TCO:

- P(TS = T | TC = T, TCO = T) = P(TS = T ^ TC = T ^ TCO = T) / P(TC = T ^ TCO = T)

= 0.16 / (0.08 + 0.16)
= 0.16 / 0.24
= 0.66

And,
P(TS = T | TC = F, TCO = T) = P(TS = T ^ TC = F ^ TCO = T) / P(TC = F ^ TCO = T)
= 0.04 / (0.12 + 0.04)
= 0.04 / 0.16
= 0.25 which is not the same result as when TC = T

Also, we can see that P(TS = T | TCO = T) = P(TS = T ^ TCO = T) / P(TCO = T)
= (0.04 + 0.16) / (0.12 + 0.08 + 0.04 + 0.16)
= 0.20 / 0.40
= 0.50 which is also not the same as the above values.

Therefore, TS is not conditionally independent of TC given TCO

c) [5 points] Examine the correctness of chain rule for calculating the $P(Tom\ has\ changed\ car's\ oil\ =\ T,\ Tom\ speeding\ =\ T,\ Tom\ crashes\ =\ T)$.

TCO = Tom has changed car's oil
TS = Tom speeding
TC = Tom crashes

From the given probabilities in the table, we see that,
P(TCO = T, TS = T, TC = T) = 0.16 ---------- labeling this as **(I)**

To verify this using chain rule, we can do the following,
P(TCO = T, TS = T, TC = T) = P(TCO = T) x P(TS = T | TCO = T) x P(TC = T | TCO = T, TS = T)
= P(TCO = T) x P(TS = T) x P(TC = T | TS = T) → (since TS is marginally independent of TCO. And since TC is conditionally independent of TCO given TS)
= (0.12 + 0.08 + 0.04 + 0.16) x (0.06 + 0.24 + 0.04 + 0.16) x (0.16+0.24 / 0.50)
= 0.40 x 0.50 x 0.40 / 0.50
= 0.20 x 0.80
= 0.16

This is the same result as we calculated above in **(I)**
Therefore, we have shown that the chain rule is correct and works in this case.

Ques 2. [20 marks] You are catching Pokemons in the wild, there are only 4 species of Pokemons available to catch. Pokemons can flee during a catch, so you might need to try

multiple times before successfully catching a Pokemon. Some species of Pokemons flee faster, thus are harder to be caught, than other species.

Species	Proportion of all Pokemons	Probability of a successful catch at first try
Pikachu	0.46	0.2
Charmander	0.16	0.3
Eevee	0.18	0.4
Snorlax	0.20	0.5

a). [5 marks] What is the probability that you successfully caught a Pokemon at your first try?

Q2.

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a: let.

A_1 = Pikachu
A_2 = Charmander
A_3 = Eevee
A_4 = Snorlax

B = caught in first try.

(i) $P(B) = P(B \cap A_1) + P(B \cap A_2) + P(B \cap A_3) + P(B \cap A_4)$

(ii) $P(B|A_1) = \dfrac{P(B \cap A_1)}{P(A_1)} \Rightarrow P(B \cap A_1) = P(B|A_1) \cdot P(A_1)$

$P(A_1|B) = \dfrac{P(B \cap A_1)}{P(B)} \Rightarrow P(B \cap A_1) = P(A_1|B) \cdot P(B)$

Using (ii) in (i)

$P(B) = 0.2(0.46) + 0.3(0.16) + 0.4(0.18) + 0.5(0.20)$

$= 0.312$

b). [15 marks] Each species of Pokemon has a special magic power depending on its type. A charmander is a fire-type Pokemon, a Pikachu is an electric-type Pokemon, Eevee and Snorlax are both normal-type Pokemons. If a Pokemon was successfully caught at first try, what is the probability that it was a normal-type Pokemon?

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b. Let

A_1 = Pikachu
A_2 = Charmander
A_3 = Eevee
A_4 = Snorlax
B = Caught in first try

$P(B) = 0.312$

Find: $P(\text{Normal} \mid B) = P(A_3 \cup A_4 \mid B)$

$= P(A_3 \mid B) + P(A_4 \mid B)$

$$P(A_3 \mid B) = \frac{P(A_3 \cap B)}{P(B)}$$

$$= \frac{P(B \mid A_3)\, P(A_3)}{P(B)}$$

$$= \frac{0.4\,(0.18)}{0.312} = 0.2307$$

$$P(A_4 \mid B) = \frac{P(A_4 \cap B)}{P(B)}$$

$$= \frac{P(B \mid A_4)\, P(A_4)}{P(B)}$$

$$= \frac{0.5\,(0.2)}{0.312} = 0.3205$$

$\therefore P(\text{Normal} \mid B) = 0.2307 + 0.3205$

$= 0.55121$

Ques 3. [10 marks] Consider the Bayesian Network below representing a problem with random variables. Let A_1, A_2, and D be Boolean variables and C, N, and L have 31 possible values each. Between the Bayesian network and the joint distribution, compute the **representational savings** (Number of fewer values that need to be stored). Show your work.

Probabilities of all variables:
N: 31 Values
C: 31 values
L: 31 values
A1 : 2 values
A2: 2 values
D: 2 values

Number of probabilities stored in the JPD = (31 * 31 * 31 * 2 * 2 * 2)-1 = 238327
We subtract 1 as the last row can be found by subtracting 1 from the sum of the remaining rows gives the last row.

Using Bayesian Network:
N: 31-1 = 30 values
A2: 2-1 = 1 value
A1 : 2-1 = 1 value
D|L: (31*1) = 31 values I
L| N,A2: (31*2*30) = 1860 values II
C| A1, L = (2 * 30*31) = 1860 values III

Number of probabilities stored in the JPD = (30+1+1+31+1860+1860) = 3783
Savings = 238327 - 3783 = 234544

Explanation:

We store the probability values in a tuple then each probability value can be represented as:

I. $P(D|L) = P(D_1,L_k)$ $1<=k<=31$ -> 31 tuples
II. $P(L|N, A_2) = P(N_i,L_k,A_{2,m})$ $1<=k<=30$, $1<=i<=31$, $1<= m <= 2$ -> 1860 tuples
III. $P(C|A_1,L) = P(C_i,L_k,A_{1,m})$ $1<=k<=31$, $1<=i<=30$, $1<= m <= 2$ -> 1860 tuples
We subtract 1 from the domain of the variable on the left since the last tuple can be found by subtracting 1 from the sub of the remaining probabilities

Bonus question

(Coding) Ques 4 [50 marks]. In this question, you are going to write code which can perform inference by calculating any conditional probability given the observation of some variables. Consider the following Bayesian Network which shows the connection between different lifestyles and heart-related diseases:

Variable *E* determines if the patient does exercises regularly.
Variable *D* shows that the patient eats healthy meals.
Variable *HD* means that the patient has heart disease.
Variable *Hb* shows that the patient is experiencing heartburn.
Variable *BP* determines if the patent is experiencing high blood pressure.
Variable *CP* means that the patent feels pain in their chest.

a). [10 marks] As you can see the tables in the above Bayesian Network are in compact forms. Rewrite the tables in such a way that each variable has its own separate column (both parent and child variables) beside the probability column, which comes last.

Exercise

Yes	0.7
No	0.3

Diet

Healthy	0.25
Not healthy	0.75

Heart Disease

Exercise	Diet	Yes	No
Yes	Healthy	0.25	0.75
Yes	Unhealthy	0.45	0.55
No	Healthy	0.55	0.45
No	Unhealthy	0.75	0.25

Heartburn

Diet	Yes	No
Healthy	0.2	0.8
Not healthy	0.85	0.15

Blood Pressure

Heart Disease	High	Low
Yes	0.85	0.15
No	0.2	0.8

Chest pain

Heart Disease	Heartburn	Yes	No
Yes	Yes	0.8	0.2
Yes	No	0.6	0.4
No	Yes	0.4	0.6
No	No	0.1	0.9

b). [10 marks] Manually perform inference by variable elimination to calculate the query *P(BP=High)*.

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Q4.

b. $P(BP=High) = \sum_{E,D,HD,Hb,CP} P(E)\,P(D)\,P(HD|E,D)\,P(Hb|D)\,P(BP|HD)\,P(CP|HD,Hb)$

$= \sum_{E,D,HD,Hb,CP} f_1(E)\,f_2(D)\,f_3(HD,E,D)\,f_4(Hb,D)\,f_5(BP,HD)\,f_6(CP,HD,Hb)$

$= \sum_{CP}\sum_{Hb}\sum_{HD} f_6(CP,HD,Hb)\,f_5(BP,HD)\,\sum_{D} f_4(Hb,D)\,f_2(D)\,\sum_{E} f_3(HD,E,D)\,f_1(E)$

$= \sum_{CP}\sum_{Hb}\sum_{HD} f_6(CP,HD,Hb)\,f_5(BP,HD)\,\sum_{D} f_4(Hb,D)\,f_7(HD,D)$

$= \sum_{CP}\sum_{Hb}\sum_{HD} f_6(CP,HD,Hb)\,f_5(BP,HD)\,f_8(Hb,HD)$

$= \sum_{CP}\sum_{Hb} f_9(CP,Hb,BP)$

$= \sum_{CP} f_{10}(CP,BP)$

$= f_{11}(BP)$

$\frac{f_{11}(BP=High)}{\sum f_{11}(BP)} = 0.5185$

$f_1(E)$

Yes	0.7
No	0.3

$f_2(D)$

Healthy	0.25
Not healthy	0.75

$f_3(HD,E,D)$

Exercise	Diet	Heart Disease	
Yes	Healthy	Yes	0.25
Yes	Healthy	No	0.75
Yes	Unhealthy	Yes	0.45
Yes	Unhealthy	No	0.55
No	Healthy	Yes	0.55
No	Healthy	No	0.45
No	Unhealthy	Yes	0.75
No	Unhealthy	No	0.25

$f_5(BP,HD)$

Heart Disease	Blood pressure	
Yes	High	0.85
Yes	Low	0.15
No	High	0.2
No	Low	0.8

f_6(CP,HD,Hb)

CP	Hb	Heart Disease	
Yes	Yes	Yes	0.8
Yes	Yes	No	0.2
Yes	No	Yes	0.6
Yes	No	No	0.4
No	Yes	Yes	0.4
No	Yes	No	0.6
No	No	Yes	0.1
No	No	No	0.9

f_4(Hb,D)

Diet	Heartburn	
Healthy	Yes	0.2
Healthy	No	0.8
Unhealthy	Yes	0.85
Unhealthy	No	0.15

f_7(HD,D)

Diet	Heart Disease	
Healthy	Yes	0.34
Healthy	No	0.66
Unhealthy	Yes	0.54
Unhealthy	No	0.46

f_8(Hb,HD)

Hb		Heart Disease	

Yes		Yes	0.34 *0.2 = 0.068+0.459 = 0.527
Yes		No	0.66*0.2 = .132+0.391=0.523
No		Yes	0.34 *0.8 = 0.272+0.081 = 0.353
No		No	0.66*0.8 = 0.528+0.069 = 0.597

f_9(CP,HD,Hb)

CP	Hb	Heart Disease	
Yes	Yes	Yes	0.8*0.527 = 0.4216
Yes	Yes	No	0.2*0.523 = .1046
Yes	No	Yes	0.6 * 0.353 = .2118
Yes	No	No	0.4 *0.597 =.2388
No	Yes	Yes	0.4*0.527=.2108
No	Yes	No	0.6*0.523=.3138
No	No	Yes	0.1 * 0.353 = .0353
No	No	No	0.9*0.597 = .5373

Heart Disease	Blood pressure	
Yes	High	0.85
Yes	Low	0.15
No	High	0.2
No	Low	0.8

CP	Hb	Heart Disease	Blood Pressure	
Yes	Yes	Yes	High	0.4216*.85
Yes	Yes	Yes	Low	0.4216*.15
Yes	Yes	No	High	0.1046 * 0.2
Yes	Yes	No	Low	0.1046 * 0.8
Yes	No	Yes	High	.2118 * .85
Yes	No	Yes	Low	.2118 * .15
Yes	No	No	High	0.2388 * 0.2
Yes	No	No	Low	0.2388 * 0.8
No	Yes	Yes	High	0.2108 * 0.85
No	Yes	Yes	Low	0.2108 * 0.15
No	Yes	No	High	
No	Yes	No	Low	
No	No	Yes	High	
No	No	Yes	Low	
No	No	No	High	
No	No	No	Low	

Heart Disease	Blood pressure	
Yes	High	0.85
Yes	Low	0.15
No	High	0.2

No	Low	0.8

[30 marks] Now write a program that inputs a query and does inference by variable elimination. The first part of the input consists of the query and evidence variables in the first and second lines respectively. The second part of the input is the value of the variables in the same order. For example, if the desired query is *P(HD=Yes | BP=High, Hb=No),* then the input should be in the following format:

HD
BP, Hb
Yes
High, No

The output is a number between 0 and 1, which represents the probability of the input query. Your program should be able to process any query with arbitrary variables of query and evidence. It is recommended to write the probabilities of the bayesian network in a separate file so that your program can read from it.

Your report should include the screenshots of the inputs and outputs of your program for the following queries:

P(HD=Yes | BP=High, Hb=No)
P(Hb=Yes | CP=No)
P(BP=High)
P(CP=Yes)
P(BP=Low | D=Healthy)