Part 2, Question 5

a) What is the risk of melt-down in the power plant during a day if no observations have been made? What if there is icy weather?

Risk for meltdown when no observation has been made: 2,6%, there is icy weather observed: 3,5%

b) Suppose that both warning sensors indicate failure. What is the risk of a meltdown in that case? Compare this result with the risk of a melt-down when there is an actual pump failure and water leak. What is the difference? The answers must be expressed as conditional probabilities of the observed variables, P(Meltdown|...).

P(Meltdown | PumpfailureWarning ∧ WaterLeakWarning) = 14,5%
P(Meltdown | PumpFailure ∧ WaterLeak) = 20%

Difference: 5,5%

c) The conditional probabilities for the stochastic variables are often estimated by repeated experiments or observations. Why is it sometimes very difficult to get accurate numbers for these? What conditional probabilites in the model of the plant do you think are difficult or impossible to estimate?

It is hard to get accurate numbers since meltdowns occur so infrequently and its not something you would want to do as a practical experiment. We guess that there are very little data available for meltdowns. Investigating a meltdown could also be problematic since the area probably is hazardous.

We think that both P(Meltdown ∧ WaterLeak) and P(Meltdown ∧ PumpFailure) is very difficult to estimate.

d) Assume that the "IcyWeather" variable is changed to a more accurate "Temperature" variable instead (don't change your model). What are the different alternatives for the domain of this variable? What will happen with the probability distribution of P(WaterLeak | Temperature) in each alternative?

There would be more alternatives. Currently its only possible to be icyWeather or not, true or false. If we were to use a temperature variable it would have to represent possible temperatures, either as all real numbers with a continous distribution of probabilities or as given discrete values(either whole degrees or intervals) with a finite set of probabilities.

Independant of if we would use a continous distribution or a finite set of probabilities that would propagate through the bayesian network.

Part 2, Question 6

a) What does a probability table in a Bayesian network represent?

All probabilites given all possible combinations of probabilites of the parents.

b) What is a joint probability distribution? Using the chain rule on the structure of the Bayesian network to rewrite the joint distribution as a product of P(child|parent) expressions, calculate manually the particular entry in the joint distribution of P(Meltdown=F, PumpFailureWarning=F, PumpFailure=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F). Is this a common state for the nuclear plant to be in?

P(¬Meltdown , ¬PumpFailureWarning ∧ ¬PumpFailure ∧ ¬WaterLeakWarning ∧ ¬WaterLeak ∧ ¬IcyWeather) = **69,3%**

P(¬Meltdown | ¬PumpFailure ∧ ¬WaterLeak) *

P(¬PumpFailureWarning | ¬PumpFailure) *

P(¬PumpFailure) *

P(¬WaterLeakWarning | ¬WaterLeak) *

P(¬WaterLeak | ¬IcyWeather) *

P(¬IcyWeather) =

0.999*0.95*0.9*0.95*0.9*0.95 = 0.693

Its a common state, we consider 70% common.

c) What is the probability of a meltdown if you know that there is both a water leak and a pump failure? Would knowing the state of any other variable matter? Explain your reasoning!

P(Meltdown | PumpFailure ∧ WaterLeak) = 20%

The other variables does not matter if the parents are known. If they are unknown however, the other variables states will make a difference since the probability of the parent will differ depending on their states.

d) Calculate manually the probability of a meltdown when you happen to know that PumpFailureWarning=F, WaterLeak=F, WaterLeakWarning=F and IcyWeather=F but you are not really sure about a pump failure.

P(Meltdown | PumpFailureWarning=F, WaterLeak=F, WaterLeakWarning=F, IcyWeather=F) = (0.00272, 0.99728)

The case meltdown=true has a probability of 0.278% and the case meltdown=false has 99.728%

Calculations:

$$\alpha\left(\sum_{pf} P(pf) \cdot P(\neg PFW \mid pf) \cdot P(M \mid pf \wedge \neg WL)\right)$$

$$= \alpha(0.1 \cdot 0.1 \cdot (0.15, 0.85) + 0.9 \cdot 0.95 \cdot (0.001, 0.999))$$

$$= \alpha((0{,}0015, 0{,}0085) + (0{,}000855, 0{,}854145))$$

$$= \alpha(0{,}002355, 0{,}862645)$$

$$\alpha = 1{,}15607$$

$$\Rightarrow (0{,}00272, 0{,}99728)$$

Part 3, Question 2

During the lunch break, the owner tries to show off for his employees by demonstrating the many features of his car stereo. To everyone's disappointment, it doesn't work. How did the owner's chances of surviving the day change after this observation?

Chance of survival
Before observation: 99%
After observation: 98.1%

How does the bicycle change the owner's chances of survival?

Change of survival with bike: 99.5%

It is possible to model any function in propositional logic with Bayesian Networks. What does this fact say about the complexity of exact inference in Bayesian Networks?
If the bayesian network is complex exact inference will not be a feasible option since the resources needed for the calculations are not available. The complexity grows exponentially with the number of unknown variables.

What alternatives are there to exact inference?
Monte carlo simulations, variational methods and loopy propagation.

Part 4

The owner had an idea that instead of employing a safety person, to replace the pump with a better one. Is it possible, in your model, to compensate for the lack of Mr H.S.'s expertise with a better pump?

Yes, it is possible by cutting the probability of pump failure by half.

Mr H.S. fell asleep on one of the plant's couches. When he wakes up he hears someone scream: "There is one or more warning signals beeping in your control room!". Mr H.S. realizes that he does not have time to fix the error before it is to late (we can assume that he wasn't in the control room at all). What is the chance of survival for Mr H.S. if he has a car with the same properties as the owner?

We added a node “Alert” which depends on PumpFailureWarning and WaterLeakWarning, which is true if one or both of them are true and false otherwise.

We also added a dependency from “Start” to “Alert” saying that the probability of starting if H.S. has not been alerted is 0.

H.S.’s chance of survival is 99.49%, a little bit lower than the owner.

What unrealistic assumptions do you make when creating a Bayesian Network model of a person?

We assume that only a small set of variables affect that persons action. We think that it would be impossible to accurately model a person with all variables that affect someone’s actions.

Describe how you would model a more dynamic world where for example the "IcyWeather" is more likely to be true the next day if it was true the day before. You only have to consider a limited sequence of days.

We could add more IcyWeather-nodes in a chain that represent the previous days weather.