Import libraries

In [51]:
```
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import confusion_matrix, classification_report, accurac
from matplotlib.backends.backend_pdf import PdfPages
import matplotlib.pyplot as plt

RANDOM_SEED = 123
np.random.seed(RANDOM_SEED)
```

Load dataset

In [52]:
```
df = pd.read_csv("UniversalBank.csv")
cols_to_drop = [c for c in ['ID','Id','Zip Code','ZIP Code','ZIP','zip','Zip
df = df.drop(columns=cols_to_drop)
if 'PersonalLoan' in df.columns and 'Personal Loan' not in df.columns:
    df = df.rename(columns={'PersonalLoan':'Personal Loan'})
```

Data Summary

In [54]:
```
df.describe()
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5000 entries, 0 to 4999
Data columns (total 12 columns):
 #   Column              Non-Null Count  Dtype  
---  ------              --------------  -----  
 0   Age                 5000 non-null   int64  
 1   Experience          5000 non-null   int64  
 2   Income              5000 non-null   int64  
 3   Family              5000 non-null   int64  
 4   CCAvg               5000 non-null   float64
 5   Education           5000 non-null   int64  
 6   Mortgage            5000 non-null   int64  
 7   Personal Loan       5000 non-null   int64  
 8   Securities Account  5000 non-null   int64  
 9   CD Account          5000 non-null   int64  
 10  Online              5000 non-null   int64  
 11  CreditCard          5000 non-null   int64  
dtypes: float64(1), int64(11)
memory usage: 468.9 KB
```

Question 1 – Partition the data (75% training, 25% validation)

In [63]:
```
X = df.drop(columns=['Personal Loan'])
y = df['Personal Loan']

if 'Education' in X.columns:
```

```
    X = pd.get_dummies(X, columns=['Education'], prefix='Education', drop_fi
if 'CreditCard' in X.columns:
    X = X.rename(columns={'CreditCard': 'CreditCard'})

X_train, X_val, y_train, y_val = train_test_split(
    X, y, train_size=0.75, random_state=RANDOM_SEED, stratify=y)

print("Training set shape:", X_train.shape)
print("Validation set shape:", X_val.shape)
print("\nThis output indicates that we have managed to split the data into t
"\nrespectively, using 75% for training and 25% for validation.")
```

```
Training set shape: (3750, 13)
Validation set shape: (1250, 13)

This output indicates that we have managed to split the data into training
(3750, 13) and validation (1250, 13) sets,
respectively, using 75% for training and 25% for validation.
```

Question 2 – Define the given customer

In [64]:
```
cust = {
    'Age':40,'Experience':10,'Income':84,'Family':2,'CCAvg':2,
    'Education_1':0,'Education_2':1,'Education_3':0,
    'Mortgage':0,'Securities Account':1,'CD Account':1,'Online':1,'CreditCar

customer_row = pd.Series(0.0, index=X_train.columns)
for k,v in cust.items():
    if k in customer_row.index:
        customer_row[k] = v
    else:
        variants = {
            'Securities Account':['Securities Account','SecuritiesAccount','
            'CD Account':['CD Account','CDAccount','CD_Account'],
            'CreditCard':['CreditCard','Credit Card','Credit_Card'],
            'CCAvg':['CCAvg','CC Avg','CC_Avg']}
        if k in variants:
            for alt in variants[k]:
                if alt in customer_row.index:
                    customer_row[alt] = v
                    break
display(customer_row.to_frame().T)
```

	Age	Experience	Income	Family	CCAvg	Mortgage	Securities Account	CD Account	Online	C
0	40.0	10.0	84.0	2.0	2.0	0.0	1.0	1.0	1.0	

Question 3 – Standardize data using training mean & std

In [71]:
```
scaler = StandardScaler()
scaler.fit(X_train)
X_train_s = pd.DataFrame(scaler.transform(X_train), columns=X_train.columns)
X_val_s   = pd.DataFrame(scaler.transform(X_val), columns=X_val.columns)
customer_std = scaler.transform([customer_row.values])[0]
```

```
print("Training mean (first 5 features):\n", scaler.mean_[:5])
print("Training std (first 5 features):\n", scaler.scale_[:5])
print("\nThe StandardScaler was used to standardize the training and validat
"\nby subtracting the mean and scaling to unit variance for consistency acrc
```

```
Training mean (first 5 features):
 [45.34346667 20.10986667 73.7872      2.38986667  1.95087467]
Training std (first 5 features):
 [11.3985919  11.39947057 46.53769851  1.14589295  1.76819618]

The StandardScaler was used to standardize the training and validation sets,
besides the customer data,
by subtracting the mean and scaling to unit variance for consistency across
all datasets.
```

```
/opt/anaconda3/lib/python3.13/site-packages/sklearn/utils/validation.py:273
9: UserWarning: X does not have valid feature names, but StandardScaler was
fitted with feature names
  warnings.warn(
```

Question 4 – k-NN classification (k = 1)

In [70]:
```
knn1 = KNeighborsClassifier(n_neighbors=1)
knn1.fit(X_train_s, y_train)
cust_pred_k1 = int(knn1.predict([customer_std])[0])

print("Q4: Customer classification using k=1 →", cust_pred_k1)
print("\nCustomer's Prediction: The customer was classified as 0, meaning th
"\nPreprocessing involved standardizing the data, using all relevant feature
"\nThe model used the closest neighbor in the training data to make this pre
"\nSince the closest neighbor was classified as 0, the model predicts this c
```

```
Q4: Customer classification using k=1 → 0

Customer's Prediction: The customer was classified as 0, meaning the model p
redicts they will not accept the loan.
Preprocessing involved standardizing the data, using all relevant features
(except ID and ZIP Code), and training a k-NN model with k=1.
The model used the closest neighbor in the training data to make this predic
tion.
Since the closest neighbor was classified as 0, the model predicts this cust
omer will not accept the loan.
```

```
/opt/anaconda3/lib/python3.13/site-packages/sklearn/utils/validation.py:273
9: UserWarning: X does not have valid feature names, but KNeighborsClassifie
r was fitted with feature names
  warnings.warn(
```

Question 5 – Find optimal k using validation

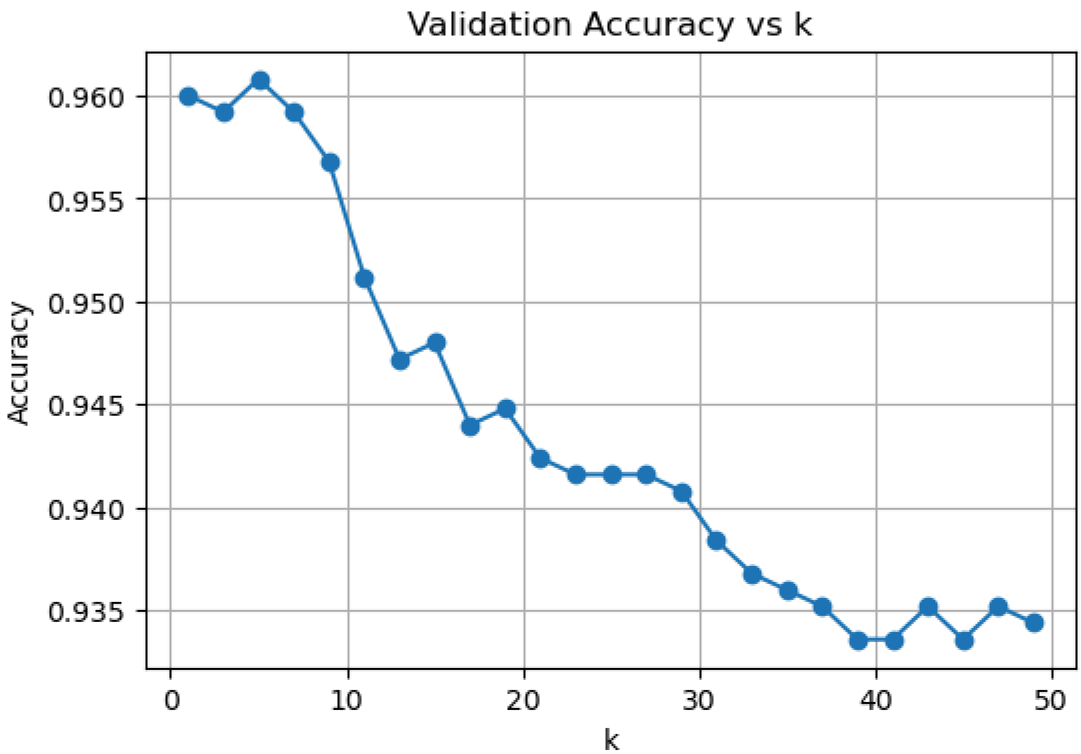
In [72]:
```
ks = [k for k in range(1, 50, 2)]
val_acc = []

for k in ks:
    knn = KNeighborsClassifier(n_neighbors=k)
    knn.fit(X_train_s, y_train)
    val_acc.append(accuracy_score(y_val, knn.predict(X_val_s)))
```

```
best_k = ks[np.argmax(val_acc)]

plt.figure(figsize=(6,4))
plt.plot(ks, val_acc, marker='o')
plt.title("Validation Accuracy vs k")
plt.xlabel("k")
plt.ylabel("Accuracy")
plt.grid(True)
plt.show()

print("Q5: Optimal k =", best_k)
print("\nGraphically, the best value for k is 5 because it actually reaches
"\nFor the values of k less than that, the model becomes overly sensitive to
"\nit becomes too simplistic and fails to capture important patterns in the
"\nk=5 provides the topmost accuracy on the validation set, ensuring the moc
"\nin the data while being simple enough to generalize well to new data.")
```




```
Q5: Optimal k = 5

Graphically, the best value for k is 5 because it actually reaches a balance
between overfitting and underfitting.
For the values of k less than that, the model becomes overly sensitive to no
ise in the data; for values of k larger than that,
it becomes too simplistic and fails to capture important patterns in the dat
a.
k=5 provides the topmost accuracy on the validation set, ensuring the model
is adequately complex to learn from the patterns
in the data while being simple enough to generalize well to new data.
```

Question 6 – Confusion matrix (validation, optimal k)

In [76]:
```
knn_best = KNeighborsClassifier(n_neighbors=best_k)
knn_best.fit(X_train_s, y_train)
y_val_pred = knn_best.predict(X_val_s)

cm_val = confusion_matrix(y_val, y_val_pred)

print("Confusion Matrix (Validation):\n", cm_val)
print("\nClassification Report (Validation):\n", classification_report(y_val
print("The overall model accuracy on the validation set is 96.08%. Its perfo
"\ndo not accept the loan, with a high precision of 95.92% and a high recall
"\nHowever, its performance on predicting customers who do take the loan is
"\nIts precision for class 1 being 98.63% indicates the model is good in cap
```

```
Confusion Matrix (Validation):
 [[1129    1]
 [  48   72]]

Classification Report (Validation):
               precision    recall  f1-score   support

           0     0.9592    0.9991    0.9788      1130
           1     0.9863    0.6000    0.7461       120

    accuracy                         0.9608      1250
   macro avg     0.9728    0.7996    0.8624      1250
weighted avg     0.9618    0.9608    0.9564      1250

The overall model accuracy on the validation set is 96.08%. Its performance
is good in correctly predicting customers who
do not accept the loan, with a high precision of 95.92% and a high recall of
99.91%.
However, its performance on predicting customers who do take the loan is low
er, with a recall of 60% and an F1-score of 0.7461.
Its precision for class 1 being 98.63% indicates the model is good in captur
ing the positives, but the recall suggests it misses out on some.
```

Question 7 – Classify the customer using best k

In [79]:
```
cust_pred_bestk = int(knn_best.predict([customer_std])[0])
print("Customer classification using best k =", best_k, "→", cust_pred_bestk
print("The output of 0 indicates that the model predicts the customer will n
"\nand the optimal k=5")
```

```
Customer classification using best k = 5 → 0
The output of 0 indicates that the model predicts the customer will not acce
pt the loan offer based on the features provided
and the optimal k=5
```

```
/opt/anaconda3/lib/python3.13/site-packages/sklearn/utils/validation.py:273
9: UserWarning: X does not have valid feature names, but KNeighborsClassifie
r was fitted with feature names
  warnings.warn(
```

Question 8 – Repartition into 50 % / 30 % / 20 % (train, val, test)

In [82]:
```
X_temp, X_test, y_temp, y_test = train_test_split(
    X, y, test_size=0.20, random_state=RANDOM_SEED, stratify=y)

train_prop_relative = 0.50 / (0.50 + 0.30)

X_train2, X_val2, y_train2, y_val2 = train_test_split(

    X_temp, y_temp, train_size=train_prop_relative, random_state=RANDOM_SEED
print("Train:", X_train2.shape, " Validation:", X_val2.shape, " Test:", X_te
print("The data has been repartitioned into three sets: 50% for training, 30
"\nensuring the proper distribution of data for model training and evaluatic
```

```
Train: (2500, 13)  Validation: (1500, 13)  Test: (1000, 13)
The data has been repartitioned into three sets: 50% for training, 30% for v
alidation, and 20% for testing,
ensuring the proper distribution of data for model training and evaluation.
```

Question 9 – Apply k-NN (best k) on new splits

In [83]:
```
scaler2 = StandardScaler()
scaler2.fit(X_train2)
X_train2_s = pd.DataFrame(scaler2.transform(X_train2), columns=X_train2.colu
X_val2_s   = pd.DataFrame(scaler2.transform(X_val2), columns=X_val2.columns)
X_test_s   = pd.DataFrame(scaler2.transform(X_test), columns=X_test.columns)

knn_final = KNeighborsClassifier(n_neighbors=best_k)
knn_final.fit(X_train2_s, y_train2)

y_train2_pred = knn_final.predict(X_train2_s)
y_val2_pred   = knn_final.predict(X_val2_s)
y_test_pred   = knn_final.predict(X_test_s)

print("k-NN applied with optimal k =", best_k)
print("The k-NN model with the optimal k=5 is applied after standardizing th
"\nand predictions are made for each dataset.")
```

```
k-NN applied with optimal k = 5
The k-NN model with the optimal k=5 is applied after standardizing the train
ing, validation, and test sets,
and predictions are made for each dataset.
```

Question 10 – Compare confusion matrices (train / validation / test)

In [85]:
```
cm_train = confusion_matrix(y_train2, y_train2_pred)
cm_val   = confusion_matrix(y_val2, y_val2_pred)
cm_test  = confusion_matrix(y_test, y_test_pred)

print("Confusion Matrix — Train\n", cm_train)
print("\nConfusion Matrix — Validation\n", cm_val)
print("\nConfusion Matrix — Test\n", cm_test)

print("\nClassification Report — Train\n", classification_report(y_train2, y
print("\nClassification Report — Validation\n", classification_report(y_val2
print("\nClassification Report — Test\n", classification_report(y_test, y_te

print("Confusion matrices indicate that the model does well on the training
```

```
"\nHowever, in the validation and test sets, there is a slight drop in perfo
"\nloan acceptance. While predictions on the training set are almost perfect
"\nshowing some underfitting. The model generalizes well but could be improv
```

```
Confusion Matrix — Train
 [[2257    3]
 [  70  170]]

Confusion Matrix — Validation
 [[1353    3]
 [  55   89]]

Confusion Matrix — Test
 [[904   0]
 [ 43  53]]

Classification Report — Train
               precision    recall  f1-score   support

           0     0.9699    0.9987    0.9841      2260
           1     0.9827    0.7083    0.8232       240

    accuracy                         0.9708      2500
   macro avg     0.9763    0.8535    0.9037      2500
weighted avg     0.9711    0.9708    0.9686      2500


Classification Report — Validation
               precision    recall  f1-score   support

           0     0.9609    0.9978    0.9790      1356
           1     0.9674    0.6181    0.7542       144

    accuracy                         0.9613      1500
   macro avg     0.9642    0.8079    0.8666      1500
weighted avg     0.9616    0.9613    0.9574      1500


Classification Report — Test
               precision    recall  f1-score   support

           0     0.9546    1.0000    0.9768       904
           1     1.0000    0.5521    0.7114        96

    accuracy                         0.9570      1000
   macro avg     0.9773    0.7760    0.8441      1000
weighted avg     0.9590    0.9570    0.9513      1000

Confusion matrices indicate that the model does well on the training set, si
nce precision and recall for both classes are high.
However, in the validation and test sets, there is a slight drop in performa
nce, especially in predicting class 1, which indicates
loan acceptance. While predictions on the training set are almost perfect, t
he test set includes more false negatives—43—already
showing some underfitting. The model generalizes well but could be improved
with respect to predictions of the first class.
```