1. We consider the training examples shown in the following table for a binary classification problem.

Instance	a_1	a_2	a_3	Target Class
1	T	T	1	+
2	T	T	6	+
3	T	F	5	-
4	F	F	4	+
5	F	T	7	-
6	F	T	3	-
7	F	F	8	-
8	T	F	7	+
9	F	T	5	-

a) What is the original entropy of this set of training instances?

The original entropy is $-\frac{4}{9}\log_2\frac{4}{9}-\frac{5}{9}\log_2\frac{5}{9}=0.991$ bit.

b) What are the information gains when a_1 and a_2 are used for partitioning the training set respectively?

After splitting on a_1, the entropy becomes

$$\frac{4}{9}\left(-\frac{3}{4}\log_2\frac{3}{4}-\frac{1}{4}\log_2\frac{1}{4}\right)+\frac{5}{9}\left(-\frac{1}{5}\log_2\frac{1}{5}-\frac{4}{5}\log_2\frac{4}{5}\right)=0.762 \text{ bit.}$$

As a result,

gain (a_1) = 0.991 – 0.762 = 0.229 bit.

After splitting on a_2, the entropy becomes

$$\frac{5}{9}(-\frac{2}{5}\log_2\frac{2}{5}-\frac{3}{5}\log_2\frac{3}{5})+\frac{4}{9}(-\frac{2}{4}\log_2\frac{2}{4}-\frac{2}{4}\log_2\frac{2}{4})=0.984 \text{ bit.}$$

As a result,

gain (a_2) = 0.991 – 0.984 = 0.007 bit.

2. We again consider the training examples shown in Q.1

   a) Calculate the respective changes in the Gini index value when a_1 and a_2 are used for partitioning the training set.

The original Gini index is $1-(\frac{4}{9})^2-(\frac{5}{9})^2=0.494$

After splitting on a_1, the Gini index becomes

$$\frac{4}{9}[1-(\frac{3}{4})^2-(\frac{1}{4})^2]+\frac{5}{9}[1-(\frac{1}{5})^2-(\frac{4}{5})^2]=0.344$$

As a result, the change in Gini index is

$\triangle$G(a_1) = 0.494 – 0.344 = 0.15.

After splitting on a_2, the Gini index becomes

$$\frac{5}{9}[1-(\frac{2}{5})^2-(\frac{3}{5})^2]+\frac{4}{9}[1-(\frac{2}{4})^2-(\frac{2}{4})^2]=0.489$$

As a result,

$\triangle$G(a_2) = 0.494 – 0.489 = 0.005.

   b) Calculate the respective changes in the classification error when a_1 and a_2 are used for partitioning the training set.

The original classification error is $1-\max(\frac{4}{9},\frac{5}{9})=\frac{4}{9}$

After splitting on a_1, the classification error becomes

$$\frac{4}{9}[1-\max(\frac{3}{4},\frac{1}{4})]+\frac{5}{9}[1-\max(\frac{1}{5},\frac{4}{5})]=\frac{2}{9}$$

As a result, the change in classification error is

$\triangle E(a_1) = 4/9 - 2/9 = 2/9.$

After splitting on a_2, the classification error becomes

$$\frac{5}{9}[1-\max(\frac{2}{5},\frac{3}{5})]+\frac{4}{9}[1-\max(\frac{2}{4},\frac{2}{4})]=\frac{4}{9}$$

As a result,

$\triangle E(a_2) = 4/9 - 4/9 = 0.$

c) For a_3, which is a continuous attribute, compute the information gain for every possible split. What is the best threshold for splitting the set of attribute values?

We consider the different possible split points for a_3 as follows:

a_3	Class label	Split point	Entropy	Info gain
1	+	2.0	0.848	0.143
3	-	3.5	0.989	0.002
4	+	4.5	0.918	0.073
5 5	- -	5.5	0.984	0.007
6	+	6.5	0.973	0.018
7 7	+ -	7.5	0.889	0.102
8	-			

The best split for a_3 occurs when the split point is equal to 2.