

Probabilistic Graphical Models Assignment 1

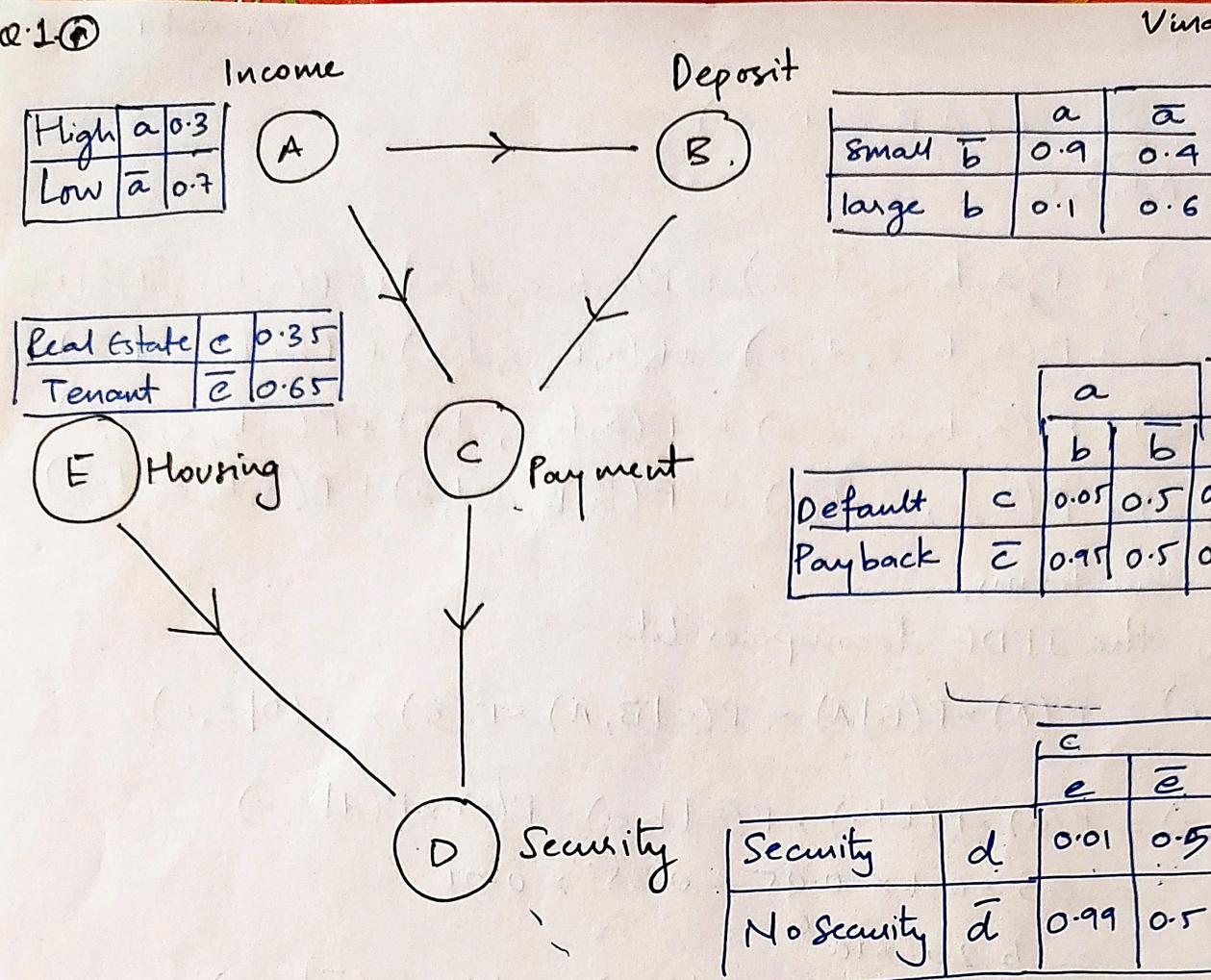
This submission is made by Group 19 for PGM Assignment 1.

Group 19

Members as follows

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We have structured our solution in two parts, first we solved manually and next we solved using `pgmpy` as well. Mentioned both the solutions on the subsequent pages.



Q.1.① False. There's an active information path $I \rightarrow P \rightarrow S$, hence telling something about security gives influences my belief in income and vice-versa.

- ② True. Specifying payment breaks all active info paths between income and security.
- ③ False. There's a direct connection between income & payment.
- ④ True. Specifying payment alone breaks all info flow between income and security.
- ⑤ False. There's a direct connection between deposit & payment.
- ⑥ False. Income and payment have a direct edge. The influence of income on payment thru deposit might come to a stop by specifying deposit however there is still the direct connection influence alive.

Q.1.② $P(A, B, C, D, E) = P(A) \times P(B|A) \times P(C|B, A) \times P(E|C, B, A) \times P(D|A, B, C, E)$

E is a root node i.e. no parents $\Rightarrow P(E|C, B, A) = P(E)$

Also D 's parents are $C, E \Rightarrow P(D|A, B, C, E) = P(D|C, E)$

$$\begin{aligned} \therefore P(A, B, C, D, E) &= P(A) \times P(B|A) \times P(C|B, A) \times P(E|C, B, A) \times P(D|A, B, C, E) \\ &= P(A) \times P(B|A) \times P(C|B, A) \times P(E) \times P(D|C, E) \end{aligned}$$

$$Q.1 \text{ (iii)} P(C) = ?$$

$$P(C) = \sum_{A, B, D, E} P(A, B, C, D, E)$$

$$= P(a, b, c, d, e) + P(a, b, c, \bar{d}, e) + P(a, b, c, d, \bar{e}) + P(a, b, c, \bar{d}, \bar{e}) + \\ P(a, \bar{b}, c, d, e) + P(a, \bar{b}, c, \bar{d}, e) + P(a, \bar{b}, c, d, \bar{e}) + P(a, \bar{b}, c, \bar{d}, \bar{e}) + \\ P(\bar{a}, b, c, d, e) + P(\bar{a}, b, c, \bar{d}, e) + P(\bar{a}, b, c, d, \bar{e}) + P(\bar{a}, b, c, \bar{d}, \bar{e}) + \\ P(\bar{a}, \bar{b}, c, d, e) + P(\bar{a}, \bar{b}, c, \bar{d}, e) + P(\bar{a}, \bar{b}, c, d, \bar{e}) + P(\bar{a}, \bar{b}, c, \bar{d}, \bar{e})$$

Solving for few terms,

We know the JPDF decomposes like

$$P(A, B, C, D, E) = P(A) \times P(B|A) \times P(C|B, A) \times P(E) \times P(D|C, E)$$

$$\therefore P(a, b, c, d, e) = P(a) \times P(b|a) \times P(c|b, a) \times P(e) \times P(d|c, e) \\ = 0.3 \times 0.1 \times 0.05 \times 0.35 \times 0.01 \\ = 5.25 \times 10^{-6}$$

$$P(a, b, c, \bar{d}, e) = P(a) \times P(b|a) \times P(c|b, a) \times P(e) \times P(\bar{d}|c, e) \\ = 0.3 \times 0.1 \times 0.05 \times 0.35 \times 0.99 \\ = 5.1975 \times 10^{-4}$$

$$P(a, b, c, d, \bar{e}) = P(a) \times P(b|a) \times P(c|b, a) \times P(\bar{e}) \times P(d|c, \bar{e}) \\ = 0.3 \times 0.1 \times 0.05 \times 0.65 \times 0.5 \\ = 4.875 \times 10^{-4}$$

$$P(a, b, c, \bar{d}, \bar{e}) = P(a) \times P(b|a) \times P(c|b, a) \times P(\bar{e}) \times P(\bar{d}|c, \bar{e}) \\ = 0.3 \times 0.1 \times 0.05 \times 0.65 \times 0.5 \\ = 4.875 \times 10^{-4}$$

~~Similarly, we can compute other probabilities and eventually, we would get~~

~~$P(C) = 5.25 \times 10^{-6} + 5.1975 \times 10^{-4} + 4.875 \times 10^{-4} + 4.875 \times 10^{-4}$~~

Computing other probabilities,

$$P(a, \bar{b}, c, d, e) = P(a) \times P(\bar{b}|a) \times P(c|\bar{b}, a) \times P(e) \times P(d|c, e) \\ = 0.3 \times 0.9 \times 0.5 \times 0.35 \times 0.01 \\ = 4.725 \times 10^{-4}$$

$$P(a, \bar{b}, c, \bar{d}, e) = P(a) \times P(\bar{b}|a) \times P(c|\bar{a}, \bar{b}) \times P(e) \times P(\bar{d}|c, e) \quad (3)$$

$$= 0.3 \times 0.9 \times 0.5 \times 0.35 \times 0.99$$

$$= \cancel{2.3625} \times 10^{-2}$$

$$P(a, \bar{b}, c, d, \bar{e}) = P(a) \times P(\bar{b}|a) \times P(c|\bar{a}, \bar{b}) \times P(\bar{e}) \times P(d|c, \bar{e})$$

$$= 0.3 \times 0.9 \times 0.5 \times 0.65 \times 0.5$$

$$= 4.3875 \times 10^{-2}$$

$$P(a, \bar{b}, c, \bar{d}, \bar{e}) = P(a) \times P(\bar{b}|a) \times P(c|\bar{b}, a) \times P(\bar{e}) \times P(\bar{d}|\bar{c}, \bar{e})$$

$$= 0.3 \times 0.9 \times 0.5 \times 0.65 \times 0.5$$

$$= 4.3875 \times 10^{-2}$$

$$P(\bar{a}, b, c, d, e) = P(\bar{a}) \times P(b|\bar{a}) \times P(c|b, \bar{a}) \times P(e) \times P(d|c, e)$$

$$= 0.7 \times 0.6 \times 0.45 \times 0.35 \times 0.01$$

$$= 6.615 \times 10^{-4}$$

$$P(\bar{a}, b, c, \bar{d}, e) = P(\bar{a}) \times P(b|\bar{a}) \times P(c|b, \bar{a}) \times P(e) \times P(\bar{d}|c, e)$$

$$= 0.7 \times 0.6 \times 0.45 \times 0.35 \times 0.99$$

$$= 6.54885 \times 10^{-2}$$

$$P(\bar{a}, b, c, d, \bar{e}) = P(\bar{a}) \times P(b|\bar{a}) \times P(c|b, \bar{a}) \times P(\bar{e}) \times P(d|c, \bar{e})$$

$$= 0.7 \times 0.6 \times 0.45 \times 0.65 \times 0.5$$

$$= 6.1425 \times 10^{-2}$$

$$P(\bar{a}, \bar{b}, c, \bar{d}, \bar{e}) = P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(c|\bar{b}, \bar{a}) \times P(\bar{e}) \times P(\bar{d}|c, \bar{e})$$

$$= 0.7 \times 0.6 \times 0.45 \times 0.65 \times 0.5$$

$$= 6.1425 \times 10^{-2}$$

$$P(\bar{a}, \bar{b}, c, d, e) = P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(c|\bar{b}, \bar{a}) \times P(e) \times P(d|c, e)$$

$$= 0.7 \times 0.4 \times 0.6 \times 0.35 \times 0.01$$

$$= 5.88 \times 10^{-4}$$

$$P(\bar{a}, \bar{b}, c, \bar{d}, e) = P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(c|\bar{b}, \bar{a}) \times P(e) \times P(\bar{d}|c, e)$$

$$= 0.7 \times 0.4 \times 0.6 \times 0.35 \times 0.99$$

$$= 5.8212 \times 10^{-2}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, c, d, \bar{e}) &= P(\bar{a}) \times P(\bar{b} | \bar{a}) \times P(c | \bar{b}, \bar{a}) \times P(\bar{e}) \times P(d | c, \bar{e}) \\
 &= 0.7 \times 0.4 \times 0.6 \times 0.65 \times 0.5 \\
 &= 5.46 \times 10^{-2}
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, c, \bar{d}, \bar{e}) &= P(\bar{a}) \times P(\bar{b} | \bar{a}) \times P(c | \bar{b}, \bar{a}) \times P(\bar{e}) \times P(\bar{d} | c, \bar{e}) \\
 &= 0.7 \times 0.4 \times 0.6 \times 0.65 \times 0.5 \\
 &= 5.46 \times 10^{-2}
 \end{aligned}$$

$$\begin{aligned}
 \therefore P(c) &= \sum_{A, B, D, E} P(A, B, C, D, E) \\
 &= 5.25 \times 10^{-6} + 5.1975 \times 10^{-4} + 4.875 \times 10^{-4} + 4.875 \times 10^{-4} + \\
 &\quad 4.725 \times 10^{-4} + 4.678 \times 10^{-2} + 4.3875 \times 10^{-2} + 4.3875 \times 10^{-2} + \\
 &\quad 6.615 \times 10^{-4} + 6.5488 \times 10^{-2} + 6.1425 \times 10^{-2} + 6.1425 \times 10^{-2} + \\
 &\quad 5.88 \times 10^{-4} + 5.8212 \times 10^{-2} + 5.46 \times 10^{-2} + 5.46 \times 10^{-2}
 \end{aligned}$$

$$\boxed{P(c) = 0.49346}$$

c is default \Rightarrow payment is false. Hence, we can say that in the absence of any prior information, default is likely to happen with slightly lower odds than toss of a fair coin.

$$Q.1(iv) P(\bar{c} | \bar{a}) = ?$$

$$P(\bar{c} | \bar{a}) = \frac{P(\bar{c} \& \bar{a})}{P(\bar{a})}$$

$$\text{We know } P(\bar{a}) = 0.7$$

$$\text{And } P(\bar{c} \& \bar{a}) = \sum_{i \in B, D, E} P(\bar{c}, \bar{a}, b_i, d_i, e_i)$$

$$\begin{aligned}
 &= P(\bar{a}, b, \bar{c}, d, e) + P(\bar{a}, \bar{b}, \bar{c}, d, e) + \\
 &\quad P(\bar{a}, b, \bar{c}, \bar{d}, e) + P(\bar{a}, \bar{b}, \bar{c}, \bar{d}, e) + \\
 &\quad P(\bar{a}, b, \bar{c}, d, \bar{e}) + P(\bar{a}, \bar{b}, \bar{c}, d, \bar{e}) + \\
 &\quad P(\bar{a}, b, \bar{c}, \bar{d}, \bar{e}) + P(\bar{a}, \bar{b}, \bar{c}, \bar{d}, \bar{e}) \quad \text{--- (1)}
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, b, \bar{c}, d, e) &= P(\bar{a}) \times P(b|\bar{a}) \times P(\bar{c}|b, \bar{a}) \times P(e) \times P(d|\bar{c}, e) \\
 &= 0.7 \times 0.6 \times 0.55 \times 0.35 \times 0.75 \\
 &= 0.06064
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, b, \bar{c}, \bar{d}, e) &= P(\bar{a}) \times P(b|\bar{a}) \times P(\bar{c}|b, \bar{a}) \times P(e) \times P(\bar{d}|\bar{c}, e) \\
 &= 0.7 \times 0.6 \times 0.55 \times 0.35 \times 0.25 \\
 &= 0.02021
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, b, \bar{c}, d, \bar{e}) &= P(\bar{a}) \times P(b|\bar{a}) \times P(\bar{c}|b, \bar{a}) \times P(\bar{e}) \times P(d|\bar{c}, \bar{e}) \\
 &= 0.7 \times 0.6 \times 0.55 \times 0.65 \times 0.31 \\
 &= 0.04655
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, b, \bar{c}, \bar{d}, \bar{e}) &= P(\bar{a}) \times P(b|\bar{a}) \times P(\bar{c}|b, \bar{a}) \times P(\bar{e}) \times P(\bar{d}|\bar{c}, \bar{e}) \\
 &= 0.7 \times 0.6 \times 0.55 \times 0.65 \times 0.69 \\
 &= 0.1036
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, \bar{c}, d, e) &= P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(\bar{c}|\bar{b}, \bar{a}) \times P(e) \times P(d|\bar{c}, e) \\
 &= 0.7 \times 0.4 \times 0.4 \times 0.35 \times 0.75 \\
 &= 0.0294
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, \bar{c}, \bar{d}, e) &= P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(\bar{c}|\bar{b}, \bar{a}) \times P(e) \times P(\bar{d}|\bar{c}, e) \\
 &= 0.7 \times 0.4 \times 0.4 \times 0.35 \times 0.25 \\
 &= 0.0098
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, \bar{c}, d, \bar{e}) &= P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(\bar{c}|\bar{b}, \bar{a}) \times P(\bar{e}) \times P(d|\bar{c}, \bar{e}) \\
 &= 0.7 \times 0.4 \times 0.4 \times 0.65 \times 0.31 \\
 &= 0.02257
 \end{aligned}$$

$$\begin{aligned}
 P(\bar{a}, \bar{b}, \bar{c}, \bar{d}, \bar{e}) &= P(\bar{a}) \times P(\bar{b}|\bar{a}) \times P(\bar{c}|\bar{b}, \bar{a}) \times P(\bar{e}) \times P(\bar{d}|\bar{c}, \bar{e}) \\
 &= 0.7 \times 0.4 \times 0.4 \times 0.65 \times 0.69 \\
 &= 0.0502
 \end{aligned}$$

From eq ① we can say,

$$P(\bar{c} \text{ & } \bar{a}) = 0.06064 + 0.02021 + 0.04655 + 0.1036 + 0.0294 + 0.0098 + 0.02257 + 0.0502$$

$$\boxed{P(\bar{c} \text{ & } \bar{a}) = 0.34297}$$

$$\text{Also } P(\bar{a}) = 0.7$$

$$\Rightarrow \boxed{P(\bar{c} | \bar{a}) = 0.34297 / 0.7 = 0.4899}$$

A] Probability of getting payment given that the income is low is 0.4899

⑦ Got payment $\rightarrow \bar{c}$

Low income $\rightarrow \bar{a}$

Large deposits $\rightarrow b$

To find: $P(\bar{c} | \bar{a}, b)$

By conditional prob. definition,

$$P(\bar{c} | \bar{a}, b) = \frac{P(\bar{c} \& \bar{a} \& b)}{P(\bar{a} \& b)}$$

$$P(\bar{c} \& \bar{a} \& b) = \sum_{D, E} P(\bar{a}, b, \bar{c}, d_i, e_i)$$

$$= P(\bar{a}, b, \bar{c}, d, e) + P(\bar{a}, b, \bar{c}, d, \bar{e})$$

$$+ P(\bar{a}, b, \bar{c}, \bar{d}, e) + P(\bar{a}, b, \bar{c}, \bar{d}, \bar{e})$$

We have already computed these 4 joint probas in previous q.
Hence using them we get

$$\frac{P(\bar{c} \& \bar{a} \& b)}{P(\bar{a} \& b)} = \frac{0.06064 + 0.04655 + 0.02021 + 0.1036}{0.231}$$

Also,

$$P(\bar{a} \& b) = \sum_{C, D, E} P(\bar{a}, b, c_i, d_i, e_i)$$

$$= \left\{ \begin{array}{l} |P(\bar{a}, b, c, d, e)| + |P(\bar{a}, b, \bar{c}, d, e)| \\ |P(\bar{a}, b, c, \bar{d}, e)| + |P(\bar{a}, b, \bar{c}, \bar{d}, e)| \\ |P(\bar{a}, b, \bar{c}, d, \bar{e})| + |P(\bar{a}, b, \bar{c}, d, \bar{e})| \\ |P(\bar{a}, b, c, \bar{d}, \bar{e})| + |P(\bar{a}, b, \bar{c}, \bar{d}, \bar{e})| \end{array} \right\} P(\bar{c}, \bar{a}, b)$$

computed above.

Probabilities are computed in 1.(ii) when marginalizing over A, B, D, E respectively.

$$\therefore P(\bar{a} \& b) = 6.615 \times 10^{-4} + 0.06549 + 0.061425 + 0.061425 + 0.231$$

$$P(\bar{a} \& b) = 0.4200$$

$$\boxed{\therefore P(\bar{c} | \bar{a}, b) = \frac{P(\bar{c}, \bar{a}, b)}{P(\bar{a}, b)} = \frac{0.231}{0.4200} = 0.55}$$

A] Probability of getting payment given income is low and you have high deposits is 0.55

(vii) Did not default $\rightarrow \bar{c}$
 High income $\rightarrow a$
 No security $\rightarrow d$

Vinayak Nayak. ⑦

To find: $P(\bar{c} | a, \bar{d})$
 By def. of conditional probability,
 $P(\bar{c} | a, \bar{d}) = \frac{P(\bar{c} \text{ & } a \text{ & } \bar{d})}{P(a \text{ & } \bar{d})}$

$$P(\bar{c}, a, \bar{d}) = \sum_{B, E} P(a, b_i, \bar{c}, \bar{d}, e_i)$$

$$= P(a, b, \bar{c}, \bar{d}, e) + P(a, \bar{b}, \bar{c}, \bar{d}, e)$$

$$P(a, \cancel{b}, \bar{c}, \bar{d}, \bar{e}) + P(a, \bar{b}, \bar{c}, \bar{d}, \bar{e})$$

$$P(a, b, \bar{c}, \bar{d}, e) = P(a) \times P(b | a) \times P(\bar{c} | b, a) \times P(e) \times P(\bar{d} | \bar{c}, e)$$

$$= 0.3 \times 0.1 \times 0.95 \times 0.35 \times 0.25$$

$$= \cancel{0.001375}$$

$$= 0.002494$$

$$P(a, \bar{b}, \bar{c}, \bar{d}, e) = P(a) \times P(\bar{b} | a) \times P(\bar{c} | \bar{b}, a) \times P(e) \times P(\bar{d} | \bar{c}, e)$$

$$= 0.3 \times 0.9 \times 0.5 \times 0.35 \times 0.25$$

$$= 0.01181$$

$$P(a, b, \bar{c}, \bar{d}, \bar{e}) = \frac{P(a) \times P(\bar{e})}{P(a) \times P(b | a) \times P(\bar{c} | b, a) \times P(\bar{e}) \times P(\bar{d} | \bar{c}, \bar{e})}$$

$$= 0.3 \times 0.1 \times 0.95 \times 0.65 \times 0.69$$

$$= 0.01278$$

$$P(a, \bar{b}, \bar{c}, \bar{d}, \bar{e}) = P(a) \times P(\bar{b} | a) \times P(\bar{c} | \bar{b}, a) \times P(\bar{e}) \times P(\bar{d} | \bar{c}, \bar{e})$$

$$= 0.3 \times 0.9 \times 0.5 \times 0.65 \times 0.69$$

$$= 0.06055$$

$$P(\bar{c}, a, \bar{d}) = 0.002494 + 0.01181 + 0.01278 + 0.06055$$

$$P(\bar{c}, a, \bar{d}) = 0.087634$$

$$P(a, \bar{d}) = \sum_{B, C, E} P(a, b_i, c_i, \bar{d}, e_i)$$

$$= P(a, b, c, \bar{d}, e) + P(a, \bar{b}, c, \bar{d}, e)$$

$$+ P(a, b, \bar{c}, \bar{d}, e) + P(a, \bar{b}, \bar{c}, \bar{d}, e)$$

$$+ P(a, b, c, \bar{d}, \bar{e}) + P(a, \bar{b}, c, \bar{d}, \bar{e})$$

$$+ P(a, b, \bar{c}, \bar{d}, \bar{e}) + P(a, \bar{b}, \bar{c}, \bar{d}, \bar{e})$$

All the above probabilities are computed above and also in question (ii), hence substituting, we get

Vinayak (8)
Nayak.

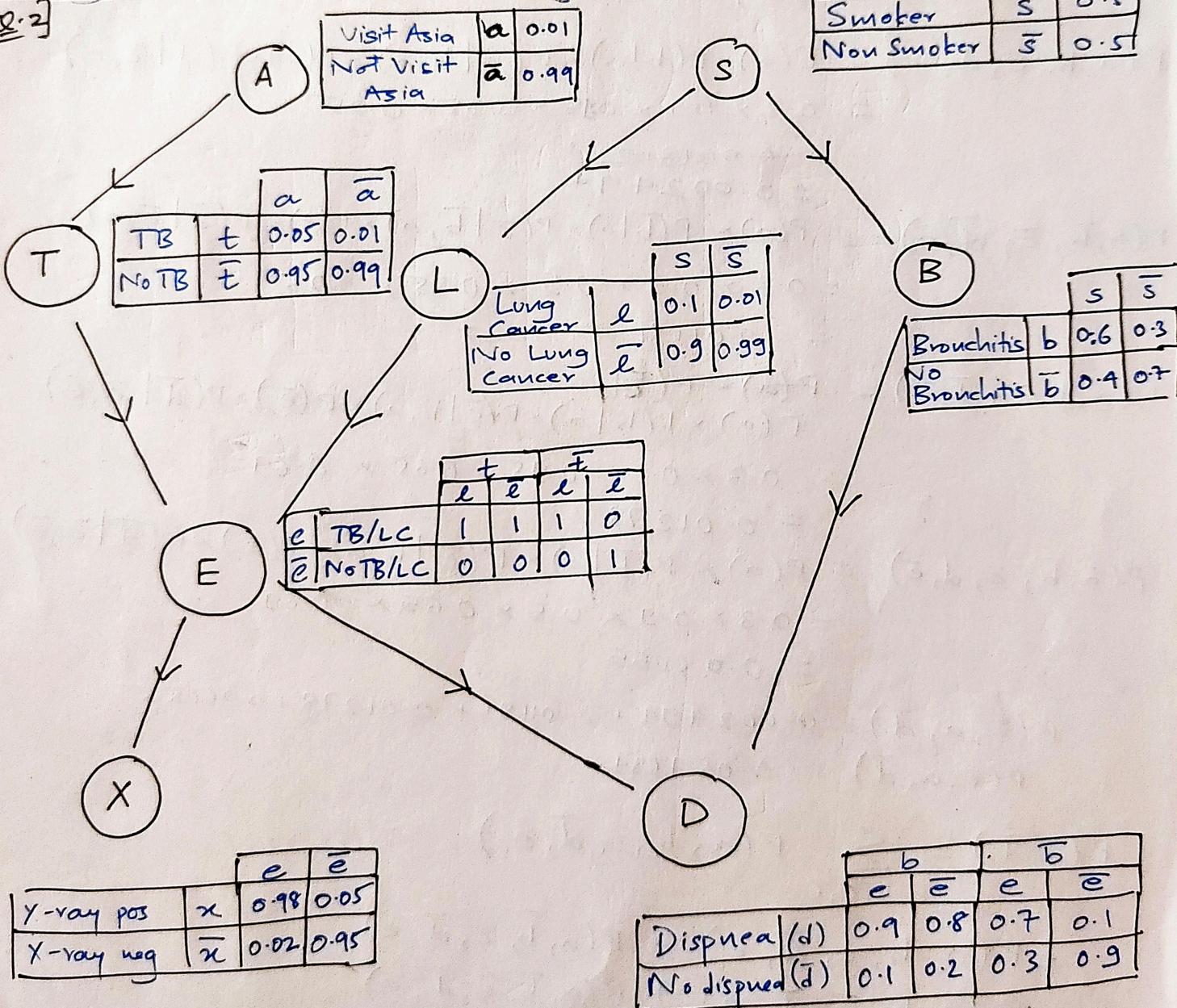
$$\begin{aligned} P(a, \bar{d}) &= 5.1975 \times 10^{-4} + 4.678 \times 10^{-2} \\ &\quad + 2.494 \times 10^{-3} + 1.181 \times 10^{-2} \\ &\quad + 4.875 \times 10^{-4} + 4.3875 \times 10^{-2} \\ &\quad + 1.278 \times 10^{-2} + 6.055 \times 10^{-2} \end{aligned}$$

$$\therefore P(a, \bar{d}) = 0.1793$$

$$\therefore P(\bar{e} | a, \bar{d}) = \frac{0.087634}{0.1793} = 0.4887$$

A) Probability of not defaulting in payment (i.e. pay back) given high income and no security is 0.4887

Q.2



a.2.① Lung cancer & bronchitis have a converging path at dyspnea ①
through E (either LC or TB)

So, my knowledge of lung cancer can influence my belief on bronchitis if I am fed additional info about dyspnea.

As per the graph hence,

$$\text{② Having tuberculosis} \rightarrow t \quad \text{Having lung cancer} \rightarrow l \\ \text{Visiting Asia} \rightarrow a \quad \Rightarrow \text{Either lung cancer/TB} \rightarrow e \\ \text{Positive X-ray} \rightarrow x \\ \Rightarrow \text{To find: } P(t | a, l, e, x)$$

$$P(t | a, l, e, x) = \frac{P(t, a, l, e, x)}{P(a, l, e, x)}$$

$$P(t, a, l, e, x) = \sum_{S, B, D} P(t, a, l, e, x, s_i, b_i, d_i)$$

$$= P(t, a, l, e, x, s, b, d) + P(t, a, l, e, x, \bar{s}, b, d)$$

$$P(t, a, l, e, x, s, \bar{b}, d) + P(t, a, l, e, x, \bar{s}, \bar{b}, d)$$

$$P(t, a, l, e, x, s, b, \bar{d}) + P(t, a, l, e, x, \bar{s}, b, \bar{d})$$

$$P(t, a, l, e, x, s, \bar{b}, \bar{d}) + P(t, a, l, e, x, \bar{s}, \bar{b}, \bar{d})$$

Factorization of Distribution

$$P(T, A, L, E, X, S, B, D) \text{ or}$$

$$P(A, S, B, T, L, E, X, D)$$

$$= P(A) \cdot P(S|A) \cdot P(B|S, A) \cdot P(L|A, B, S) \cdot P(T|A, B, L, S) \cdot P(E|A, B, L, S, T) \\ \cdot P(X|A, B, E, L, S, T) \cdot P(D|A, B, E, L, S, T, X)$$

$$= P(A) \cdot P(S) \cdot P(B|S) \cdot P(L|S) \cdot P(T|A) \cdot P(E|T, L) \cdot P(X|E) \cdot P(D|E, B)$$

—(From the network, factorizing based on JPDF = $\prod P(X|Pa(X))$)

$$\therefore P(t, a, l, e, x, s, b, d) = 0.01 \times 0.5 \times 0.6 \times 0.1 \times 0.05 \times 1 \times 0.98 \times 0.9 \\ = 1.323 \times 10^{-5}$$

$$P(t, a, l, e, x, \bar{s}, b, d) = 0.01 \times 0.5 \times 0.3 \times 0.01 \times 0.05 \times 1 \times 0.98 \times 0.9 \\ = 6.615 \times 10^{-7}$$

$$\begin{aligned}
 P(t, a, l, e, x, s, \bar{s}, \bar{b}, d) &= P(a) P(s) P(\bar{b}|s) P(l|s) P(t|a) P(e|t, l) P(x|e) P(d|e, b) \\
 &= 0.01 \times 0.5 \times 0.4 \times 0.1 \times 0.05 \times 1 \times 0.98 \times 0.7 \\
 &= 6.86 \times 10^{-6}
 \end{aligned} \tag{16}$$

similarly, we can find remaining terms as

$$\begin{aligned}
 P(t, a, l, e, x, \bar{s}, \bar{b}, d) &= 1.2 \times 10^{-6} \quad P(t, a, l, e, x, \bar{s}, b, \bar{d}) = 7.35 \times 10^{-8} \\
 P(t, a, l, e, x, s, b, \bar{d}) &= 1.47 \times 10^{-6} \quad P(t, a, l, e, x, s, \bar{b}, \bar{d}) = 2.94 \times 10^{-6} \\
 P(t, a, l, e, x, \bar{s}, \bar{b}, \bar{d}) &= 5.145 \times 10^{-7} \\
 \therefore P(t, a, l, e, x) &= 1.323 \times 10^{-5} + 6.615 \times 10^{-7} + 6.86 \times 10^{-6} + 1.2 \times 10^{-6} + \\
 &\quad 7.35 \times 10^{-8} + 1.47 \times 10^{-6} + 2.94 \times 10^{-6} + 5.145 \times 10^{-7} \\
 &= 10^{-6} \times [13.23 + 0.6615 + 6.86 + 1.2 + 0.0735 + \\
 &\quad 1.47 + 2.94 + 0.5145] \\
 &= 10^{-6} \times 26.945 \\
 \therefore P(t, a, l, e, x) &= 2.694 \times 10^{-6}
 \end{aligned}$$

$$P(a, l, e, x) = \sum_{T, S, B, D} P(a, l, e, x, t_i, s_i, b_i, d_i)$$

$$\begin{aligned}
 &= P(a, l, e, x, t, s, b, d) + P(a, l, e, x, \bar{t}, s, b, d) \\
 &P(a, l, e, x, t, s, \bar{b}, \bar{d}) + P(a, l, e, x, \bar{t}, s, b, \bar{d}) \\
 &P(a, l, e, x, t, s, \bar{b}, d) + P(a, l, e, x, \bar{t}, s, \bar{b}, d) \\
 &P(a, l, e, x, t, s, \bar{b}, \bar{d}) + P(a, l, e, x, \bar{t}, s, \bar{b}, \bar{d}) \\
 &P(a, l, e, x, t, \bar{s}, b, d) + P(a, l, e, x, \bar{t}, \bar{s}, b, d) \\
 &P(a, l, e, x, t, \bar{s}, \bar{b}, \bar{d}) + P(a, l, e, x, \bar{t}, \bar{s}, b, \bar{d}) \\
 &P(a, l, e, x, t, \bar{s}, \bar{b}, d) + P(a, l, e, x, \bar{t}, \bar{s}, \bar{b}, d) \\
 &P(a, l, e, x, t, \bar{s}, \bar{b}, \bar{d}) + P(a, l, e, x, \bar{t}, \bar{s}, \bar{b}, \bar{d})
 \end{aligned}$$

Terms on LHS have already been calculated in the previous computation. We need to compute RHS terms now.

$$\begin{aligned}
 P(a, l, e, x, \bar{t}, s, b, d) &= P(a) \times P(s) \times P(\bar{b}|s) \times P(l|s) \times P(\bar{t}|a) \\
 &\quad \times P(e|\bar{t}, l) \times P(x|e) \times P(d|e, b) \\
 &= 0.01 \times 0.5 \times 0.6 \times 0.1 \times 0.95 \times 1 \times 0.98 \times 0.9 \\
 &= 2.51 \times 10^{-4}
 \end{aligned}$$

Similarly we could compute all the joint probabilities and eventually, we get

$$P(t, a, l, e, x) = 2.694 \times 10^{-6} \quad P(a, l, e, x) = 5.39 \times 10^{-4}$$

$$\therefore P\left(\frac{t}{a, l, e, x}\right) = \frac{2.694 \times 10^{-6}}{5.39 \times 10^{-4}} = 0.05$$

⑪ What is the probability that you have dispnea given that you have positive x-ray?

Vinayak
Nayak ⑪

Having Dispnea - d ; Positive x-ray - x

∴ To find : $P(d/x)$ or $P(d|x)$

$$P(d|x) = P(d,x) / P(x)$$

$$P(d,x) = \sum_{A,S,T,L,B,E} P(a_i, t_i, s_i, l_i, b_i, e_i, d_i, x)$$

This summation contains close to 64 terms since we're marginalizing over 6 binary variables ($2^6 = 64$). Accounting for all those and summing we finally obtain

$$P(d,x) = 0.0707$$

Similarly

$$P(x) = \sum_{A,S,T,L,B,E,D} P(a_i, t_i, s_i, l_i, b_i, e_i, d_i, x)$$

Same as above this expansion contains $2^7 = 128$ terms.

Summing over all these, we eventually obtain

$$P(x) = 0.1103$$

$$\therefore P(d|x) = \frac{P(d,x)}{P(x)} = \frac{0.0707}{0.1103} = 0.6407$$

∴ ∵ Probability of having dispnea given positive x-ray is 0.6407

⑫ Find out all the independencies in the given graph.

There are a lot of independencies in the given graph. Some of the striking ones are as follows.

Asia \perp Bronchitis, Smoking, Lung Cancer

Asia \perp X-ray \mid Tb/Lc

Asia \perp Dispnea \mid Tb, Lung Cancer, Tb/Lc

Dispnea \perp X-ray, Asia \mid Tb/Lc

Tb \perp Bronchitis, Smoking, Lung Cancer

Tb \perp Smoking \mid

Tb \perp X-ray \mid Tb/Lc, Lc

X-ray \perp Smoker \mid Lc, Tb/Lc

tb | smoking | lung cancer, bronchitis

tb | asia | tb or lc

tb | x-ray | tb or lc

lung cancer | asia | dispnea, smoking, x-ray, tb

lung cancer | tb | asia, bronchitis, smoking

lung cancer | tb | asia, tb

lung cancer | x-ray | tb or lc

dispnea | asia | bronchitis, x-ray, tb

dispnea | smoker | lung cancer, bronchitis, x-ray

dispnea | x-ray | tb or lc

smoking | x-ray | dispnea, asia, tb or lc

smoking | asia | tb

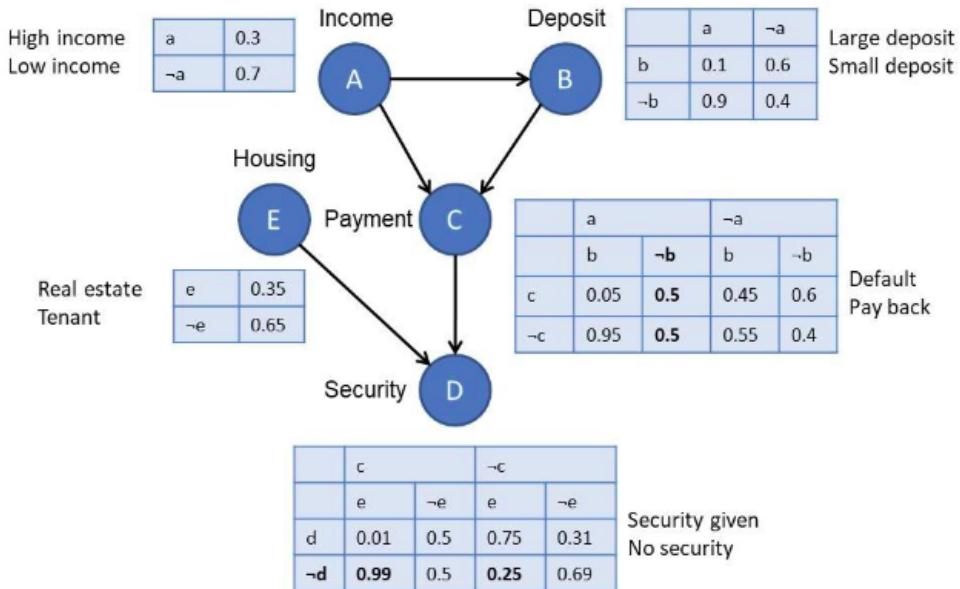
tb or lc | asia | tb

tb or lc | bronchitis | smoking

bronchitis | asia | lung cancer, dispnea, tb

bronchitis | tb | asia

Question 1



```

        evidence_card = [2, 2])
cpd_security = TabularCPD("security", 2,
                           [[.01, .5, .75, .31], [.99, 0.5, .25, .69]],
                           evidence = ["payment", "housing"],
                           evidence_card = [2, 2])

# Add the CPDs to the model
model.add_cpds(*[cpd_income, cpd_housing, cpd_deposit,
                 cpd_payment, cpd_security])

```

Question

Indicate whether the following independence statements are true or false according to this model. Provide a very brief justification of your answer (not more than two or three sentences)

- **Income \perp Security** - False. There's an active information path $I \rightarrow P \rightarrow S$.
 - **Income \perp Security | Payment** - True. Specifying payment breaks active paths between income and security.
 - **Income \perp Payment** - False. Income and payment have a direct connection.
 - **Income \perp Security | Payment, Deposit** - True. Specifying payment alone breaks all the direct connections between income and security
 - **Deposit \perp Payment** - False. There is a direct connection between the two
 - **Income \perp Payment | Deposit** - False. Income and payment have a direct edge; Specifying deposit might stop the influence of payment on income through deposit but there's still a direct connection through which independence can't be established.
-

Question

Show the factorized form of the joint distribution over all of the variables, $P(A, B, C, D, E)$

$$P(A, B, C, D, E) = P(A) \times P(B|A) \times P(C|B, A) \times P(E|C, B, A) \times P(D|E, C, B, A)$$

$$\therefore P(A, B, C, D, E) = P(A) \times P(B|A) \times P(C|B, A) \times P(E) \times P(D|E, C)$$

First, applying the chain rule of probability and second, since we know the structure of the graph, expressing individual CPDs in the form $P(X|Pa(X))$.

Question

Find out probability for payment is false, when no prior information is available.

```
In [ ]: infer = VariableElimination(model)
g_dist = infer.query(["income", "deposit", "payment",
                      "housing", "security"])
```

```
g_dist.marginalize(["income", "deposit", "housing", "security"])
print(g_dist)
```

+-----+-----+	
payment	phi(payment)
payment(0)	0.4935
payment(1)	0.5065

From the above, the probability that the payment is false is 0.4935

Question

What is the probability that you have got Payment, given that the income is low?

$$P(\bar{C}|\bar{A}) = ?$$

```
In [ ]: infer = VariableElimination(model)
g_dist = infer.query(["income", "deposit", "payment",
                      "housing", "security"])
g_dist.marginalize(["deposit", "housing", "security"])
print(g_dist)
```

+-----+-----+-----+		
income	payment	phi(income,payment)
income(0)	payment(0)	0.1365
income(0)	payment(1)	0.1635
income(1)	payment(0)	0.3570
income(1)	payment(1)	0.3430

```
In [ ]: cbar_and_abar = g_dist.values[1][1]
```

```
In [ ]: g_dist.marginalize(["payment"])
print(g_dist)
```

+-----+-----+	
income	phi(income)
income(0)	0.3000
income(1)	0.7000

```
In [ ]: cbar = g_dist.values[1]
```

```
In [ ]: p_cbar_given_abar = cbar_and_abar / cbar
p_cbar_given_abar
```

```
Out[ ]: 0.49
```

The probability of getting payment given low income is 0.49

Question

What is the probability that you have got Payment, given that the income is low and you have large deposits?

$$P(\bar{C}|\bar{A}, B) = ?$$

```
In [ ]: infer = VariableElimination(model)
g_dist = infer.query(["income", "deposit", "payment",
                      "housing", "security"])
g_dist.marginalize(["housing", "security"])
p_cbar_abar_b = g_dist.values[1][0][1]
p_cbar_abar_b
```

```
Out[ ]: 0.23099999999999998
```

```
In [ ]: g_dist.marginalize(["payment"])
p_abar_b = g_dist.values[1][0]
p_abar_b
```

```
Out[ ]: 0.42
```

```
In [ ]: p_cbar_given_abar_b = p_cbar_abar_b / p_abar_b
p_cbar_given_abar_b
```

```
Out[ ]: 0.5499999999999999
```

Probability of getting payment given that the income is low and having high deposits is 0.55

Question

What is the probability that you didn't default in payment given high income and no security is given?

$$P(\bar{C}|A, \bar{D}) = ?$$

```
In [ ]: infer = VariableElimination(model)
g_dist = infer.query(["income", "deposit", "payment",
                      "housing", "security"])
g_dist.marginalize(["deposit", "housing"])
p_cbar_a_dbar = g_dist.values[0][1][1]
p_cbar_a_dbar
```

```
Out[ ]: 0.08763599999999999
```

```
In [ ]: g_dist.marginalize(["payment"])
p_a_dbar = g_dist.values[0][1]
p_a_dbar
```

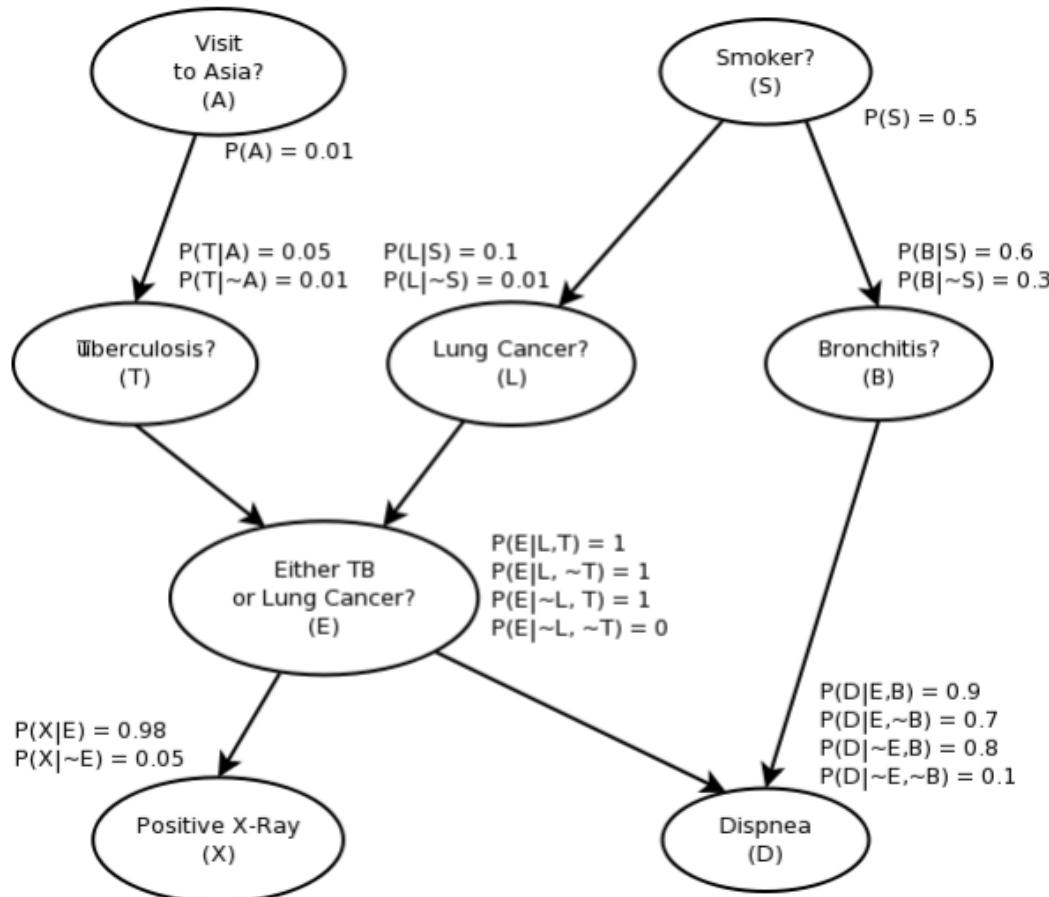
```
Out[ ]: 0.17929575
```

```
In [ ]: p_cbar_given_a_dbar = p_cbar_a_dbar / p_a_dbar
p_cbar_given_a_dbar
```

```
Out[ ]: 0.48877901456113704
```

Probability of not defaulting in payment given high income and no security is 0.4888

Question 2



```
In [ ]: # Create a DAG
g = DAG()
```

```
# Add nodes to the DAG
g.add_nodes_from(["asia", "smoker", "tb", "lung_cancer", "bronchitis",
```

```

        "tb_or_lc", "xray", "dispnea"])

# Define relationships in the DAG
g.add_edges_from(ebunch = [("asia", "tb"), ("smoker", "lung_cancer"),
                           ("smoker", "bronchitis"), ("tb", "tb_or_lc"),
                           ("lung_cancer", "tb_or_lc"), ("tb_or_lc", "xray")
                           ("tb_or_lc", "dispnea"), ("bronchitis", "dispnea")]

# Marginal Distribution of Visiting Asia
cpd_asia = TabularCPD('asia', 2, [[0.01], [0.99]])

# Marginal Distribution of Smoking
cpd_smoker = TabularCPD("smoker", 2, [[0.5], [0.5]])

# Conditional Distribution of TB given visit to Asia
cpd_tb = TabularCPD("tb", 2, [[0.05, .01], [0.95, 0.99]],
                     evidence = ["asia"], evidence_card = [2])

# Conditional Distribution of Lung Cancer given smoker
cpd_lc = TabularCPD("lung_cancer", 2, [[.1, .01], [.9, .99]],
                     evidence = ["smoker"], evidence_card = [2])

# Conditional Distribution of Bronchitis given smoker
cpd_bronchitis = TabularCPD("bronchitis", 2, [[.6, .3], [.4, .7]],
                            evidence = ["smoker"], evidence_card = [2])

# TB or Lung Cancer Node modelling
cpd_lc_or_tb = TabularCPD("tb_or_lc", 2, [[1, 1, 1, 0], [0, 0, 0, 1]],
                           evidence = ["tb", "lung_cancer"],
                           evidence_card = [2, 2])

# Conditional Distribution of xray given tb or lc
cpd_xray = TabularCPD("xray", 2, [[.98, .05], [.02, .95]],
                       evidence = ["tb_or_lc"],
                       evidence_card = [2])

# Conditional Distribution of dispnea given bronchitis or either of lc/tb
cpd_dispnea = TabularCPD("dispnea", 2, [[.9, .8, .7, .1], [.1, .2, .3, .9]],
                           evidence = ["bronchitis", "tb_or_lc"],
                           evidence_card = [2, 2])

# Create a BN model and add all the conditional distributions
model = BayesianNetwork(g)
model.add_cpds(*[cpd_asia, cpd_smoker, cpd_tb, cpd_lc, cpd_bronchitis, cpd_lc_or_tb, cpd_xray, cpd_dispnea])

```

Question

What is the probability that you have the tuberculosis, given that you have visited Asia, you have Lung Cancer, and you know that you have positive x-ray?

$$\text{To find: } P(T|A, L, E, X) = \frac{P(T, A, L, E, X)}{P(A, L, E, X)}$$

In []: `infer = VariableElimination(model)`

```

g_dist = infer.query(["asia", "smoker", "tb", "lung_cancer",
                      "bronchitis", "tb_or_lc", "xray", "dispnea"])
g_dist.marginalize(["smoker", "bronchitis", "dispnea"])
p_talex = g_dist.values[0][0][0][0][0]
p_talex

```

Out[]: 2.695000000000005e-05

```

In [ ]: g_dist.marginalize(["tb"])
p_alex = g_dist.values[0][0][0][0]
p_alex

```

Out[]: 0.0005390000000000001

```

In [ ]: required_cpd = p_talex / p_alex
required_cpd

```

Out[]: 0.05

The probability that you have the tuberculosis, given that you have visited Asia, you have Lung Cancer, and you know that you have positive x-ray is 0.05 .

Question

What is the probability of having Dispnea given that you have positive x-ray

$$\text{To find: } P(D|X) = \frac{P(D,X)}{P(X)}$$

```

In [ ]: infer = VariableElimination(model)
g_dist = infer.query(["asia", "smoker", "tb", "lung_cancer",
                      "bronchitis", "tb_or_lc", "xray", "dispnea"])
g_dist.marginalize(["asia", "smoker", "tb", "lung_cancer",
                      "bronchitis", "tb_or_lc"])
p_dx = g_dist.values[0][0]
p_dx

```

Out[]: 0.07067010440000002

```

In [ ]: g_dist.marginalize(["dispnea"])
p_xray = g_dist.values[0]
p_xray

```

Out[]: 0.1102900400000003

```

In [ ]: p_d_given_x = p_dx / p_xray
p_d_given_x

```

Out[]: 0.6407659694384007

Probability of having dispnea given positive X-ray is 0.641 .

Question

List all the independencies in the given graph

```
In [ ]: print(model.get_independencies())
```

(xray \perp dispnea, tb, bronchitis, lung_cancer, asia, smoker | tb_or_lc)
(xray \perp asia | tb)
(xray \perp smoker, bronchitis | lung_cancer)
(xray \perp bronchitis | smoker)
(xray \perp tb, bronchitis, lung_cancer, asia, smoker | dispnea, tb_or_lc)
(xray \perp asia | dispnea, tb)
(xray \perp dispnea, bronchitis, lung_cancer, asia, smoker | tb_or_lc, tb)
(xray \perp dispnea, tb, lung_cancer, asia, smoker | tb_or_lc, bronchitis)
(xray \perp dispnea, tb, bronchitis, asia, smoker | lung_cancer, tb_or_lc)
(xray \perp dispnea, tb, bronchitis, lung_cancer, smoker | asia, tb_or_lc)
(xray \perp dispnea, tb, bronchitis, lung_cancer, asia | tb_or_lc, smoker)
(xray \perp asia | bronchitis, tb)
(xray \perp asia, bronchitis, smoker | lung_cancer, tb)
(xray \perp asia, bronchitis | smoker, tb)
(xray \perp smoker | lung_cancer, bronchitis)
(xray \perp smoker, bronchitis | lung_cancer, asia)
(xray \perp bronchitis | lung_cancer, smoker)
(xray \perp bronchitis | asia, smoker)
(xray \perp lung_cancer, asia, bronchitis, smoker | dispnea, tb_or_lc, tb)
(xray \perp lung_cancer, asia, tb, smoker | dispnea, tb_or_lc, bronchitis)
(xray \perp tb, asia, bronchitis, smoker | lung_cancer, dispnea, tb_or_lc)
(xray \perp lung_cancer, tb, smoker, bronchitis | dispnea, tb_or_lc, asia)
(xray \perp lung_cancer, tb, asia, bronchitis | dispnea, tb_or_lc, smoker)
(xray \perp asia | bronchitis, dispnea, tb)
(xray \perp asia | lung_cancer, dispnea, tb)
(xray \perp asia | dispnea, smoker, tb)
(xray \perp smoker | lung_cancer, dispnea, bronchitis)
(xray \perp lung_cancer, dispnea, asia, smoker | bronchitis, tb_or_lc, tb)
(xray \perp dispnea, asia, bronchitis, smoker | lung_cancer, tb_or_lc, tb)
(xray \perp lung_cancer, dispnea, smoker, bronchitis | asia, tb_or_lc, tb)
(xray \perp lung_cancer, dispnea, asia, bronchitis | tb_or_lc, tb, smoker)
(xray \perp dispnea, asia, tb, smoker | lung_cancer, tb_or_lc, bronchitis)
(xray \perp lung_cancer, dispnea, tb, smoker | asia, tb_or_lc, bronchitis)
(xray \perp lung_cancer, dispnea, asia, tb | tb_or_lc, bronchitis, smoker)
(xray \perp tb, dispnea, smoker, bronchitis | lung_cancer, asia, tb_or_lc)
(xray \perp tb, dispnea, asia, bronchitis | lung_cancer, tb_or_lc, smoker)
(xray \perp lung_cancer, dispnea, tb, bronchitis | asia, tb_or_lc, smoker)
(xray \perp asia, smoker | bronchitis, lung_cancer, tb)
(xray \perp asia | bronchitis, smoker, tb)
(xray \perp smoker, bronchitis | lung_cancer, asia, tb)
(xray \perp asia, bronchitis | lung_cancer, smoker, tb)
(xray \perp bronchitis | asia, tb, smoker)
(xray \perp smoker | lung_cancer, asia, bronchitis)
(xray \perp bronchitis | lung_cancer, asia, smoker)
(xray \perp lung_cancer, asia, smoker | bronchitis, dispnea, tb_or_lc, tb)
(xray \perp asia, bronchitis, smoker | lung_cancer, dispnea, tb_or_lc, tb)
(xray \perp lung_cancer, bronchitis, smoker | dispnea, tb_or_lc, tb, asia)
(xray \perp lung_cancer, asia, bronchitis | dispnea, tb_or_lc, tb, smoker)
(xray \perp asia, tb, smoker | lung_cancer, dispnea, tb_or_lc, bronchitis)
(xray \perp lung_cancer, tb, smoker | dispnea, tb_or_lc, bronchitis, asia)
(xray \perp lung_cancer, asia, tb | dispnea, tb_or_lc, bronchitis, smoker)
(xray \perp tb, smoker, bronchitis | lung_cancer, dispnea, tb_or_lc, asia)
(xray \perp tb, asia, bronchitis | lung_cancer, dispnea, tb_or_lc, smoker)
(xray \perp lung_cancer, tb, bronchitis | dispnea, tb_or_lc, smoker, asia)
(xray \perp asia, smoker | bronchitis, dispnea, lung_cancer, tb)
(xray \perp asia | bronchitis, dispnea, smoker, tb)

(xray \perp asia | lung_cancer, dispnea, smoker, tb)
(xray \perp smoker | lung_cancer, dispnea, asia, bronchitis)
(xray \perp dispnea, asia, smoker | bronchitis, lung_cancer, tb_or_lc, tb)
(xray \perp lung_cancer, dispnea, smoker | bronchitis, asia, tb_or_lc, tb)
(xray \perp bronchitis, dispnea, smoker | lung_cancer, asia, tb_or_lc, tb)
(xray \perp dispnea, asia, bronchitis | lung_cancer, tb_or_lc, tb, smoker)
(xray \perp lung_cancer, dispnea, bronchitis | asia, tb_or_lc, tb, smoker)
(xray \perp tb, dispnea, smoker | lung_cancer, asia, tb_or_lc, bronchitis)
(xray \perp dispnea, asia, tb | lung_cancer, tb_or_lc, bronchitis, smoker)
(xray \perp lung_cancer, dispnea, tb | asia, tb_or_lc, bronchitis, smoker)
(xray \perp tb, dispnea, bronchitis | lung_cancer, asia, tb_or_lc, smoker)
(xray \perp smoker | bronchitis, lung_cancer, asia, tb)
(xray \perp asia | bronchitis, lung_cancer, smoker, tb)
(xray \perp bronchitis | lung_cancer, asia, tb, smoker)
(xray \perp asia, smoker | tb_or_lc, dispnea, bronchitis, tb, lung_cancer)
(xray \perp lung_cancer, smoker | tb_or_lc, asia, dispnea, bronchitis, tb)
(xray \perp lung_cancer, asia | tb_or_lc, dispnea, bronchitis, tb, smoker)
(xray \perp bronchitis, smoker | tb_or_lc, asia, dispnea, tb, lung_cancer)
(xray \perp asia, bronchitis | tb_or_lc, dispnea, tb, lung_cancer, smoker)
(xray \perp lung_cancer, bronchitis | tb_or_lc, asia, dispnea, tb, smoker)
(xray \perp tb, smoker | tb_or_lc, asia, dispnea, bronchitis, lung_cancer)
(xray \perp asia, tb | tb_or_lc, dispnea, bronchitis, lung_cancer, smoker)
(xray \perp lung_cancer, tb | tb_or_lc, asia, dispnea, bronchitis, smoker)
(xray \perp tb, bronchitis | tb_or_lc, asia, dispnea, lung_cancer, smoker)
(xray \perp smoker | asia, dispnea, bronchitis, tb, lung_cancer)
(xray \perp asia | dispnea, bronchitis, tb, lung_cancer, smoker)
(xray \perp dispnea, smoker | tb_or_lc, asia, bronchitis, tb, lung_cancer)
(xray \perp dispnea, asia | tb_or_lc, bronchitis, tb, lung_cancer, smoker)
(xray \perp lung_cancer, dispnea | tb_or_lc, asia, bronchitis, tb, smoker)
(xray \perp dispnea, bronchitis | tb_or_lc, asia, tb, lung_cancer, smoker)
(xray \perp dispnea, tb | tb_or_lc, asia, bronchitis, lung_cancer, smoker)
(xray \perp smoker | tb_or_lc, asia, dispnea, bronchitis, tb, lung_cancer)
(xray \perp asia | tb_or_lc, dispnea, bronchitis, tb, lung_cancer, smoker)
(xray \perp lung_cancer | tb_or_lc, asia, dispnea, bronchitis, tb, smoker)
(xray \perp bronchitis | tb_or_lc, asia, dispnea, tb, lung_cancer, smoker)
(xray \perp tb | tb_or_lc, asia, dispnea, bronchitis, lung_cancer, smoker)
(xray \perp dispnea | tb_or_lc, asia, bronchitis, tb, lung_cancer, smoker)
(tb_or_lc \perp asia | tb)
(tb_or_lc \perp smoker, bronchitis | lung_cancer)
(tb_or_lc \perp bronchitis | smoker)
(tb_or_lc \perp asia | xray, tb)
(tb_or_lc \perp smoker, bronchitis | xray, lung_cancer)
(tb_or_lc \perp bronchitis | xray, smoker)
(tb_or_lc \perp asia | dispnea, tb)
(tb_or_lc \perp asia | bronchitis, tb)
(tb_or_lc \perp asia, bronchitis, smoker | lung_cancer, tb)
(tb_or_lc \perp asia, bronchitis | smoker, tb)
(tb_or_lc \perp smoker | lung_cancer, bronchitis)
(tb_or_lc \perp smoker, bronchitis | lung_cancer, asia)
(tb_or_lc \perp bronchitis | lung_cancer, smoker)
(tb_or_lc \perp bronchitis | asia, smoker)
(tb_or_lc \perp asia | xray, dispnea, tb)
(tb_or_lc \perp asia | xray, bronchitis, tb)
(tb_or_lc \perp asia, bronchitis, smoker | xray, lung_cancer, tb)
(tb_or_lc \perp asia, bronchitis | xray, smoker, tb)

(tb_or_lc \perp smoker | xray, lung_cancer, bronchitis)
(tb_or_lc \perp smoker, bronchitis | xray, lung_cancer, asia)
(tb_or_lc \perp bronchitis | xray, lung_cancer, smoker)
(tb_or_lc \perp bronchitis | xray, asia, smoker)
(tb_or_lc \perp asia | bronchitis, dispnea, tb)
(tb_or_lc \perp asia | lung_cancer, dispnea, tb)
(tb_or_lc \perp asia | dispnea, smoker, tb)
(tb_or_lc \perp smoker | lung_cancer, dispnea, bronchitis)
(tb_or_lc \perp asia, smoker | bronchitis, lung_cancer, tb)
(tb_or_lc \perp asia | bronchitis, smoker, tb)
(tb_or_lc \perp bronchitis, smoker | lung_cancer, asia, tb)
(tb_or_lc \perp asia, bronchitis | lung_cancer, smoker, tb)
(tb_or_lc \perp bronchitis | asia, tb, smoker)
(tb_or_lc \perp smoker | lung_cancer, asia, bronchitis)
(tb_or_lc \perp bronchitis | lung_cancer, asia, smoker)
(tb_or_lc \perp asia | xray, bronchitis, dispnea, tb)
(tb_or_lc \perp asia | xray, lung_cancer, dispnea, tb)
(tb_or_lc \perp asia | xray, dispnea, smoker, tb)
(tb_or_lc \perp smoker | xray, lung_cancer, dispnea, bronchitis)
(tb_or_lc \perp asia, smoker | xray, bronchitis, lung_cancer, tb)
(tb_or_lc \perp asia | xray, bronchitis, smoker, tb)
(tb_or_lc \perp bronchitis, smoker | xray, lung_cancer, asia, tb)
(tb_or_lc \perp asia, bronchitis | xray, lung_cancer, smoker, tb)
(tb_or_lc \perp bronchitis | xray, asia, tb, smoker)
(tb_or_lc \perp smoker | xray, lung_cancer, asia, bronchitis)
(tb_or_lc \perp bronchitis | xray, lung_cancer, asia, smoker)
(tb_or_lc \perp asia, smoker | bronchitis, dispnea, lung_cancer, tb)
(tb_or_lc \perp asia | bronchitis, dispnea, smoker, tb)
(tb_or_lc \perp asia | lung_cancer, dispnea, smoker, tb)
(tb_or_lc \perp smoker | lung_cancer, dispnea, asia, bronchitis)
(tb_or_lc \perp smoker | bronchitis, lung_cancer, asia, tb)
(tb_or_lc \perp asia | bronchitis, lung_cancer, smoker, tb)
(tb_or_lc \perp bronchitis | lung_cancer, asia, tb, smoker)
(tb_or_lc \perp asia, smoker | xray, dispnea, bronchitis, tb, lung_cancer)
(tb_or_lc \perp asia | xray, dispnea, bronchitis, tb, smoker)
(tb_or_lc \perp asia | xray, dispnea, tb, lung_cancer, smoker)
(tb_or_lc \perp smoker | xray, asia, dispnea, bronchitis, lung_cancer)
(tb_or_lc \perp smoker | xray, asia, bronchitis, tb, lung_cancer)
(tb_or_lc \perp asia | xray, bronchitis, tb, lung_cancer, smoker)
(tb_or_lc \perp bronchitis | xray, asia, tb, lung_cancer, smoker)
(tb_or_lc \perp smoker | asia, dispnea, bronchitis, tb, lung_cancer)
(tb_or_lc \perp asia | dispnea, bronchitis, tb, lung_cancer, smoker)
(tb_or_lc \perp smoker | xray, asia, dispnea, bronchitis, tb, lung_cancer)
(tb_or_lc \perp asia | xray, dispnea, bronchitis, tb, lung_cancer, smoker)
(asia \perp lung_cancer, smoker, bronchitis)
(asia \perp xray | tb_or_lc)
(asia \perp xray, dispnea, tb_or_lc, bronchitis, lung_cancer, smoker | tb)
(asia \perp lung_cancer, smoker | bronchitis)
(asia \perp smoker, bronchitis | lung_cancer)
(asia \perp lung_cancer, bronchitis | smoker)
(asia \perp dispnea, tb_or_lc, bronchitis, lung_cancer, smoker | xray, tb)
(asia \perp smoker, bronchitis | xray, lung_cancer)
(asia \perp bronchitis | xray, smoker)
(asia \perp xray | dispnea, tb_or_lc)
(asia \perp xray, tb_or_lc, bronchitis, lung_cancer, smoker | dispnea, tb)
(asia \perp xray, dispnea, bronchitis, lung_cancer, smoker | tb_or_lc, tb)

(asia ⊥ xray, dispnea | tb_or_lc, bronchitis)
(asia ⊥ xray, dispnea, smoker, bronchitis | lung_cancer, tb_or_lc)
(asia ⊥ xray, dispnea, bronchitis | tb_or_lc, smoker)
(asia ⊥ xray, dispnea, tb_or_lc, lung_cancer, smoker | bronchitis, tb)
(asia ⊥ xray, dispnea, tb_or_lc, bronchitis, smoker | lung_cancer, tb)
(asia ⊥ xray, dispnea, tb_or_lc, bronchitis, lung_cancer | smoker, tb)
(asia ⊥ smoker | lung_cancer, bronchitis)
(asia ⊥ lung_cancer | smoker, bronchitis)
(asia ⊥ bronchitis | lung_cancer, smoker)
(asia ⊥ lung_cancer, tb_or_lc, bronchitis, smoker | xray, dispnea, tb)
(asia ⊥ lung_cancer, dispnea, smoker, bronchitis | xray, tb_or_lc, tb)
(asia ⊥ dispnea | xray, tb_or_lc, bronchitis)
(asia ⊥ dispnea, smoker, bronchitis | xray, lung_cancer, tb_or_lc)
(asia ⊥ dispnea, bronchitis | xray, tb_or_lc, smoker)
(asia ⊥ lung_cancer, dispnea, tb_or_lc, smoker | xray, bronchitis, tb)
(asia ⊥ dispnea, tb_or_lc, bronchitis, smoker | xray, lung_cancer, tb)
(asia ⊥ lung_cancer, dispnea, tb_or_lc, bronchitis | xray, smoker, tb)
(asia ⊥ smoker | xray, lung_cancer, bronchitis)
(asia ⊥ bronchitis | xray, lung_cancer, smoker)
(asia ⊥ xray, lung_cancer, bronchitis, smoker | dispnea, tb_or_lc, tb)
(asia ⊥ xray | dispnea, tb_or_lc, bronchitis)
(asia ⊥ xray, smoker, bronchitis | lung_cancer, dispnea, tb_or_lc)
(asia ⊥ xray, bronchitis | dispnea, tb_or_lc, smoker)
(asia ⊥ xray, lung_cancer, tb_or_lc, smoker | bronchitis, dispnea, tb)
(asia ⊥ xray, tb_or_lc, bronchitis, smoker | lung_cancer, dispnea, tb)
(asia ⊥ xray, lung_cancer, tb_or_lc, bronchitis | dispnea, smoker, tb)
(asia ⊥ smoker | lung_cancer, dispnea, bronchitis)
(asia ⊥ xray, lung_cancer, dispnea, smoker | bronchitis, tb_or_lc, tb)
(asia ⊥ xray, bronchitis, dispnea, smoker | lung_cancer, tb_or_lc, tb)
(asia ⊥ xray, lung_cancer, dispnea, bronchitis | tb_or_lc, tb, smoker)
(asia ⊥ xray, dispnea, smoker | lung_cancer, tb_or_lc, bronchitis)
(asia ⊥ xray, dispnea | tb_or_lc, bronchitis, smoker)
(asia ⊥ xray, dispnea, bronchitis | lung_cancer, tb_or_lc, smoker)
(asia ⊥ xray, dispnea, tb_or_lc, smoker | bronchitis, lung_cancer, tb)
(asia ⊥ xray, lung_cancer, dispnea, tb_or_lc | bronchitis, smoker, tb)
(asia ⊥ xray, dispnea, tb_or_lc, bronchitis | lung_cancer, smoker, tb)
(asia ⊥ lung_cancer, bronchitis, smoker | xray, dispnea, tb_or_lc, tb)
(asia ⊥ smoker, bronchitis | xray, lung_cancer, dispnea, tb_or_lc)
(asia ⊥ bronchitis | xray, dispnea, tb_or_lc, smoker)
(asia ⊥ lung_cancer, tb_or_lc, smoker | xray, bronchitis, dispnea, tb)
(asia ⊥ tb_or_lc, bronchitis, smoker | xray, lung_cancer, dispnea, tb)
(asia ⊥ lung_cancer, tb_or_lc, bronchitis | xray, dispnea, smoker, tb)
(asia ⊥ smoker | xray, lung_cancer, dispnea, bronchitis)
(asia ⊥ lung_cancer, dispnea, smoker | xray, bronchitis, tb_or_lc, tb)
(asia ⊥ bronchitis, dispnea, smoker | xray, lung_cancer, tb_or_lc, tb)
(asia ⊥ lung_cancer, dispnea, bronchitis | xray, tb_or_lc, tb, smoker)
(asia ⊥ dispnea, smoker | xray, lung_cancer, tb_or_lc, bronchitis)
(asia ⊥ dispnea | xray, tb_or_lc, bronchitis, smoker)
(asia ⊥ dispnea, bronchitis | xray, lung_cancer, tb_or_lc, smoker)
(asia ⊥ dispnea, tb_or_lc, smoker | xray, bronchitis, lung_cancer, tb)
(asia ⊥ lung_cancer, dispnea, tb_or_lc | xray, bronchitis, smoker, tb)
(asia ⊥ dispnea, tb_or_lc, bronchitis | xray, lung_cancer, smoker, tb)
(asia ⊥ xray, lung_cancer, smoker | bronchitis, dispnea, tb_or_lc, tb)
(asia ⊥ xray, bronchitis, smoker | lung_cancer, dispnea, tb_or_lc, tb)
(asia ⊥ xray, lung_cancer, bronchitis | dispnea, tb_or_lc, tb, smoker)
(asia ⊥ xray, smoker | lung_cancer, dispnea, tb_or_lc, bronchitis)

(asia \perp xray | dispnea, tb_or_lc, bronchitis, smoker)
(asia \perp xray, bronchitis | lung_cancer, dispnea, tb_or_lc, smoker)
(asia \perp xray, tb_or_lc, smoker | bronchitis, dispnea, lung_cancer, tb)
(asia \perp xray, lung_cancer, tb_or_lc | bronchitis, dispnea, smoker, tb)
(asia \perp xray, tb_or_lc, bronchitis | lung_cancer, dispnea, smoker, tb)
(asia \perp xray, dispnea, smoker | bronchitis, lung_cancer, tb_or_lc, tb)
(asia \perp xray, lung_cancer, dispnea | bronchitis, tb_or_lc, tb, smoker)
(asia \perp xray, dispnea, bronchitis | lung_cancer, tb_or_lc, tb, smoker)
(asia \perp xray, dispnea | lung_cancer, tb_or_lc, bronchitis, smoker)
(asia \perp xray, dispnea, tb_or_lc | bronchitis, lung_cancer, smoker, tb)
(asia \perp lung_cancer, smoker | xray, tb_or_lc, dispnea, bronchitis, tb)
(asia \perp bronchitis, smoker | xray, tb_or_lc, dispnea, tb, lung_cancer)
(asia \perp lung_cancer, bronchitis | xray, tb_or_lc, dispnea, tb, smoker)
(asia \perp smoker | xray, tb_or_lc, dispnea, bronchitis, lung_cancer)
(asia \perp bronchitis | xray, tb_or_lc, dispnea, lung_cancer, smoker)
(asia \perp tb_or_lc, smoker | xray, dispnea, bronchitis, tb, lung_cancer)
(asia \perp lung_cancer, tb_or_lc | xray, dispnea, bronchitis, tb, smoker)
(asia \perp tb_or_lc, bronchitis | xray, dispnea, tb, lung_cancer, smoker)
(asia \perp dispnea, smoker | xray, tb_or_lc, bronchitis, tb, lung_cancer)
(asia \perp lung_cancer, dispnea | xray, tb_or_lc, bronchitis, tb, smoker)
(asia \perp dispnea, bronchitis | xray, tb_or_lc, tb, lung_cancer, smoker)
(asia \perp dispnea | xray, tb_or_lc, bronchitis, lung_cancer, smoker)
(asia \perp dispnea, tb_or_lc | xray, bronchitis, tb, lung_cancer, smoker)
(asia \perp xray, smoker | tb_or_lc, dispnea, bronchitis, tb, lung_cancer)
(asia \perp xray, lung_cancer | tb_or_lc, dispnea, bronchitis, tb, smoker)
(asia \perp xray, bronchitis | tb_or_lc, dispnea, tb, lung_cancer, smoker)
(asia \perp xray | tb_or_lc, dispnea, bronchitis, lung_cancer, smoker)
(asia \perp xray, tb_or_lc | dispnea, bronchitis, tb, lung_cancer, smoker)
(asia \perp xray, dispnea | tb_or_lc, bronchitis, tb, lung_cancer, smoker)
(asia \perp smoker | xray, tb_or_lc, dispnea, bronchitis, tb, lung_cancer)
(asia \perp lung_cancer | xray, tb_or_lc, dispnea, bronchitis, tb, smoker)
(asia \perp bronchitis | xray, tb_or_lc, dispnea, tb, lung_cancer, smoker)
(asia \perp tb_or_lc | xray, dispnea, bronchitis, tb, lung_cancer, smoker)
(asia \perp dispnea | xray, tb_or_lc, bronchitis, tb, lung_cancer, smoker)
(asia \perp xray | tb_or_lc, dispnea, bronchitis, tb, lung_cancer, smoker)
(dispnea \perp xray | tb_or_lc)
(dispnea \perp asia | tb)
(dispnea \perp asia | xray, tb)
(dispnea \perp xray, asia | tb_or_lc, tb)
(dispnea \perp xray, tb, lung_cancer, asia, smoker | tb_or_lc, bronchitis)
(dispnea \perp xray, asia, tb | lung_cancer, tb_or_lc)
(dispnea \perp xray | asia, tb_or_lc)
(dispnea \perp xray, lung_cancer, asia, tb | tb_or_lc, smoker)
(dispnea \perp asia | bronchitis, tb)
(dispnea \perp asia | lung_cancer, tb)
(dispnea \perp asia | smoker, tb)
(dispnea \perp smoker | lung_cancer, bronchitis)
(dispnea \perp asia | xray, tb_or_lc, tb)
(dispnea \perp lung_cancer, asia, tb, smoker | xray, tb_or_lc, bronchitis)
(dispnea \perp asia, tb | xray, lung_cancer, tb_or_lc)
(dispnea \perp lung_cancer, asia, tb | xray, tb_or_lc, smoker)
(dispnea \perp asia | xray, bronchitis, tb)
(dispnea \perp asia | xray, lung_cancer, tb)
(dispnea \perp asia | xray, smoker, tb)
(dispnea \perp smoker | xray, lung_cancer, bronchitis)
(dispnea \perp xray, lung_cancer, asia, smoker | bronchitis, tb_or_lc, tb)

(dispnea \perp xray, asia | lung_cancer, tb_or_lc, tb)
(dispnea \perp xray | asia, tb_or_lc, tb)
(dispnea \perp xray, lung_cancer, asia | tb_or_lc, tb, smoker)
(dispnea \perp xray, asia, tb, smoker | lung_cancer, tb_or_lc, bronchitis)
(dispnea \perp xray, lung_cancer, tb, smoker | asia, tb_or_lc, bronchitis)
(dispnea \perp xray, lung_cancer, asia, tb | tb_or_lc, bronchitis, smoker)
(dispnea \perp xray, tb | lung_cancer, asia, tb_or_lc)
(dispnea \perp xray, asia, tb | lung_cancer, tb_or_lc, smoker)
(dispnea \perp xray, lung_cancer, tb | asia, tb_or_lc, smoker)
(dispnea \perp asia, smoker | bronchitis, lung_cancer, tb)
(dispnea \perp asia | bronchitis, smoker, tb)
(dispnea \perp asia | lung_cancer, smoker, tb)
(dispnea \perp smoker | lung_cancer, asia, bronchitis)
(dispnea \perp lung_cancer, asia, smoker | xray, bronchitis, tb_or_lc, tb)
(dispnea \perp asia | xray, lung_cancer, tb_or_lc, tb)
(dispnea \perp lung_cancer, asia | xray, tb_or_lc, tb, smoker)
(dispnea \perp asia, tb, smoker | xray, lung_cancer, tb_or_lc, bronchitis)
(dispnea \perp lung_cancer, tb, smoker | xray, asia, tb_or_lc, bronchitis)
(dispnea \perp lung_cancer, asia, tb | xray, tb_or_lc, bronchitis, smoker)
(dispnea \perp tb | xray, lung_cancer, asia, tb_or_lc)
(dispnea \perp asia, tb | xray, lung_cancer, tb_or_lc, smoker)
(dispnea \perp lung_cancer, tb | xray, asia, tb_or_lc, smoker)
(dispnea \perp asia, smoker | xray, bronchitis, lung_cancer, tb)
(dispnea \perp asia | xray, bronchitis, smoker, tb)
(dispnea \perp asia | xray, lung_cancer, smoker, tb)
(dispnea \perp smoker | xray, lung_cancer, asia, bronchitis)
(dispnea \perp xray, asia, smoker | bronchitis, lung_cancer, tb_or_lc, tb)
(dispnea \perp xray, lung_cancer, smoker | bronchitis, asia, tb_or_lc, tb)
(dispnea \perp xray, lung_cancer, asia | bronchitis, tb_or_lc, tb, smoker)
(dispnea \perp xray | lung_cancer, asia, tb_or_lc, tb)
(dispnea \perp xray, asia | lung_cancer, tb_or_lc, tb, smoker)
(dispnea \perp xray, lung_cancer | asia, tb_or_lc, tb, smoker)
(dispnea \perp xray, tb, smoker | lung_cancer, asia, tb_or_lc, bronchitis)
(dispnea \perp xray, asia, tb | lung_cancer, tb_or_lc, bronchitis, smoker)
(dispnea \perp xray, lung_cancer, tb | asia, tb_or_lc, bronchitis, smoker)
(dispnea \perp xray, tb | lung_cancer, asia, tb_or_lc, smoker)
(dispnea \perp smoker | bronchitis, lung_cancer, asia, tb)
(dispnea \perp asia | bronchitis, lung_cancer, smoker, tb)
(dispnea \perp asia, smoker | xray, tb_or_lc, bronchitis, tb, lung_cancer)
(dispnea \perp lung_cancer, smoker | xray, tb_or_lc, asia, bronchitis, tb)
(dispnea \perp lung_cancer, asia | xray, tb_or_lc, bronchitis, tb, smoker)
(dispnea \perp asia | xray, tb_or_lc, tb, lung_cancer, smoker)
(dispnea \perp lung_cancer | xray, tb_or_lc, asia, tb, smoker)
(dispnea \perp tb, smoker | xray, tb_or_lc, asia, bronchitis, lung_cancer)
(dispnea \perp asia, tb | xray, tb_or_lc, bronchitis, lung_cancer, smoker)
(dispnea \perp lung_cancer, tb | xray, tb_or_lc, asia, bronchitis, smoker)
(dispnea \perp tb | xray, tb_or_lc, asia, lung_cancer, smoker)
(dispnea \perp smoker | xray, asia, bronchitis, tb, lung_cancer)
(dispnea \perp asia | xray, bronchitis, tb, lung_cancer, smoker)
(dispnea \perp xray, smoker | tb_or_lc, asia, bronchitis, tb, lung_cancer)
(dispnea \perp xray, asia | tb_or_lc, bronchitis, tb, lung_cancer, smoker)
(dispnea \perp xray, lung_cancer | tb_or_lc, asia, bronchitis, tb, smoker)
(dispnea \perp xray | tb_or_lc, asia, tb, lung_cancer, smoker)
(dispnea \perp xray, tb | tb_or_lc, asia, bronchitis, lung_cancer, smoker)
(dispnea \perp smoker | xray, tb_or_lc, asia, bronchitis, tb, lung_cancer)
(dispnea \perp asia | xray, tb_or_lc, bronchitis, tb, lung_cancer, smoker)

(dispnea \perp lung_cancer | xray, tb_or_lc, asia, bronchitis, tb, smoker)
(dispnea \perp tb | xray, tb_or_lc, asia, bronchitis, lung_cancer, smoker)
(dispnea \perp xray | tb_or_lc, asia, bronchitis, tb, lung_cancer, smoker)
(tb \perp lung_cancer, smoker, bronchitis)
(tb \perp xray | tb_or_lc)
(tb \perp lung_cancer, smoker | bronchitis)
(tb \perp smoker, bronchitis | lung_cancer)
(tb \perp lung_cancer, smoker, bronchitis | asia)
(tb \perp lung_cancer, bronchitis | smoker)
(tb \perp smoker, bronchitis | xray, lung_cancer)
(tb \perp bronchitis | xray, smoker)
(tb \perp xray | dispnea, tb_or_lc)
(tb \perp xray, dispnea | tb_or_lc, bronchitis)
(tb \perp xray, dispnea, smoker, bronchitis | lung_cancer, tb_or_lc)
(tb \perp xray | asia, tb_or_lc)
(tb \perp xray, dispnea, bronchitis | tb_or_lc, smoker)
(tb \perp smoker | lung_cancer, bronchitis)
(tb \perp lung_cancer, smoker | asia, bronchitis)
(tb \perp lung_cancer | smoker, bronchitis)
(tb \perp smoker, bronchitis | lung_cancer, asia)
(tb \perp bronchitis | lung_cancer, smoker)
(tb \perp lung_cancer, bronchitis | asia, smoker)
(tb \perp dispnea | xray, tb_or_lc, bronchitis)
(tb \perp dispnea, smoker, bronchitis | xray, lung_cancer, tb_or_lc)
(tb \perp dispnea, bronchitis | xray, tb_or_lc, smoker)
(tb \perp smoker | xray, lung_cancer, bronchitis)
(tb \perp smoker, bronchitis | xray, lung_cancer, asia)
(tb \perp bronchitis | xray, lung_cancer, smoker)
(tb \perp bronchitis | xray, asia, smoker)
(tb \perp xray | dispnea, tb_or_lc, bronchitis)
(tb \perp xray, smoker, bronchitis | lung_cancer, dispnea, tb_or_lc)
(tb \perp xray | dispnea, tb_or_lc, asia)
(tb \perp xray, bronchitis | dispnea, tb_or_lc, smoker)
(tb \perp smoker | lung_cancer, dispnea, bronchitis)
(tb \perp xray, dispnea, smoker | lung_cancer, tb_or_lc, bronchitis)
(tb \perp xray, dispnea | asia, tb_or_lc, bronchitis)
(tb \perp xray, dispnea | tb_or_lc, bronchitis, smoker)
(tb \perp xray, bronchitis, dispnea, smoker | lung_cancer, asia, tb_or_lc)
(tb \perp xray, dispnea, bronchitis | lung_cancer, tb_or_lc, smoker)
(tb \perp xray, dispnea, bronchitis | asia, tb_or_lc, smoker)
(tb \perp smoker | lung_cancer, asia, bronchitis)
(tb \perp lung_cancer | asia, bronchitis, smoker)
(tb \perp bronchitis | lung_cancer, asia, smoker)
(tb \perp smoker, bronchitis | xray, lung_cancer, dispnea, tb_or_lc)
(tb \perp bronchitis | xray, dispnea, tb_or_lc, smoker)
(tb \perp smoker | xray, lung_cancer, dispnea, bronchitis)
(tb \perp dispnea, smoker | xray, lung_cancer, tb_or_lc, bronchitis)
(tb \perp dispnea | xray, asia, tb_or_lc, bronchitis)
(tb \perp dispnea | xray, tb_or_lc, bronchitis, smoker)
(tb \perp bronchitis, dispnea, smoker | xray, lung_cancer, asia, tb_or_lc)
(tb \perp dispnea, bronchitis | xray, lung_cancer, tb_or_lc, smoker)
(tb \perp dispnea, bronchitis | xray, asia, tb_or_lc, smoker)
(tb \perp smoker | xray, lung_cancer, asia, bronchitis)
(tb \perp bronchitis | xray, lung_cancer, asia, smoker)
(tb \perp xray, smoker | lung_cancer, dispnea, tb_or_lc, bronchitis)
(tb \perp xray | dispnea, tb_or_lc, bronchitis, asia)

(tb \perp xray | dispnea, tb_or_lc, bronchitis, smoker)
(tb \perp xray, bronchitis, smoker | lung_cancer, dispnea, tb_or_lc, asia)
(tb \perp xray, bronchitis | lung_cancer, dispnea, tb_or_lc, smoker)
(tb \perp xray, bronchitis | dispnea, tb_or_lc, smoker, asia)
(tb \perp smoker | lung_cancer, dispnea, asia, bronchitis)
(tb \perp xray, dispnea, smoker | lung_cancer, asia, tb_or_lc, bronchitis)
(tb \perp xray, dispnea | lung_cancer, tb_or_lc, bronchitis, smoker)
(tb \perp xray, dispnea | asia, tb_or_lc, bronchitis, smoker)
(tb \perp xray, dispnea, bronchitis | lung_cancer, asia, tb_or_lc, smoker)
(tb \perp smoker | xray, tb_or_lc, dispnea, bronchitis, lung_cancer)
(tb \perp bronchitis, smoker | xray, tb_or_lc, asia, dispnea, lung_cancer)
(tb \perp bronchitis | xray, tb_or_lc, dispnea, lung_cancer, smoker)
(tb \perp bronchitis | xray, tb_or_lc, asia, dispnea, smoker)
(tb \perp smoker | xray, asia, dispnea, bronchitis, lung_cancer)
(tb \perp dispnea, smoker | xray, tb_or_lc, asia, bronchitis, lung_cancer)
(tb \perp dispnea | xray, tb_or_lc, bronchitis, lung_cancer, smoker)
(tb \perp dispnea | xray, tb_or_lc, asia, bronchitis, smoker)
(tb \perp dispnea, bronchitis | xray, tb_or_lc, asia, lung_cancer, smoker)
(tb \perp xray, smoker | tb_or_lc, asia, dispnea, bronchitis, lung_cancer)
(tb \perp xray | tb_or_lc, dispnea, bronchitis, lung_cancer, smoker)
(tb \perp xray | tb_or_lc, asia, dispnea, bronchitis, smoker)
(tb \perp xray, bronchitis | tb_or_lc, asia, dispnea, lung_cancer, smoker)
(tb \perp xray, dispnea | tb_or_lc, asia, bronchitis, lung_cancer, smoker)
(tb \perp smoker | xray, tb_or_lc, asia, dispnea, bronchitis, lung_cancer)
(tb \perp bronchitis | xray, tb_or_lc, asia, dispnea, lung_cancer, smoker)
(tb \perp dispnea | xray, tb_or_lc, asia, bronchitis, lung_cancer, smoker)
(tb \perp xray | tb_or_lc, asia, dispnea, bronchitis, lung_cancer, smoker)
(bronchitis \perp asia, tb)
(bronchitis \perp xray | tb_or_lc)
(bronchitis \perp asia | tb)
(bronchitis \perp xray, asia, tb_or_lc, tb | lung_cancer)
(bronchitis \perp tb | asia)
(bronchitis \perp xray, tb_or_lc, tb, lung_cancer, asia | smoker)
(bronchitis \perp asia | xray, tb)
(bronchitis \perp asia, tb_or_lc, tb | xray, lung_cancer)
(bronchitis \perp lung_cancer, asia, tb_or_lc, tb | xray, smoker)
(bronchitis \perp xray | dispnea, tb_or_lc)
(bronchitis \perp asia | dispnea, tb)
(bronchitis \perp xray, asia | tb_or_lc, tb)
(bronchitis \perp xray, asia, tb | lung_cancer, tb_or_lc)
(bronchitis \perp xray | asia, tb_or_lc)
(bronchitis \perp xray, lung_cancer, asia, tb | tb_or_lc, smoker)
(bronchitis \perp xray, asia, tb_or_lc | lung_cancer, tb)
(bronchitis \perp xray, lung_cancer, asia, tb_or_lc | smoker, tb)
(bronchitis \perp xray, tb_or_lc, tb | lung_cancer, asia)
(bronchitis \perp xray, asia, tb_or_lc, tb | lung_cancer, smoker)
(bronchitis \perp xray, lung_cancer, tb_or_lc, tb | asia, smoker)
(bronchitis \perp asia | xray, dispnea, tb)
(bronchitis \perp asia | xray, tb_or_lc, tb)
(bronchitis \perp asia, tb | xray, lung_cancer, tb_or_lc)
(bronchitis \perp lung_cancer, asia, tb | xray, tb_or_lc, smoker)
(bronchitis \perp asia, tb_or_lc | xray, lung_cancer, tb)
(bronchitis \perp lung_cancer, asia, tb_or_lc | xray, smoker, tb)
(bronchitis \perp tb_or_lc, tb | xray, lung_cancer, asia)
(bronchitis \perp asia, tb_or_lc, tb | xray, lung_cancer, smoker)
(bronchitis \perp lung_cancer, tb_or_lc, tb | xray, asia, smoker)

(bronchitis \perp xray, asia | dispnea, tb_or_lc, tb)
(bronchitis \perp xray, asia, tb | lung_cancer, dispnea, tb_or_lc)
(bronchitis \perp xray | dispnea, tb_or_lc, asia)
(bronchitis \perp xray, lung_cancer, asia, tb | dispnea, tb_or_lc, smoker)
(bronchitis \perp asia | lung_cancer, dispnea, tb)
(bronchitis \perp asia | dispnea, smoker, tb)
(bronchitis \perp xray, asia | lung_cancer, tb_or_lc, tb)
(bronchitis \perp xray | asia, tb_or_lc, tb)
(bronchitis \perp xray, lung_cancer, asia | tb_or_lc, tb, smoker)
(bronchitis \perp xray, tb | lung_cancer, asia, tb_or_lc)
(bronchitis \perp xray, asia, tb | lung_cancer, tb_or_lc, smoker)
(bronchitis \perp xray, lung_cancer, tb | asia, tb_or_lc, smoker)
(bronchitis \perp xray, tb_or_lc | lung_cancer, asia, tb)
(bronchitis \perp xray, asia, tb_or_lc | lung_cancer, smoker, tb)
(bronchitis \perp xray, lung_cancer, tb_or_lc | asia, tb, smoker)
(bronchitis \perp xray, tb_or_lc, tb | lung_cancer, asia, smoker)
(bronchitis \perp asia | xray, dispnea, tb_or_lc, tb)
(bronchitis \perp asia, tb | xray, lung_cancer, dispnea, tb_or_lc)
(bronchitis \perp lung_cancer, asia, tb | xray, dispnea, tb_or_lc, smoker)
(bronchitis \perp asia | xray, lung_cancer, dispnea, tb)
(bronchitis \perp asia | xray, dispnea, smoker, tb)
(bronchitis \perp asia | xray, lung_cancer, tb_or_lc, tb)
(bronchitis \perp lung_cancer, asia | xray, tb_or_lc, tb, smoker)
(bronchitis \perp tb | xray, lung_cancer, asia, tb_or_lc)
(bronchitis \perp asia, tb | xray, lung_cancer, tb_or_lc, smoker)
(bronchitis \perp lung_cancer, tb | xray, asia, tb_or_lc, smoker)
(bronchitis \perp tb_or_lc | xray, lung_cancer, asia, tb)
(bronchitis \perp asia, tb_or_lc | xray, lung_cancer, smoker, tb)
(bronchitis \perp lung_cancer, tb_or_lc | xray, asia, tb, smoker)
(bronchitis \perp tb_or_lc, tb | xray, lung_cancer, asia, smoker)
(bronchitis \perp xray, asia | lung_cancer, dispnea, tb_or_lc, tb)
(bronchitis \perp xray | dispnea, tb_or_lc, tb, asia)
(bronchitis \perp xray, lung_cancer, asia | dispnea, tb_or_lc, tb, smoker)
(bronchitis \perp xray, tb | lung_cancer, dispnea, tb_or_lc, asia)
(bronchitis \perp xray, asia, tb | lung_cancer, dispnea, tb_or_lc, smoker)
(bronchitis \perp xray, lung_cancer, tb | dispnea, tb_or_lc, smoker, asia)
(bronchitis \perp asia | lung_cancer, dispnea, smoker, tb)
(bronchitis \perp xray | lung_cancer, asia, tb_or_lc, tb)
(bronchitis \perp xray, asia | lung_cancer, tb_or_lc, tb, smoker)
(bronchitis \perp xray, lung_cancer | asia, tb_or_lc, tb, smoker)
(bronchitis \perp xray, tb | lung_cancer, asia, tb_or_lc, smoker)
(bronchitis \perp xray, tb_or_lc | lung_cancer, asia, tb, smoker)
(bronchitis \perp asia | xray, tb_or_lc, dispnea, tb, lung_cancer)
(bronchitis \perp lung_cancer, asia | xray, tb_or_lc, dispnea, tb, smoker)
(bronchitis \perp tb | xray, tb_or_lc, asia, dispnea, lung_cancer)
(bronchitis \perp asia, tb | xray, tb_or_lc, dispnea, lung_cancer, smoker)
(bronchitis \perp lung_cancer, tb | xray, tb_or_lc, asia, dispnea, smoker)
(bronchitis \perp asia | xray, dispnea, tb, lung_cancer, smoker)
(bronchitis \perp asia | xray, tb_or_lc, tb, lung_cancer, smoker)
(bronchitis \perp lung_cancer | xray, tb_or_lc, asia, tb, smoker)
(bronchitis \perp tb | xray, tb_or_lc, asia, lung_cancer, smoker)
(bronchitis \perp tb_or_lc | xray, asia, tb, lung_cancer, smoker)
(bronchitis \perp xray | tb_or_lc, asia, dispnea, tb, lung_cancer)
(bronchitis \perp xray, asia | tb_or_lc, dispnea, tb, lung_cancer, smoker)
(bronchitis \perp xray, lung_cancer | tb_or_lc, asia, dispnea, tb, smoker)
(bronchitis \perp xray, tb | tb_or_lc, asia, dispnea, lung_cancer, smoker)

(bronchitis \perp xray | tb_or_lc, asia, tb, lung_cancer, smoker)
(bronchitis \perp asia | xray, tb_or_lc, dispnea, tb, lung_cancer, smoker)
(bronchitis \perp lung_cancer | xray, tb_or_lc, asia, dispnea, tb, smoker)
(bronchitis \perp tb | xray, tb_or_lc, asia, dispnea, lung_cancer, smoker)
(bronchitis \perp xray | tb_or_lc, asia, dispnea, tb, lung_cancer, smoker)
(lung_cancer \perp asia, tb)
(lung_cancer \perp xray | tb_or_lc)
(lung_cancer \perp asia | tb)
(lung_cancer \perp asia, tb | bronchitis)
(lung_cancer \perp tb | asia)
(lung_cancer \perp tb, asia, bronchitis | smoker)
(lung_cancer \perp asia | xray, tb)
(lung_cancer \perp bronchitis | xray, smoker)
(lung_cancer \perp xray | dispnea, tb_or_lc)
(lung_cancer \perp asia | dispnea, tb)
(lung_cancer \perp xray, asia | tb_or_lc, tb)
(lung_cancer \perp xray, dispnea | tb_or_lc, bronchitis)
(lung_cancer \perp xray | asia, tb_or_lc)
(lung_cancer \perp xray, dispnea, bronchitis | tb_or_lc, smoker)
(lung_cancer \perp asia | bronchitis, tb)
(lung_cancer \perp asia, bronchitis | smoker, tb)
(lung_cancer \perp tb | asia, bronchitis)
(lung_cancer \perp asia, tb | smoker, bronchitis)
(lung_cancer \perp tb, bronchitis | asia, smoker)
(lung_cancer \perp asia | xray, dispnea, tb)
(lung_cancer \perp asia | xray, tb_or_lc, tb)
(lung_cancer \perp dispnea | xray, tb_or_lc, bronchitis)
(lung_cancer \perp dispnea, bronchitis | xray, tb_or_lc, smoker)
(lung_cancer \perp asia | xray, bronchitis, tb)
(lung_cancer \perp asia, bronchitis | xray, smoker, tb)
(lung_cancer \perp bronchitis | xray, asia, smoker)
(lung_cancer \perp xray, asia | dispnea, tb_or_lc, tb)
(lung_cancer \perp xray | dispnea, tb_or_lc, bronchitis)
(lung_cancer \perp xray | dispnea, tb_or_lc, asia)
(lung_cancer \perp xray, bronchitis | dispnea, tb_or_lc, smoker)
(lung_cancer \perp asia | bronchitis, dispnea, tb)
(lung_cancer \perp asia | dispnea, smoker, tb)
(lung_cancer \perp xray, dispnea, asia | bronchitis, tb_or_lc, tb)
(lung_cancer \perp xray | asia, tb_or_lc, tb)
(lung_cancer \perp xray, dispnea, asia, bronchitis | tb_or_lc, tb, smoker)
(lung_cancer \perp xray, dispnea | asia, tb_or_lc, bronchitis)
(lung_cancer \perp xray, dispnea | tb_or_lc, bronchitis, smoker)
(lung_cancer \perp xray, dispnea, bronchitis | asia, tb_or_lc, smoker)
(lung_cancer \perp asia | bronchitis, smoker, tb)
(lung_cancer \perp bronchitis | asia, tb, smoker)
(lung_cancer \perp tb | asia, bronchitis, smoker)
(lung_cancer \perp asia | xray, dispnea, tb_or_lc, tb)
(lung_cancer \perp bronchitis | xray, dispnea, tb_or_lc, smoker)
(lung_cancer \perp asia | xray, bronchitis, dispnea, tb)
(lung_cancer \perp asia | xray, dispnea, smoker, tb)
(lung_cancer \perp dispnea, asia | xray, bronchitis, tb_or_lc, tb)
(lung_cancer \perp dispnea, asia, bronchitis | xray, tb_or_lc, tb, smoker)
(lung_cancer \perp dispnea | xray, asia, tb_or_lc, bronchitis)
(lung_cancer \perp dispnea | xray, tb_or_lc, bronchitis, smoker)
(lung_cancer \perp dispnea, bronchitis | xray, asia, tb_or_lc, smoker)
(lung_cancer \perp asia | xray, bronchitis, smoker, tb)

(lung_cancer \perp bronchitis | xray, asia, tb, smoker)
(lung_cancer \perp xray, asia | bronchitis, dispnea, tb_or_lc, tb)
(lung_cancer \perp xray | dispnea, tb_or_lc, tb, asia)
(lung_cancer \perp xray, asia, bronchitis | dispnea, tb_or_lc, tb, smoker)
(lung_cancer \perp xray | dispnea, tb_or_lc, bronchitis, asia)
(lung_cancer \perp xray | dispnea, tb_or_lc, bronchitis, smoker)
(lung_cancer \perp xray, bronchitis | dispnea, tb_or_lc, smoker, asia)
(lung_cancer \perp asia | bronchitis, dispnea, smoker, tb)
(lung_cancer \perp xray, dispnea | bronchitis, asia, tb_or_lc, tb)
(lung_cancer \perp xray, dispnea, asia | bronchitis, tb_or_lc, tb, smoker)
(lung_cancer \perp xray, dispnea, bronchitis | asia, tb_or_lc, tb, smoker)
(lung_cancer \perp xray, dispnea | asia, tb_or_lc, bronchitis, smoker)
(lung_cancer \perp asia | xray, tb_or_lc, dispnea, bronchitis, tb)
(lung_cancer \perp asia, bronchitis | xray, tb_or_lc, dispnea, tb, smoker)
(lung_cancer \perp bronchitis | xray, tb_or_lc, asia, dispnea, smoker)
(lung_cancer \perp asia | xray, dispnea, bronchitis, tb, smoker)
(lung_cancer \perp dispnea | xray, tb_or_lc, asia, bronchitis, tb)
(lung_cancer \perp dispnea, asia | xray, tb_or_lc, bronchitis, tb, smoker)
(lung_cancer \perp dispnea, bronchitis | xray, tb_or_lc, asia, tb, smoker)
(lung_cancer \perp dispnea | xray, tb_or_lc, asia, bronchitis, smoker)
(lung_cancer \perp xray | tb_or_lc, asia, dispnea, bronchitis, tb)
(lung_cancer \perp xray, asia | tb_or_lc, dispnea, bronchitis, tb, smoker)
(lung_cancer \perp xray, bronchitis | tb_or_lc, asia, dispnea, tb, smoker)
(lung_cancer \perp xray | tb_or_lc, asia, dispnea, bronchitis, smoker)
(lung_cancer \perp xray, dispnea | tb_or_lc, asia, bronchitis, tb, smoker)
(lung_cancer \perp asia | xray, tb_or_lc, dispnea, bronchitis, tb, smoker)
(lung_cancer \perp bronchitis | xray, tb_or_lc, asia, dispnea, tb, smoker)
(lung_cancer \perp dispnea | xray, tb_or_lc, asia, bronchitis, tb, smoker)
(lung_cancer \perp xray | tb_or_lc, asia, dispnea, bronchitis, tb, smoker)
(smoker \perp asia, tb)
(smoker \perp xray | tb_or_lc)
(smoker \perp asia | tb)
(smoker \perp asia, tb | bronchitis)
(smoker \perp xray, asia, tb_or_lc, tb | lung_cancer)
(smoker \perp tb | asia)
(smoker \perp asia | xray, tb)
(smoker \perp asia, tb_or_lc, tb | xray, lung_cancer)
(smoker \perp xray | dispnea, tb_or_lc)
(smoker \perp asia | dispnea, tb)
(smoker \perp xray, asia | tb_or_lc, tb)
(smoker \perp xray, dispnea | tb_or_lc, bronchitis)
(smoker \perp xray, asia, tb | lung_cancer, tb_or_lc)
(smoker \perp xray | asia, tb_or_lc)
(smoker \perp asia | bronchitis, tb)
(smoker \perp xray, asia, tb_or_lc | lung_cancer, tb)
(smoker \perp xray, dispnea, tb_or_lc, tb, asia | lung_cancer, bronchitis)
(smoker \perp tb | asia, bronchitis)
(smoker \perp xray, tb_or_lc, tb | lung_cancer, asia)
(smoker \perp asia | xray, dispnea, tb)
(smoker \perp asia | xray, tb_or_lc, tb)
(smoker \perp dispnea | xray, tb_or_lc, bronchitis)
(smoker \perp asia, tb | xray, lung_cancer, tb_or_lc)
(smoker \perp asia | xray, bronchitis, tb)
(smoker \perp asia, tb_or_lc | xray, lung_cancer, tb)
(smoker \perp dispnea, tb_or_lc, tb, asia | xray, lung_cancer, bronchitis)
(smoker \perp tb_or_lc, tb | xray, lung_cancer, asia)

(smoker \perp xray, asia | dispnea, tb_or_lc, tb)
(smoker \perp xray | dispnea, tb_or_lc, bronchitis)
(smoker \perp xray, asia, tb | lung_cancer, dispnea, tb_or_lc)
(smoker \perp xray | dispnea, tb_or_lc, asia)
(smoker \perp asia | bronchitis, dispnea, tb)
(smoker \perp asia | lung_cancer, dispnea, tb)
(smoker \perp xray, tb_or_lc, asia, tb | lung_cancer, dispnea, bronchitis)
(smoker \perp xray, dispnea, asia | bronchitis, tb_or_lc, tb)
(smoker \perp xray, asia | lung_cancer, tb_or_lc, tb)
(smoker \perp xray | asia, tb_or_lc, tb)
(smoker \perp xray, dispnea, asia, tb | lung_cancer, tb_or_lc, bronchitis)
(smoker \perp xray, dispnea | asia, tb_or_lc, bronchitis)
(smoker \perp xray, tb | lung_cancer, asia, tb_or_lc)
(smoker \perp xray, dispnea, tb_or_lc, asia | bronchitis, lung_cancer, tb)
(smoker \perp xray, tb_or_lc | lung_cancer, asia, tb)
(smoker \perp xray, dispnea, tb_or_lc, tb | lung_cancer, asia, bronchitis)
(smoker \perp asia | xray, dispnea, tb_or_lc, tb)
(smoker \perp asia, tb | xray, lung_cancer, dispnea, tb_or_lc)
(smoker \perp asia | xray, bronchitis, dispnea, tb)
(smoker \perp asia | xray, lung_cancer, dispnea, tb)
(smoker \perp tb_or_lc, asia, tb | xray, lung_cancer, dispnea, bronchitis)
(smoker \perp dispnea, asia | xray, bronchitis, tb_or_lc, tb)
(smoker \perp asia | xray, lung_cancer, tb_or_lc, tb)
(smoker \perp dispnea, asia, tb | xray, lung_cancer, tb_or_lc, bronchitis)
(smoker \perp dispnea | xray, asia, tb_or_lc, bronchitis)
(smoker \perp tb | xray, lung_cancer, asia, tb_or_lc)
(smoker \perp dispnea, tb_or_lc, asia | xray, bronchitis, lung_cancer, tb)
(smoker \perp tb_or_lc | xray, lung_cancer, asia, tb)
(smoker \perp dispnea, tb_or_lc, tb | xray, lung_cancer, asia, bronchitis)
(smoker \perp xray, asia | bronchitis, dispnea, tb_or_lc, tb)
(smoker \perp xray, asia | lung_cancer, dispnea, tb_or_lc, tb)
(smoker \perp xray | dispnea, tb_or_lc, tb, asia)
(smoker \perp xray, asia, tb | lung_cancer, dispnea, tb_or_lc, bronchitis)
(smoker \perp xray | dispnea, tb_or_lc, bronchitis, asia)
(smoker \perp xray, tb | lung_cancer, dispnea, tb_or_lc, asia)
(smoker \perp xray, tb_or_lc, asia | bronchitis, dispnea, lung_cancer, tb)
(smoker \perp xray, tb_or_lc, tb | lung_cancer, dispnea, asia, bronchitis)
(smoker \perp xray, dispnea, asia | bronchitis, lung_cancer, tb_or_lc, tb)
(smoker \perp xray, dispnea | bronchitis, asia, tb_or_lc, tb)
(smoker \perp xray | lung_cancer, asia, tb_or_lc, tb)
(smoker \perp xray, dispnea, tb | lung_cancer, asia, tb_or_lc, bronchitis)
(smoker \perp xray, dispnea, tb_or_lc | bronchitis, lung_cancer, asia, tb)
(smoker \perp asia | xray, tb_or_lc, dispnea, bronchitis, tb)
(smoker \perp asia | xray, tb_or_lc, dispnea, tb, lung_cancer)
(smoker \perp asia, tb | xray, tb_or_lc, dispnea, bronchitis, lung_cancer)
(smoker \perp tb | xray, tb_or_lc, asia, dispnea, lung_cancer)
(smoker \perp tb_or_lc, asia | xray, dispnea, bronchitis, tb, lung_cancer)
(smoker \perp tb_or_lc, tb | xray, asia, dispnea, bronchitis, lung_cancer)
(smoker \perp dispnea, asia | xray, tb_or_lc, bronchitis, tb, lung_cancer)
(smoker \perp dispnea | xray, tb_or_lc, asia, bronchitis, tb)
(smoker \perp dispnea, tb | xray, tb_or_lc, asia, bronchitis, lung_cancer)
(smoker \perp dispnea, tb_or_lc | xray, asia, bronchitis, tb, lung_cancer)
(smoker \perp xray, asia | tb_or_lc, dispnea, bronchitis, tb, lung_cancer)
(smoker \perp xray | tb_or_lc, asia, dispnea, bronchitis, tb)
(smoker \perp xray | tb_or_lc, asia, dispnea, tb, lung_cancer)
(smoker \perp xray, tb | tb_or_lc, asia, dispnea, bronchitis, lung_cancer)

(smoker \perp xray, tb_or_lc | asia, dispnea, bronchitis, tb, lung_cancer)
(smoker \perp xray, dispnea | tb_or_lc, asia, bronchitis, tb, lung_cancer)
(smoker \perp asia | xray, tb_or_lc, dispnea, bronchitis, tb, lung_cancer)
(smoker \perp tb | xray, tb_or_lc, asia, dispnea, bronchitis, lung_cancer)
(smoker \perp tb_or_lc | xray, asia, dispnea, bronchitis, tb, lung_cancer)
(smoker \perp dispnea | xray, tb_or_lc, asia, bronchitis, tb, lung_cancer)
(smoker \perp xray | tb_or_lc, asia, dispnea, bronchitis, tb, lung_cancer)