In [173]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

In [174]:
```
df = pd.read_csv("https://d2beiqkhq929f0.cloudfront.net/public_assets/assets/000/003/549/original/logistic_regression.csv?1651045
```

In [175]:
```
df.head()
```

Out[175]:

	loan_amnt	term	int_rate	installment	grade	sub_grade	emp_title	emp_length	home_ownership	annual_inc	verification_status	issue_d	loan_status
0	10000.0	36 months	11.44	329.48	B	B4	Marketing	10+ years	RENT	117000.0	Not Verified	Jan-2015	Fully Paid
1	8000.0	36 months	11.99	265.68	B	B5	Credit analyst	4 years	MORTGAGE	65000.0	Not Verified	Jan-2015	Fully Paid
2	15600.0	36 months	10.49	506.97	B	B3	Statistician	< 1 year	RENT	43057.0	Source Verified	Jan-2015	Fully Paid
3	7200.0	36 months	6.49	220.65	A	A2	Client Advocate	6 years	RENT	54000.0	Not Verified	Nov-2014	Fully Paid
4	24375.0	60 months	17.27	609.33	C	C5	Destiny Management Inc.	9 years	MORTGAGE	55000.0	Verified	Apr-2013	Charged Off

In [176]:
```
df.shape
```

Out[176]:
```
(396030, 27)
```

In [177]:
```
df.describe()
```

Out[177]:

	loan_amnt	int_rate	installment	annual_inc	dti	open_acc	pub_rec	revol_bal	revol_util	total_acc
count	396030.000000	396030.000000	396030.000000	3.960300e+05	396030.000000	396030.000000	396030.000000	3.960300e+05	395754.000000	396030.000000
mean	14113.888089	13.639400	431.849698	7.420318e+04	17.379514	11.311153	0.178191	1.584454e+04	53.791749	25.414744
std	8357.441341	4.472157	250.727790	6.163762e+04	18.019092	5.137649	0.530671	2.059184e+04	24.452193	11.886991
min	500.000000	5.320000	16.080000	0.000000e+00	0.000000	0.000000	0.000000	0.000000e+00	0.000000	2.000000
25%	8000.000000	10.490000	250.330000	4.500000e+04	11.280000	8.000000	0.000000	6.025000e+03	35.800000	17.000000
50%	12000.000000	13.330000	375.430000	6.400000e+04	16.910000	10.000000	0.000000	1.118100e+04	54.800000	24.000000
75%	20000.000000	16.490000	567.300000	9.000000e+04	22.980000	14.000000	0.000000	1.962000e+04	72.900000	32.000000
max	40000.000000	30.990000	1533.810000	8.706582e+06	9999.000000	90.000000	86.000000	1.743266e+06	892.300000	151.000000

In [178]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 396030 entries, 0 to 396029
Data columns (total 27 columns):
 #   Column                Non-Null Count   Dtype  
---  ------                --------------   -----  
 0   loan_amnt             396030 non-null  float64
 1   term                  396030 non-null  object 
 2   int_rate              396030 non-null  float64
 3   installment           396030 non-null  float64
 4   grade                 396030 non-null  object 
 5   sub_grade             396030 non-null  object 
 6   emp_title             373103 non-null  object 
 7   emp_length            377729 non-null  object 
 8   home_ownership        396030 non-null  object 
 9   annual_inc            396030 non-null  float64
 10  verification_status   396030 non-null  object 
 11  issue_d               396030 non-null  object 
 12  loan_status           396030 non-null  object 
 13  purpose               396030 non-null  object 
 14  title                 394275 non-null  object 
 15  dti                   396030 non-null  float64
 16  earliest_cr_line      396030 non-null  object 
 17  open_acc              396030 non-null  float64
 18  pub_rec               396030 non-null  float64
 19  revol_bal             396030 non-null  float64
 20  revol_util            395754 non-null  float64
 21  total_acc             396030 non-null  float64
 22  initial_list_status   396030 non-null  object 
 23  application_type      396030 non-null  object 
 24  mort_acc              358235 non-null  float64
 25  pub_rec_bankruptcies  395495 non-null  float64
 26  address               396030 non-null  object 
dtypes: float64(12), object(15)
memory usage: 81.6+ MB
```

In [179]:
```
df.isnull().sum()
```

Out[179]:
```
loan_amnt                 0
term                      0
int_rate                  0
installment               0
grade                     0
sub_grade                 0
emp_title             22927
emp_length            18301
home_ownership            0
annual_inc                0
verification_status       0
issue_d                   0
loan_status               0
purpose                   0
title                  1755
dti                       0
earliest_cr_line          0
open_acc                  0
pub_rec                   0
revol_bal                 0
revol_util              276
total_acc                 0
initial_list_status       0
application_type          0
mort_acc              37795
pub_rec_bankruptcies    535
address                   0
dtype: int64
```

In [180]:
```
round((df.isnull().sum().sort_values(ascending=False) / len(df))*100, 2)
```

Out[180]:
```
mort_acc                9.54
emp_title               5.79
emp_length              4.62
title                   0.44
pub_rec_bankruptcies    0.14
revol_util              0.07
loan_amnt               0.00
dti                     0.00
application_type        0.00
initial_list_status     0.00
total_acc               0.00
revol_bal               0.00
pub_rec                 0.00
open_acc                0.00
earliest_cr_line        0.00
purpose                 0.00
term                    0.00
loan_status             0.00
issue_d                 0.00
verification_status     0.00
annual_inc              0.00
home_ownership          0.00
sub_grade               0.00
grade                   0.00
installment             0.00
int_rate                0.00
address                 0.00
dtype: float64
```

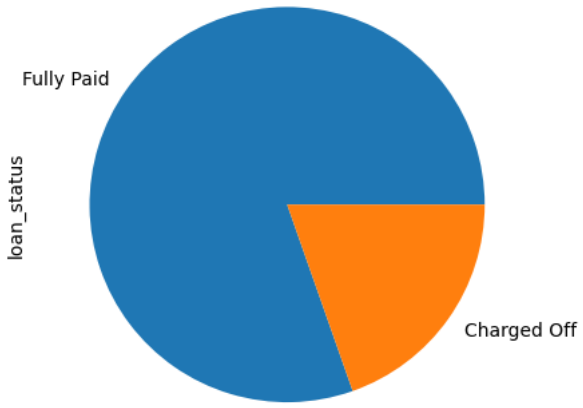
In [181]:
```
df.duplicated().sum()
```

Out[181]:
```
0
```

In [182]:
```
df.loan_status.value_counts(normalize=True)*100
```

Out[182]:
```
Fully Paid     80.387092
Charged Off    19.612908
Name: loan_status, dtype: float64
```

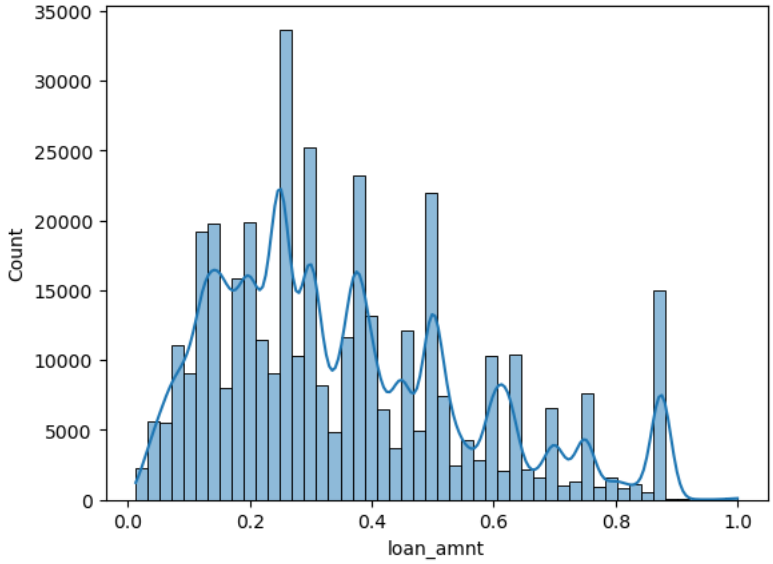
In [183]:
```
df.loan_status.value_counts(normalize=True).plot(kind='pie')
plt.show()
```

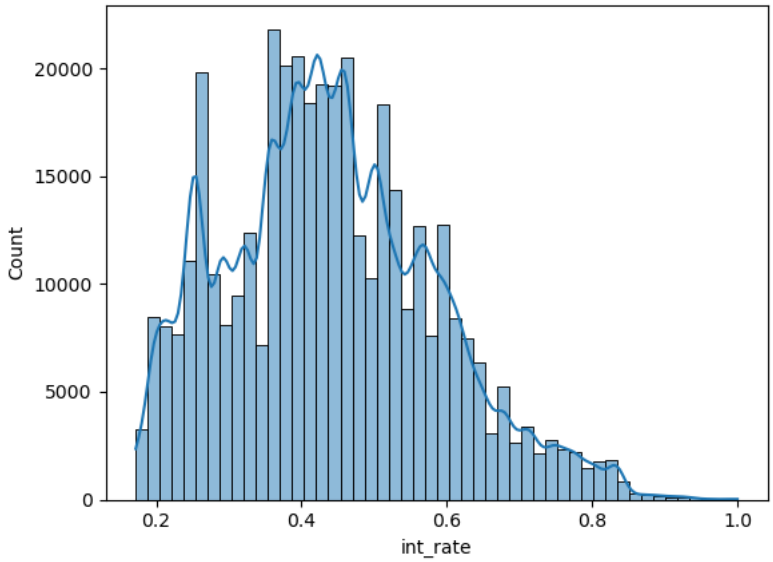


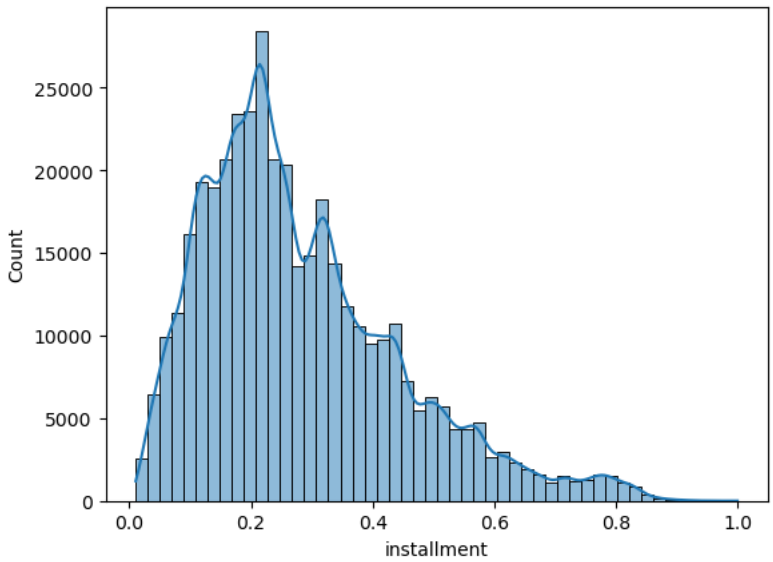
In [184]:
```
target = "loan_status"
cat_columns = df.select_dtypes(include=['object']).columns.tolist()
cat_columns.remove(target)
```

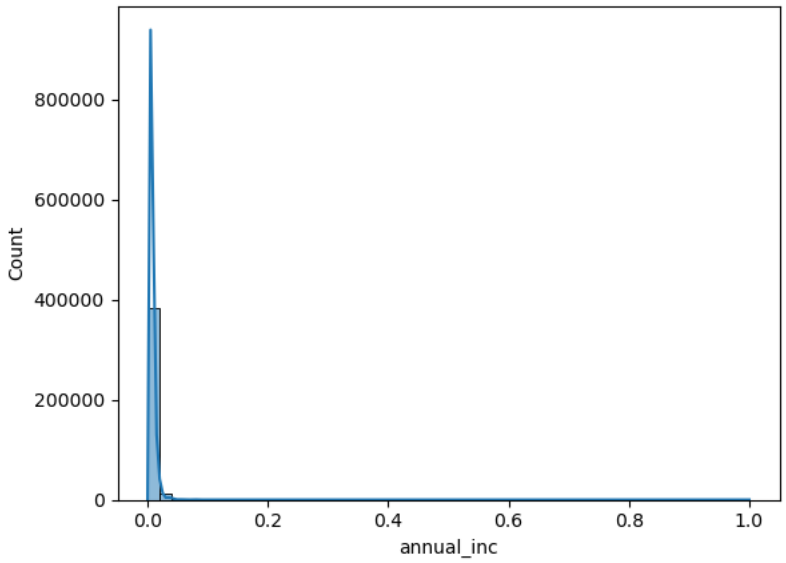
In [185]:
```
num_columns = df.select_dtypes(exclude=['object']).columns.tolist()
```

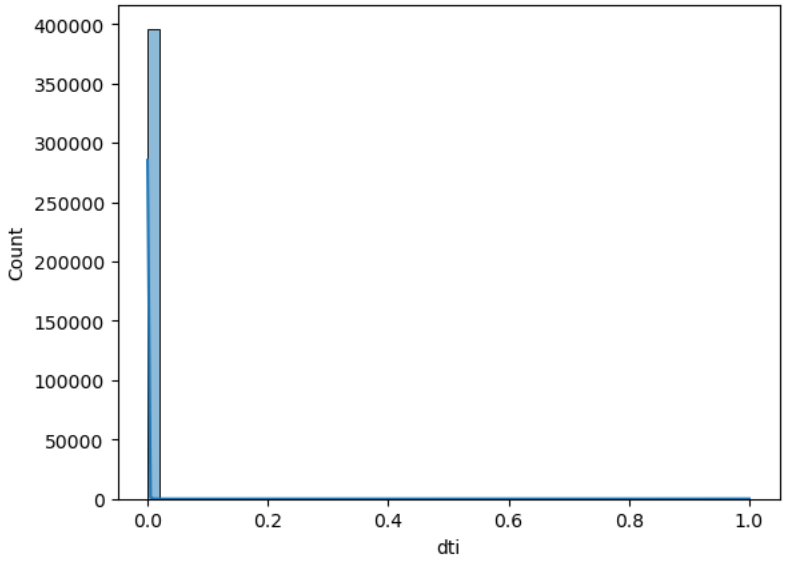
In [186]:
```
for i in num_columns:
    sns.histplot(df[i]/df[i].max(), kde=True, bins=50)
    plt.show()
```

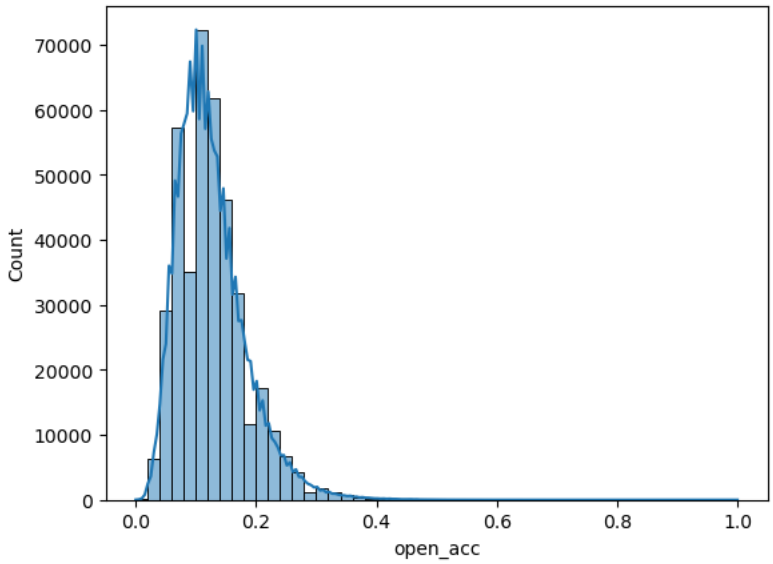


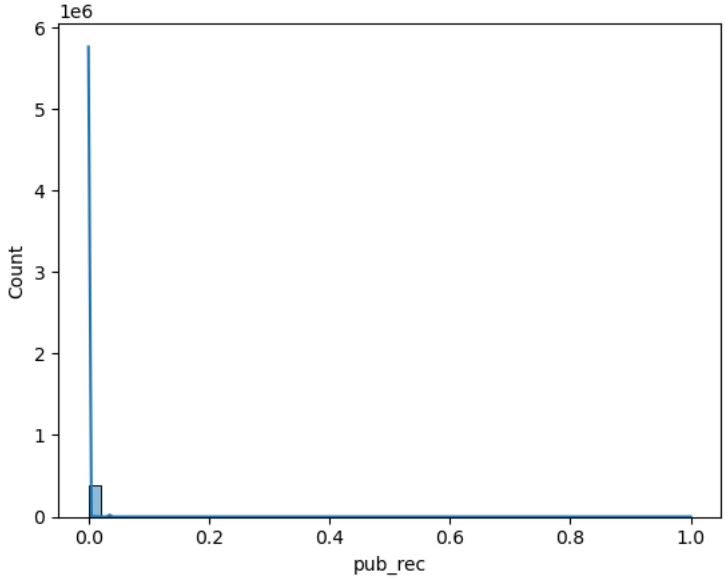


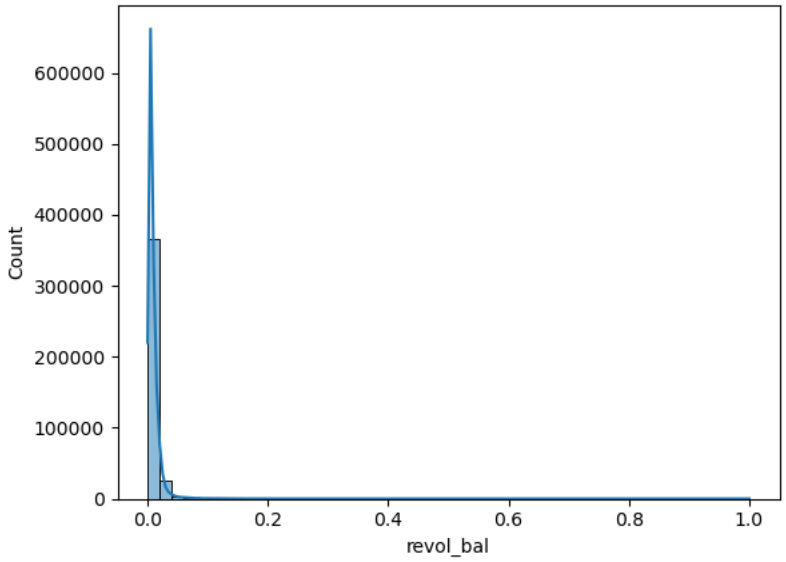


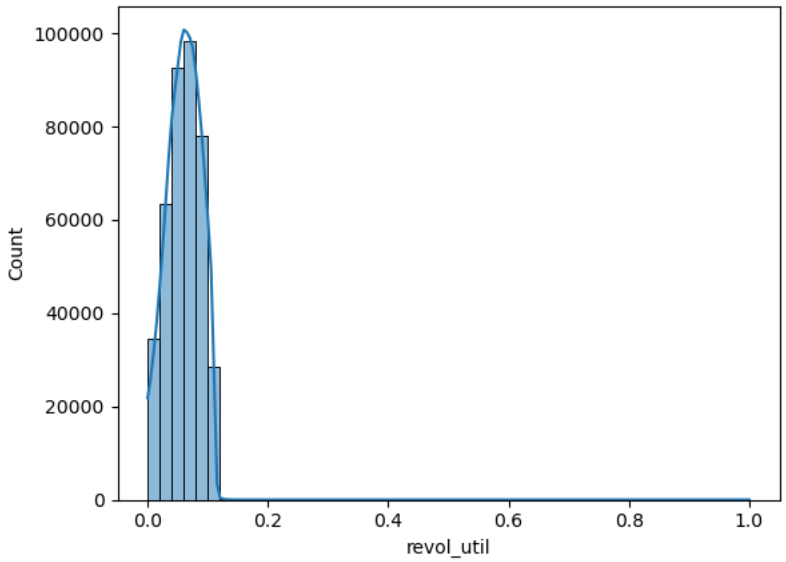

800000
600000
400000
200000
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
annual_inc

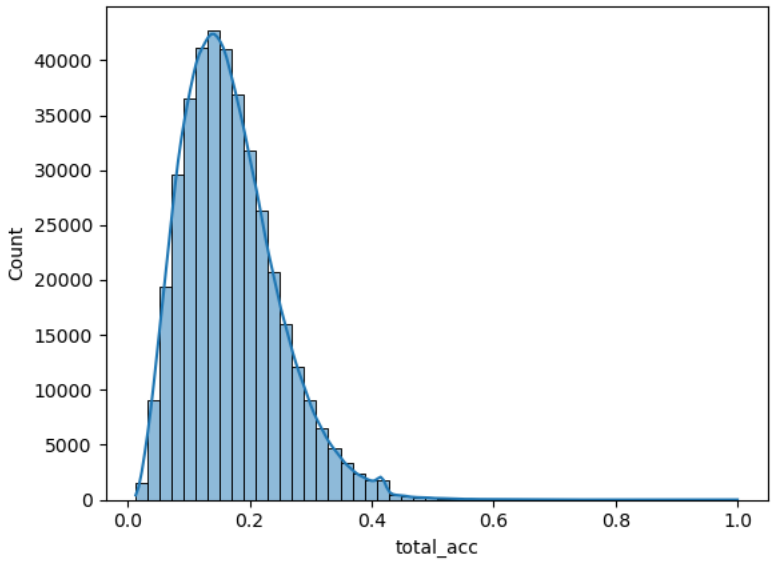

400000
350000
300000
250000
200000
150000
100000
50000
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
dti

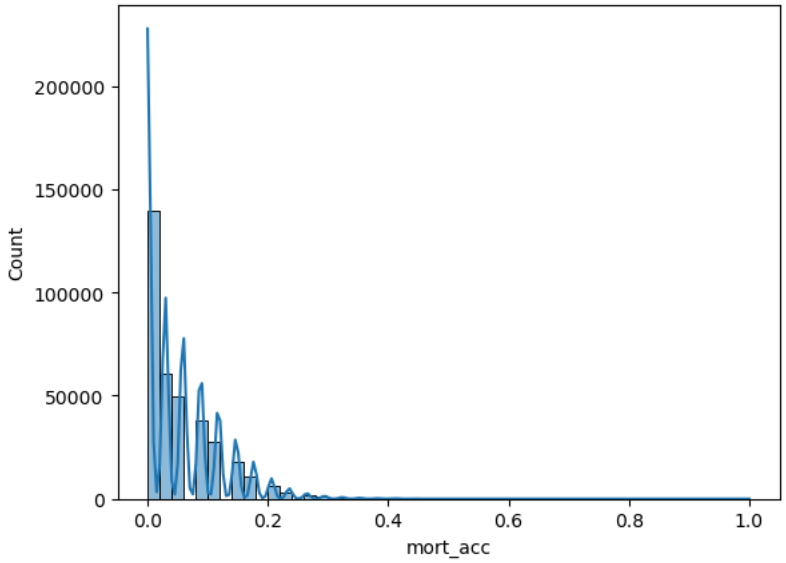

70000
60000
50000
40000
30000
20000
10000
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
open_acc

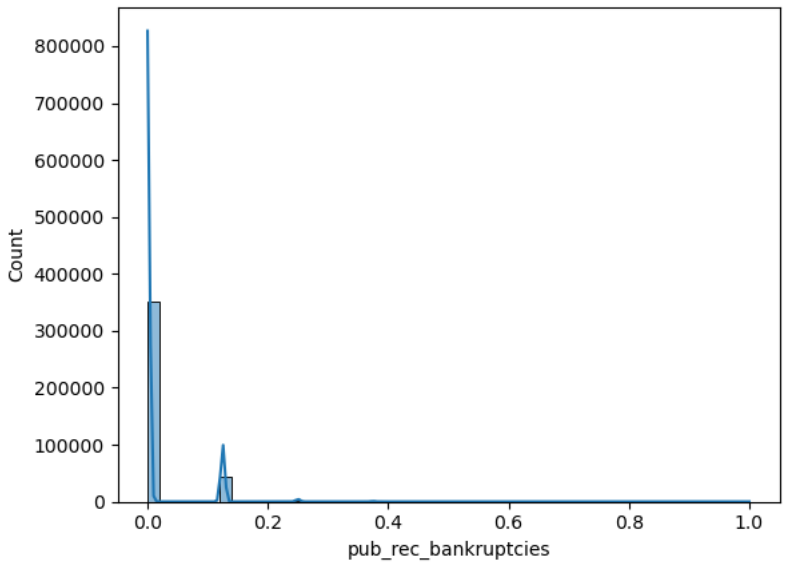

1e6
6
5
4
3
2
1
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
pub_rec


600000
500000
400000
300000
200000
100000
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
revol_bal

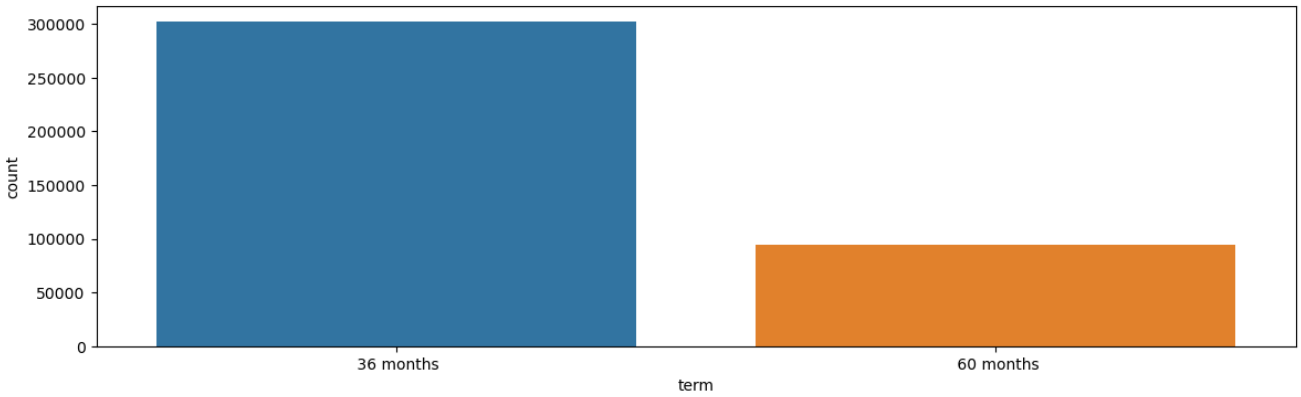

100000
80000
60000
40000
20000
0
Count
0.0
0.2
0.4
0.6
0.8
1.0
revol_util

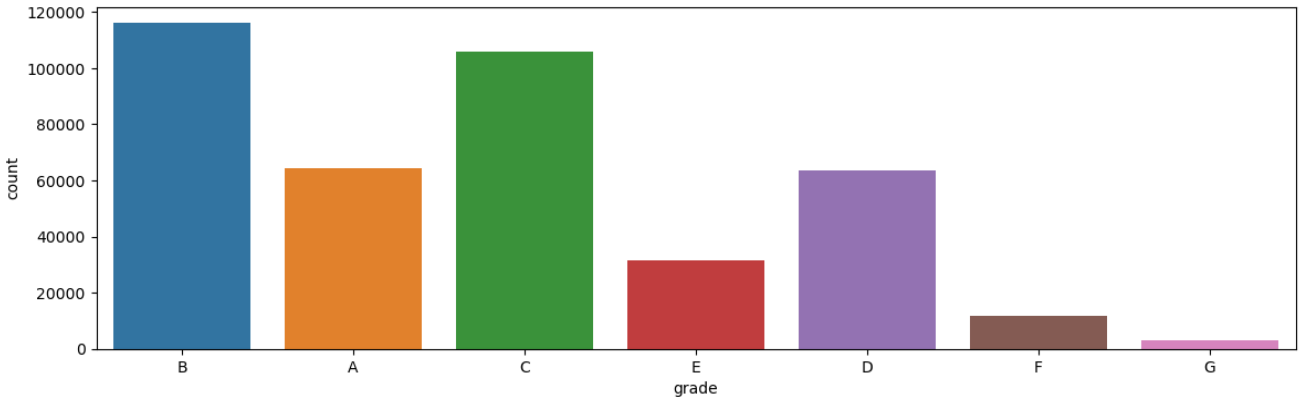

Count
total_acc

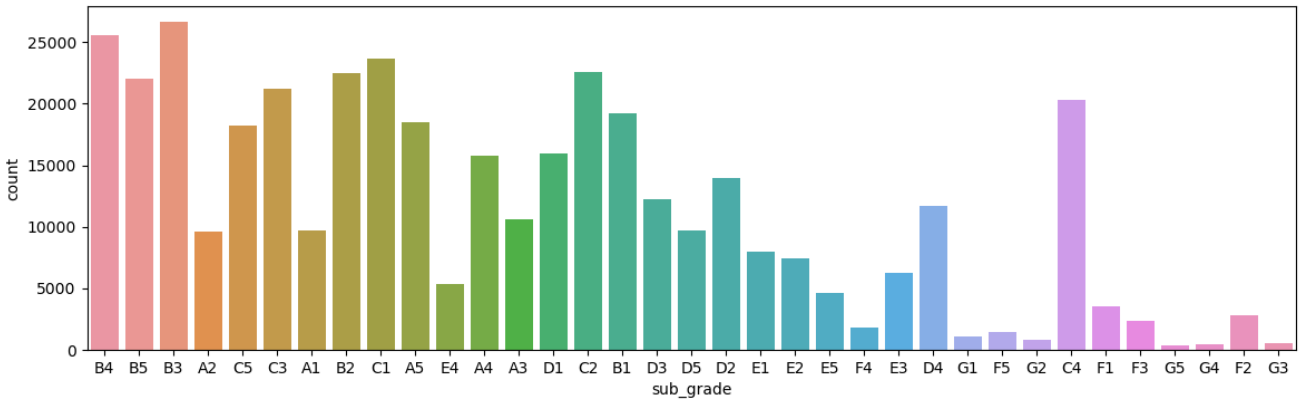

Count
mort_acc

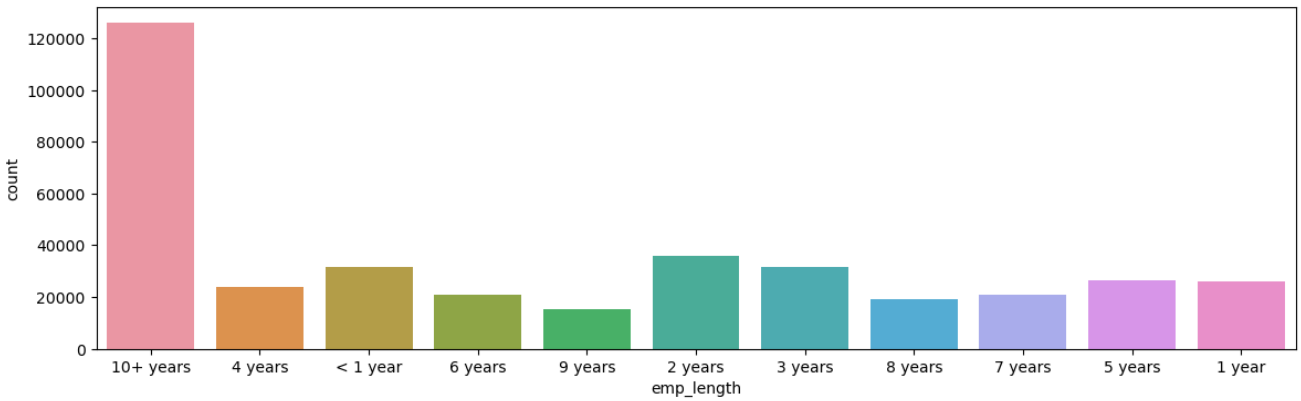

Count
pub_rec_bankruptcies

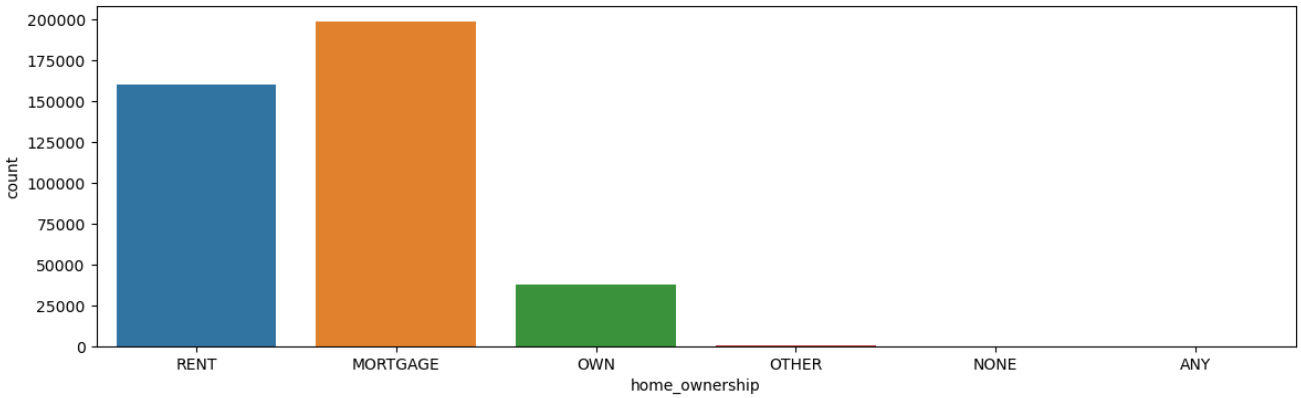
In [187]:
```
to_ignore = ('emp_title', 'issue_d', 'title', 'earliest_cr_line', 'address')
for col in cat_columns:
    if col not in to_ignore:
        plt.figure(figsize=(14,4))
        sns.countplot(data=df, x=col)
        plt.show()
```

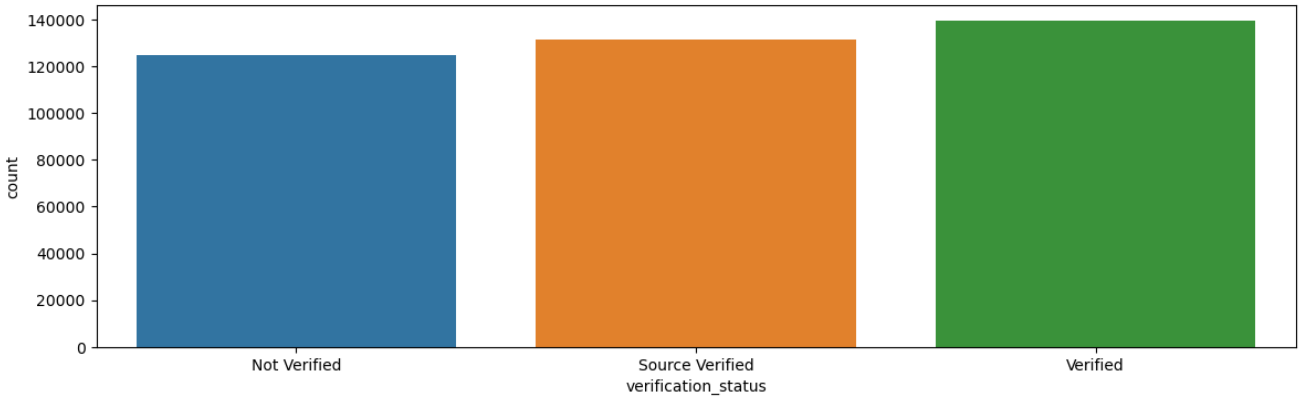


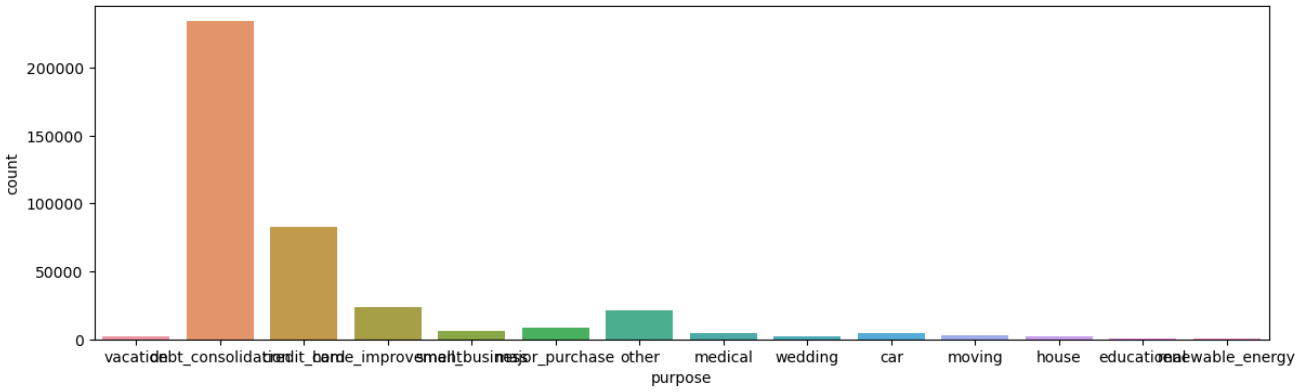


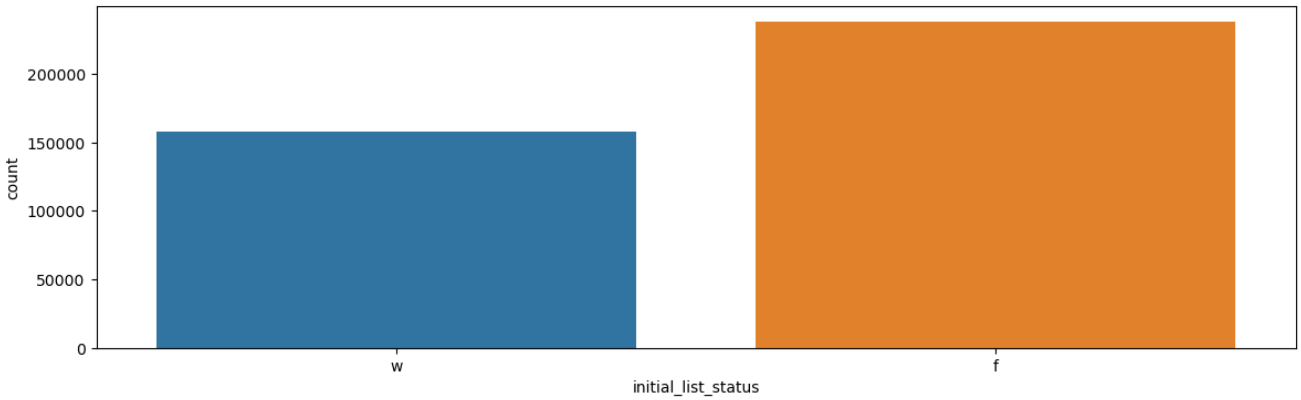


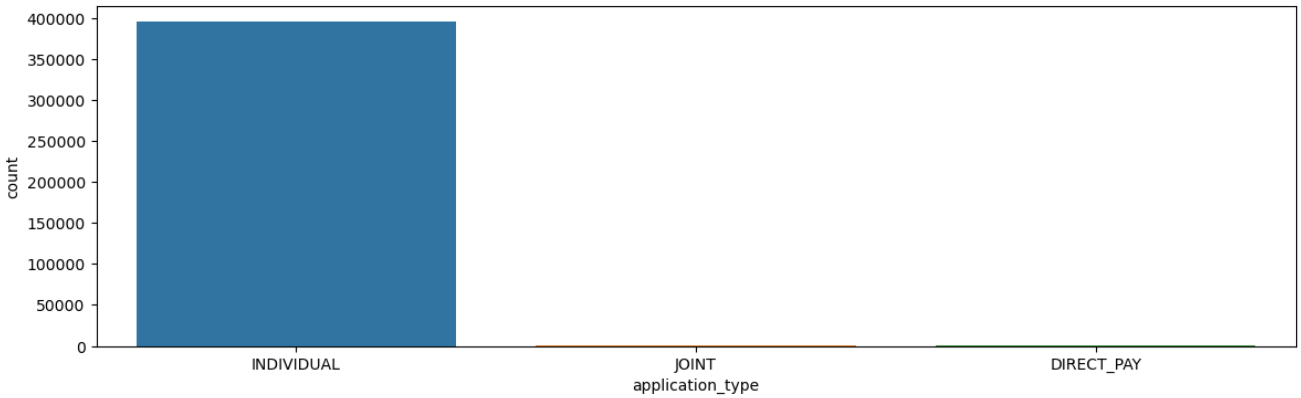



count
home_ownership
RENT
MORTGAGE
OWN
OTHER
NONE
ANY

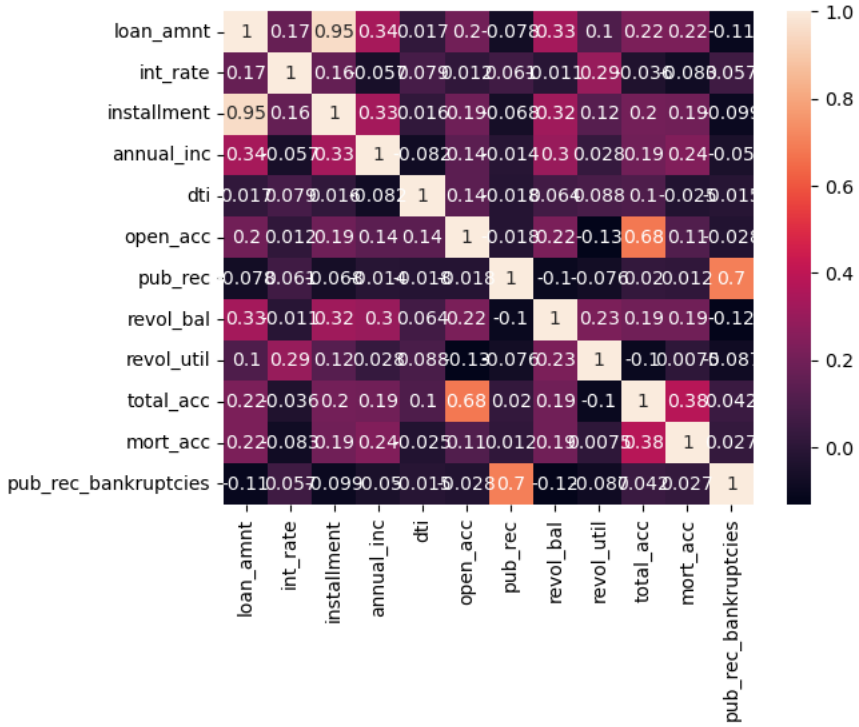

count
verification_status
Not Verified
Source Verified
Verified


count
purpose
vacation
debt_consolidation
credit_card
home_improvement
small_business
major_purchase
other
medical
wedding
car
moving
house
educational
renewable_energy


count
initial_list_status
w
f

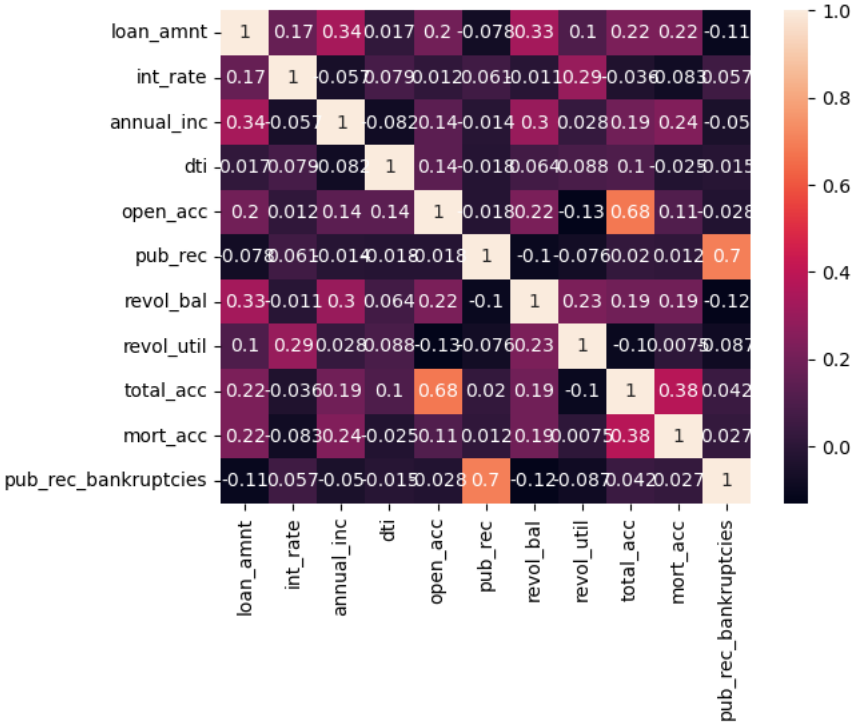


In [188]:
```
sns.heatmap(data = df.corr(), annot = True)
plt.show()
```



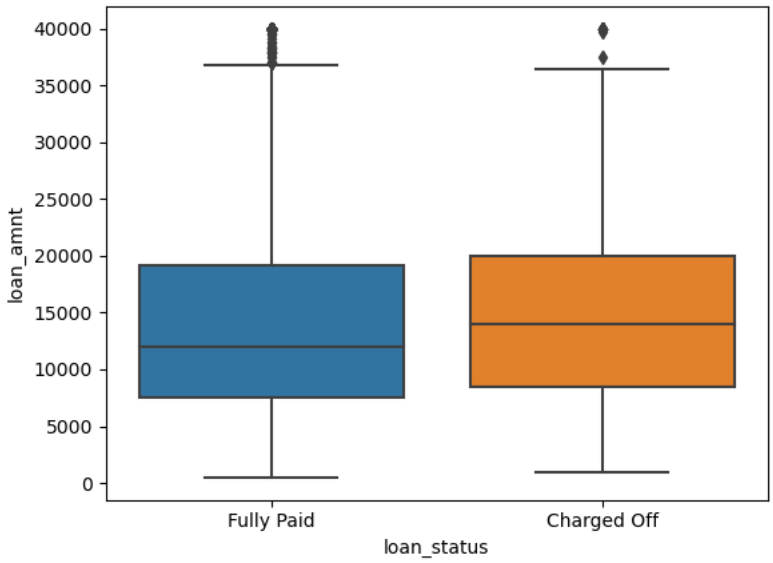
In [189]:
```
df.drop(columns=['installment'],axis=1,inplace=True)
```

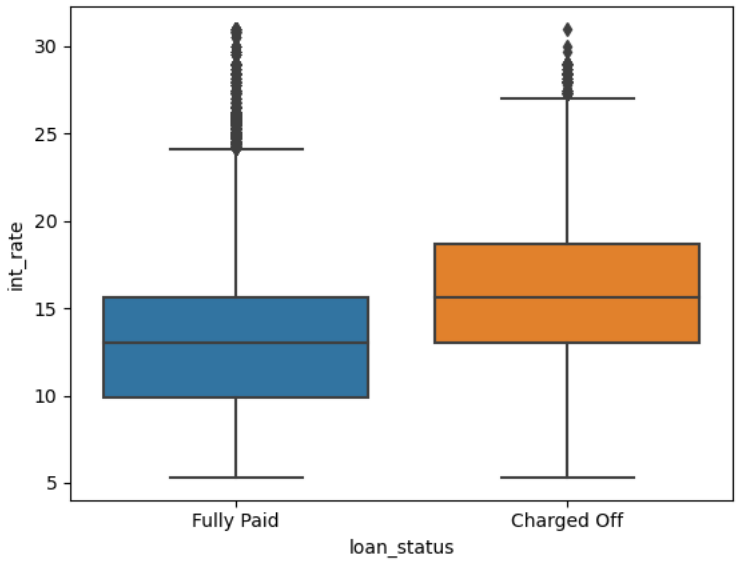
In [190]:
```
sns.heatmap(data = df.corr(), annot = True)
plt.show()
```

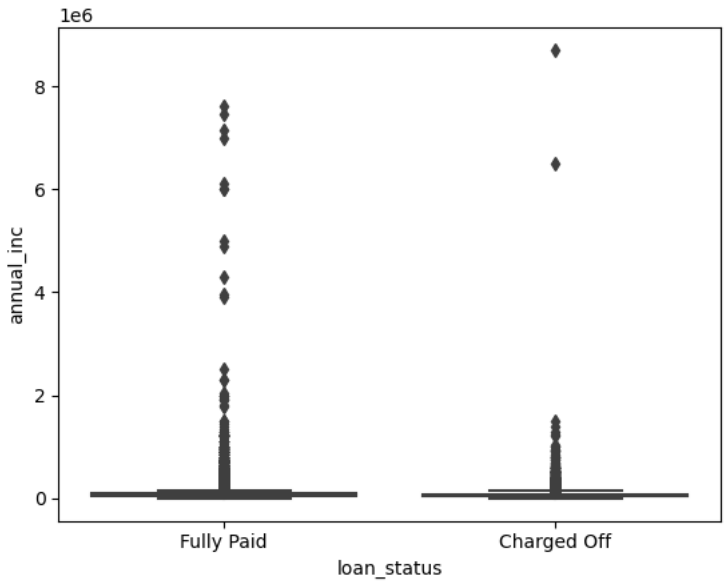


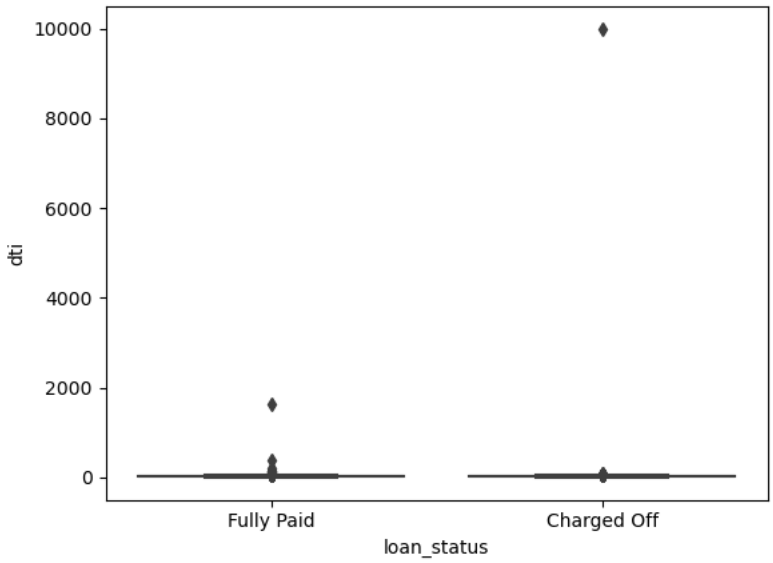
In [191]:
```
num_columns.remove("installment")
```

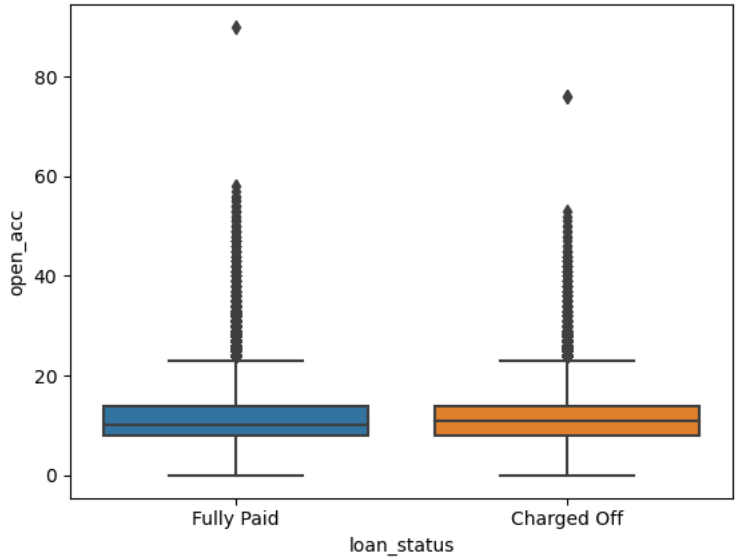
In [192]:
```
for col in num_columns:
    sns.boxplot(x=target, y=col, data=df)
    plt.show()
```

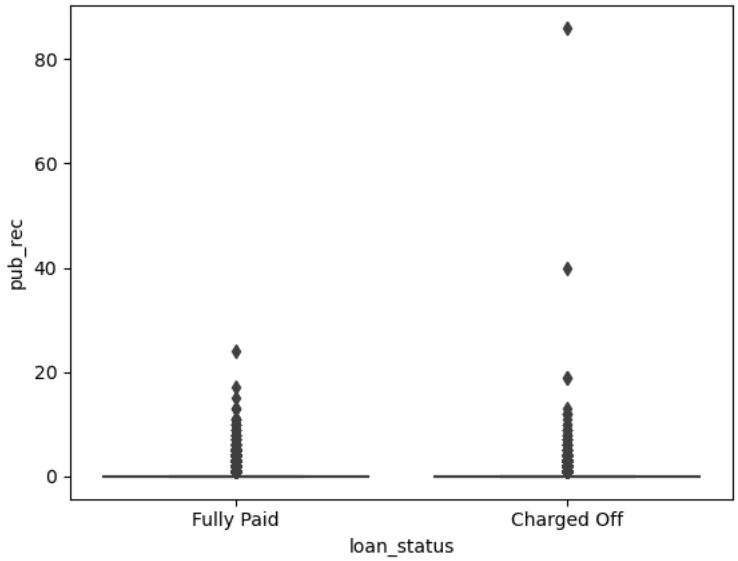


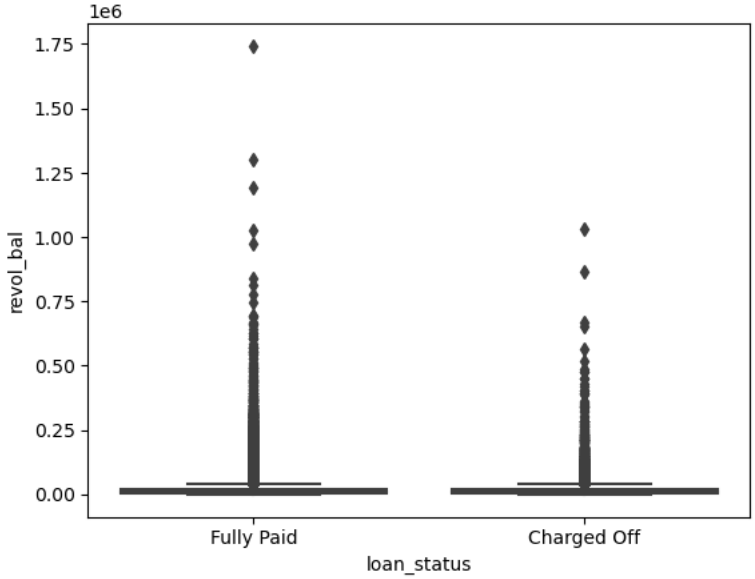


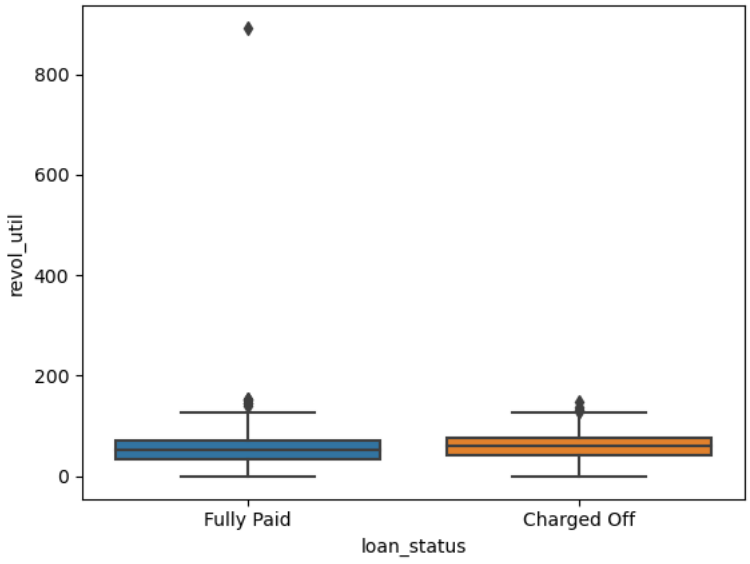


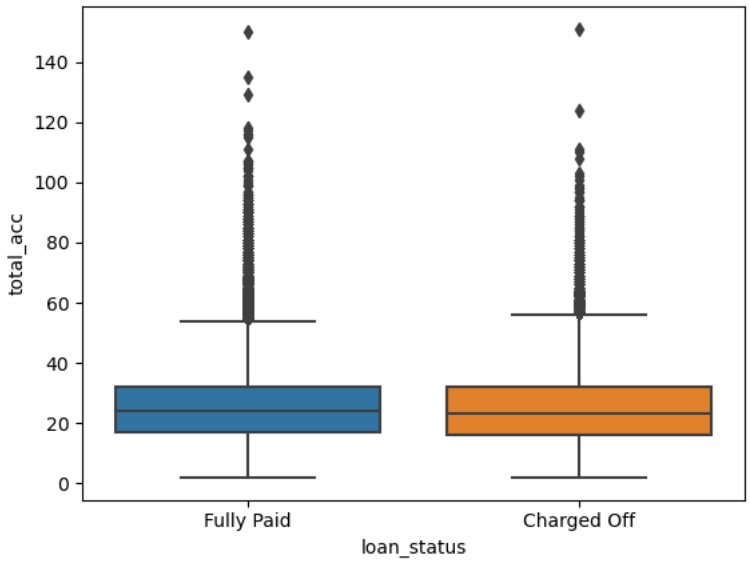

10000
8000
6000
4000
2000
0
dti
Fully Paid
Charged Off
loan_status

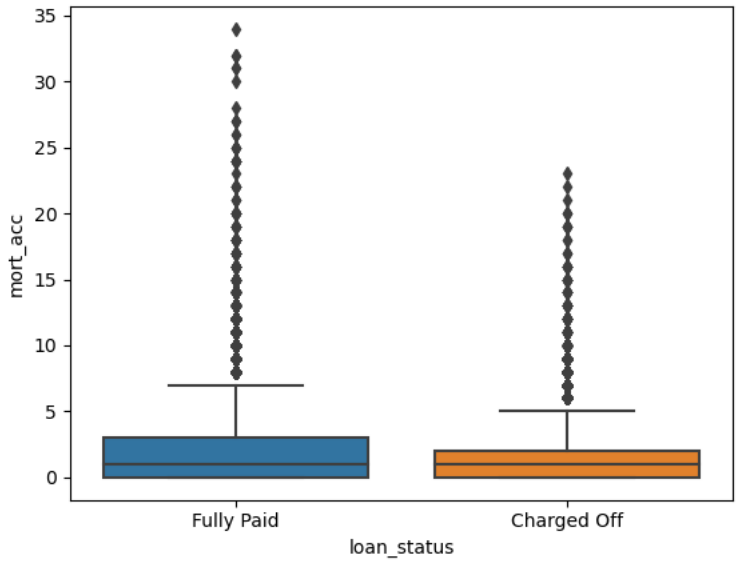

80
60
40
20
0
open_acc
Fully Paid
Charged Off
loan_status

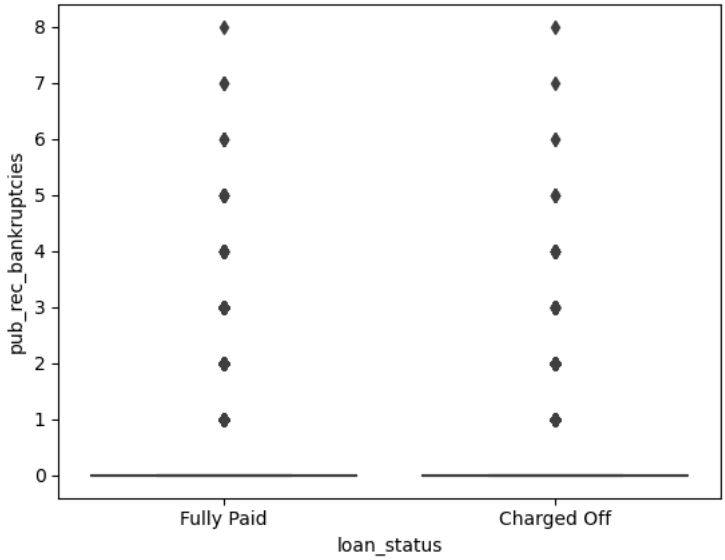

80
60
40
20
0
pub_rec
Fully Paid
Charged Off
loan_status


1e6
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
revol_bal
Fully Paid
Charged Off
loan_status


800
600
400
200
0
revol_util
Fully Paid
Charged Off
loan_status


140
120
100
80
60
40
20
0
total_acc
Fully Paid
Charged Off
loan_status





In [193]:
```
df.groupby(by='loan_status')['loan_amnt'].describe()
```

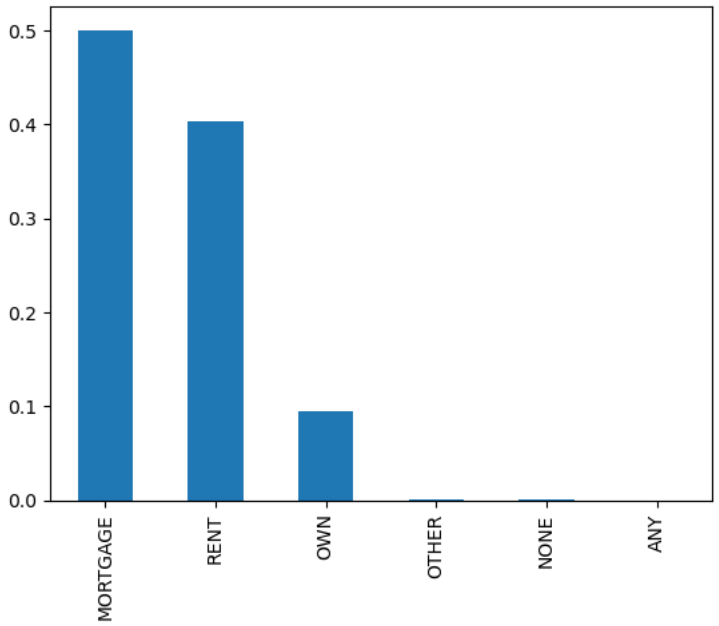
Out[193]:

loan_status	count	mean	std	min	25%	50%	75%	max
Charged Off	77673.0	15126.300967	8505.090557	1000.0	8525.0	14000.0	20000.0	40000.0
Fully Paid	318357.0	13866.878771	8302.319699	500.0	7500.0	12000.0	19225.0	40000.0

In [194]:
```
df['home_ownership'].value_counts()
```

Out[194]:
```
MORTGAGE    198348
RENT        159790
OWN          37746
OTHER          112
NONE            31
ANY              3
Name: home_ownership, dtype: int64
```

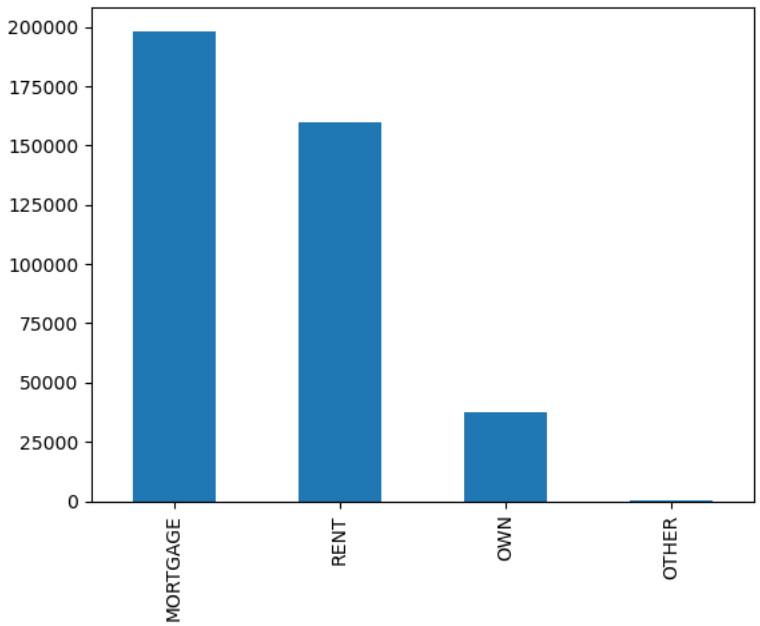
In [195]:
```
df['home_ownership'].value_counts(normalize = True).plot(kind="bar")
plt.show()
```



In [196]:
```
df.loc[(df.home_ownership == 'ANY') | (df.home_ownership == 'NONE'), 'home_ownership'] = 'OTHER'
df.home_ownership.value_counts()
```

Out[196]:
```
MORTGAGE    198348
RENT        159790
OWN          37746
OTHER          146
Name: home_ownership, dtype: int64
```

In [197]:
```
df.home_ownership.value_counts().plot(kind="bar")
plt.show()
```

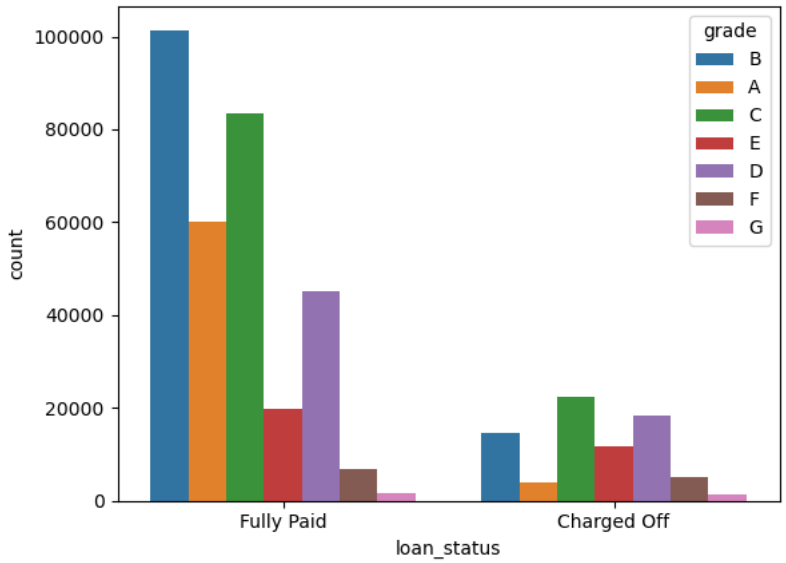


In [198]:
```
df['issue_d']=pd.to_datetime(df['issue_d'])
df['earliest_cr_line']=pd.to_datetime(df['earliest_cr_line'])
```

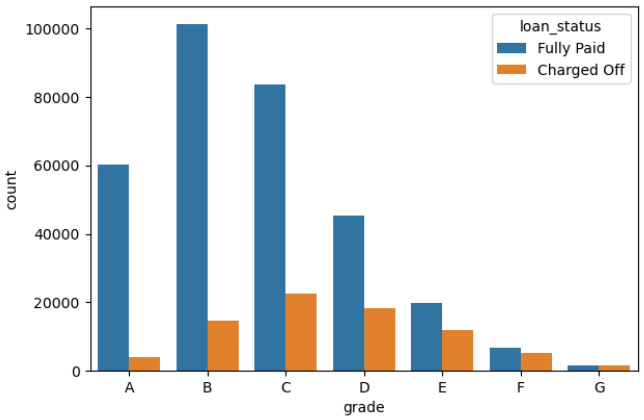
In [199]:
```
df['emp_title'].value_counts().sort_values(ascending=False)
```

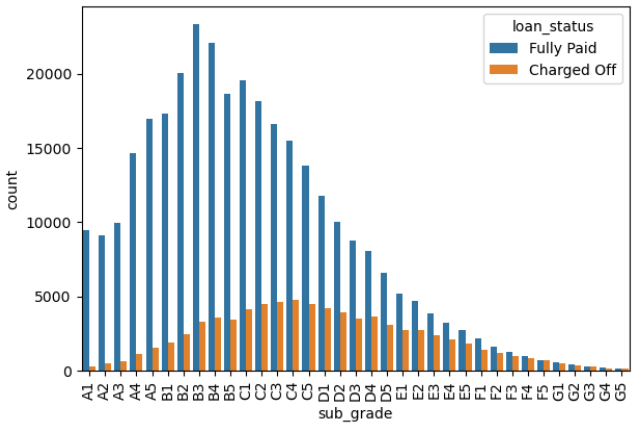
...

In [200]:
```
sns.countplot(x=target, data=df, hue='grade')
plt.show()
```



In [201]:
```
plt.figure(figsize=(15, 10))

plt.subplot(2, 2, 1)
grade = sorted(df.grade.unique().tolist())
sns.countplot(x='grade', data=df, hue='loan_status', order=grade)

plt.subplot(2, 2, 2)
sub_grade = sorted(df.sub_grade.unique().tolist())
g = sns.countplot(x='sub_grade', data=df, hue='loan_status', order=sub_grade)
g.set_xticklabels(g.get_xticklabels(), rotation=90)
plt.show()
```





In [202]:
```
df['mort_acc'] = df['mort_acc'].fillna(0.0)
df['emp_title'] = df['emp_title'].fillna("unknown_emp_title")
df['emp_length'] = df['emp_length'].fillna("unknown_emp_length")
df['title'] = df['mort_acc'].fillna("unknown_title")
df['pub_rec_bankruptcies'] = df['pub_rec_bankruptcies'].fillna(0.0)
```

In [203]:
```
df['loan_status']=df.loan_status.map({'Fully Paid':0, 'Charged Off':1})
```

In [204]:
```
df.groupby(by='total_acc').mean()
```

Out[204]:

total_acc	loan_amnt	int_rate	annual_inc	loan_status	title	dti	open_acc	pub_rec	revol_bal	revol_util	mort_acc	pub_rec_bankr
2.0	6672.222222	15.801111	64277.777778	0.222222	0.000000	2.279444	1.611111	0.000000	2860.166667	53.527778	0.000000	0.
3.0	6042.966361	15.615566	41270.753884	0.220183	0.027523	6.502813	2.611621	0.045872	3382.807339	49.991022	0.027523	0.
4.0	7587.399031	15.069491	42426.565969	0.214055	0.046850	8.411963	3.324717	0.041195	4874.231826	58.477400	0.046850	0.
5.0	7845.734714	14.917564	44394.098003	0.203156	0.077416	10.118328	3.921598	0.071499	5475.253452	56.890311	0.077416	0.
6.0	8529.019843	14.651752	48470.001156	0.215874	0.120082	11.222542	4.511119	0.104003	6546.374957	57.812483	0.120082	0.
7.0	9350.283611	14.415810	50623.501002	0.211200	0.180545	11.829829	5.093169	0.116099	7363.941588	56.787540	0.180545	0.
8.0	9788.345760	14.271851	52571.393657	0.217707	0.254613	12.684623	5.576887	0.143523	7850.161603	57.348173	0.254613	0.
9.0	10042.600597	14.244870	52572.312693	0.213141	0.308394	13.296349	6.028765	0.161584	8205.770041	56.583065	0.308394	0.
10.0	10487.255605	14.109811	55751.004093	0.205553	0.367570	14.004592	6.466111	0.146507	9124.531283	57.029202	0.367570	0.
11.0	11009.701493	14.062403	57114.213227	0.207711	0.456015	14.485288	6.923677	0.167345	9464.866011	56.545816	0.456015	0.

In [205]:
```
total_act_mean = df.groupby(by='total_acc').mean().mort_acc
```

In [206]:
```
df.isnull().sum()
```

Out[206]:
```
loan_amnt               0
term                    0
int_rate                0
grade                   0
sub_grade               0
emp_title               0
emp_length              0
home_ownership          0
annual_inc              0
verification_status     0
issue_d                 0
loan_status             0
purpose                 0
title                   0
dti                     0
earliest_cr_line        0
open_acc                0
pub_rec                 0
revol_bal               0
revol_util            276
total_acc               0
initial_list_status     0
application_type        0
mort_acc                0
pub_rec_bankruptcies    0
address                 0
dtype: int64
```

In [207]:
```
df.dropna(inplace=True)
```

In [208]:
```
df.isnull().sum()
```

Out[208]:
```
loan_amnt               0
term                    0
int_rate                0
grade                   0
sub_grade               0
emp_title               0
emp_length              0
home_ownership          0
annual_inc              0
verification_status     0
issue_d                 0
loan_status             0
purpose                 0
title                   0
dti                     0
earliest_cr_line        0
open_acc                0
pub_rec                 0
revol_bal               0
revol_util              0
total_acc               0
initial_list_status     0
application_type        0
mort_acc                0
pub_rec_bankruptcies    0
address                 0
dtype: int64
```

In [209]:
```
df.shape
```

Out[209]:
```
(395754, 26)
```

In [210]:
```
df.term.unique()
```

Out[210]:
```
array([' 36 months', ' 60 months'], dtype=object)
```

In [211]:
```
term_values={' 36 months': 36, ' 60 months':60}
df['term'] = df.term.map(term_values)
```

In [212]:
```
df['initial_list_status'].unique()
```

Out[212]:
```
array(['w', 'f'], dtype=object)
```

In [213]:
```
list_status = {'w':0, 'f':1}
df['initial_list_status'] = df.initial_list_status.map(list_status)
```

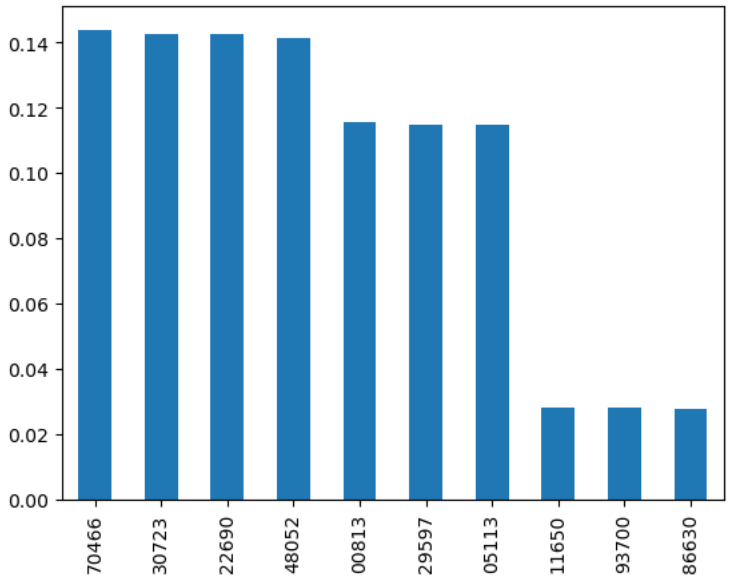
In [214]:
```
df['zip_code'] = df.address.apply(lambda x: x[-5:])
```

In [215]:
```
df['zip_code'].value_counts(normalize=True)*100
```

Out[215]:
```
70466    14.388484
30723    14.275535
22690    14.275029
48052    14.120893
00813    11.571077
29597    11.485670
05113    11.462424
11650     2.834336
93700     2.814122
86630     2.772429
Name: zip_code, dtype: float64
```

In [216]:
```
df['zip_code'].value_counts(normalize=True).plot(kind='bar')
```

Out[216]: <AxesSubplot:>



In [217]:
```
df.drop(columns=['issue_d','emp_title','title','sub_grade','address','earliest_cr_line','emp_length'], axis=1, inplace=True)
```

In [218]:
```
dummie = ['purpose','zip_code','grade','verification_status','application_type','home_ownership']
df=pd.get_dummies(df, columns=dummie, drop_first=True)
```

In [219]:
```
pd.set_option('display.max_columns', None)
pd.set_option('display.max_rows', None)

df.head()
```

Out[219]:

	loan_amnt	term	int_rate	annual_inc	loan_status	dti	open_acc	pub_rec	revol_bal	revol_util	total_acc	initial_list_status	mort_acc	pub_rec_bankruptc
0	10000.0	36	11.44	117000.0	0	26.24	16.0	0.0	36369.0	41.8	25.0	0	0.0	
1	8000.0	36	11.99	65000.0	0	22.05	17.0	0.0	20131.0	53.3	27.0	1	3.0	
2	15600.0	36	10.49	43057.0	0	12.79	13.0	0.0	11987.0	92.2	26.0	1	0.0	
3	7200.0	36	6.49	54000.0	0	2.60	6.0	0.0	5472.0	21.5	13.0	1	0.0	
4	24375.0	60	17.27	55000.0	1	33.95	13.0	0.0	24584.0	69.8	43.0	1	1.0	

In [220]:
```
df.shape
```

Out[220]: (395754, 49)

In [221]:
```
X=df.drop('loan_status', axis=1)
y=df['loan_status']
```

In [222]:
```
from scipy import stats
from sklearn.linear_model import LogisticRegression
from sklearn import metrics
from sklearn.metrics import confusion_matrix
from sklearn.metrics import classification_report
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
from sklearn.metrics import precision_recall_curve
from sklearn.model_selection import train_test_split, KFold, cross_val_score
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import (
    accuracy_score, confusion_matrix, classification_report,
    roc_auc_score, roc_curve, auc,
    ConfusionMatrixDisplay, RocCurveDisplay
)
from statsmodels.stats.outliers_influence import variance_inflation_factor
```

In [223]:
```
X_train, X_test, y_train, y_test = train_test_split(X,y,test_size=0.2, stratify=y, random_state=42)
```

In [224]:
```
print(X_train.shape)
print(X_test.shape)
```

```
(316603, 48)
(79151, 48)
```

In [225]:
```
scale = MinMaxScaler()
X_train = scale.fit_transform(X_train)
X_test = scale.fit_transform(X_test)
```

In [226]:
```
Log_R = LogisticRegression(max_iter=1000)
Log_R.fit(X_train, y_train)
```

Out[226]:
```
LogisticRegression(max_iter=1000)
```

In [227]:
```
y_pred = Log_R.predict(X_test)
```

In [228]:
```
print("Accuracy of the model on test :", Log_R.score(X_test, y_test).round(2))
```

```
Accuracy of the model on test : 0.81
```

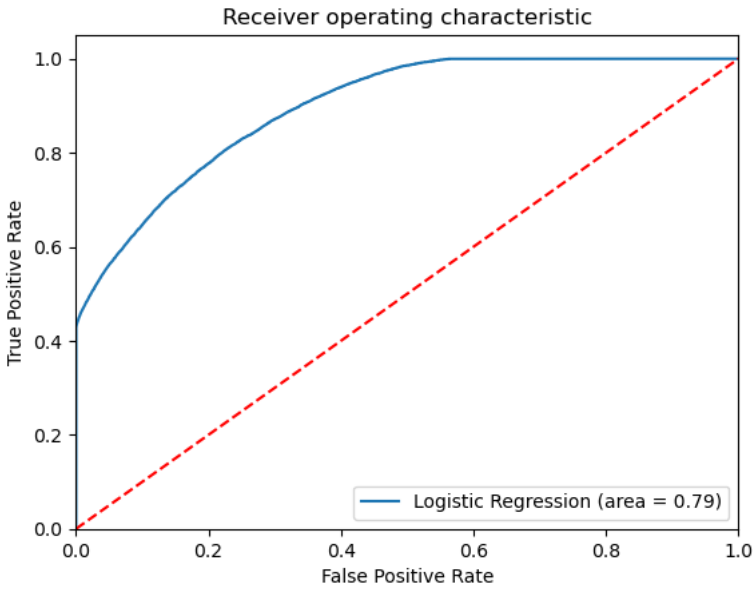
In [229]:
```
confusion_matrix=confusion_matrix(y_test,y_pred)
print(confusion_matrix)
```

```
[[52866 10763]
 [ 3994 11528]]
```

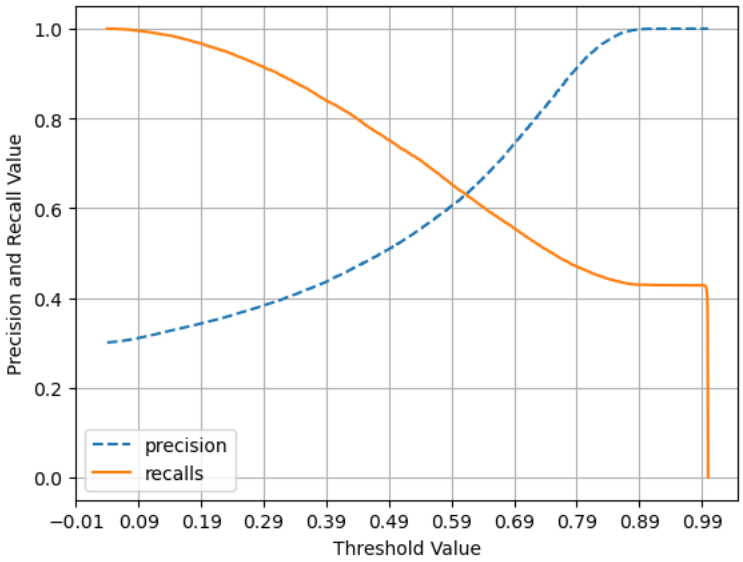
In [230]:
```
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.93      0.83      0.88     63629
           1       0.52      0.74      0.61     15522

    accuracy                           0.81     79151
   macro avg       0.72      0.79      0.74     79151
weighted avg       0.85      0.81      0.83     79151
```

In [231]:
```
logit_roc_auc=roc_auc_score(y_test,Log_R.predict(X_test))
fpr,tpr,thresholds=roc_curve(y_test,Log_R.predict_proba(X_test)[:,1])
plt.figure()
plt.plot(fpr,tpr,label='Logistic Regression (area = %0.2f)' % logit_roc_auc)
plt.plot([0,1],[0,1],'r--')
plt.xlim([0.0,1.0])
plt.ylim([0.0,1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic')
plt.legend(loc="lower right")
plt.show()
```



In [232]:
```
def precission_recall_curve_plot(y_test,pred_proba_c1):
    precisions, recalls, thresholds = precision_recall_curve(y_test,pred_proba_c1)

    threshold_boundary = thresholds.shape[0]

    plt.plot(thresholds,precisions[0:threshold_boundary],linestyle='--',label='precision')

    plt.plot(thresholds,recalls[0:threshold_boundary],label='recalls')

    start,end=plt.xlim()
    plt.xticks(np.round(np.arange(start,end,0.1),2))

    plt.xlabel('Threshold Value')
    plt.ylabel('Precision and Recall Value')
    plt.legend()
    plt.grid()
    plt.show()

precission_recall_curve_plot(y_test,Log_R.predict_proba(X_test)[:,1])
```



In [233]:
```
def calc_vif(X):
    vif=pd.DataFrame()
    vif['Feature']=X.columns
    vif['VIF']=[variance_inflation_factor(X.values,i) for i in range(X.shape[1])]
    vif['VIF']=round(vif['VIF'],2)
    vif=vif.sort_values(by='VIF',ascending=False)
    return vif

calc_vif(X)[:5]
```

Out[233]:

	Feature	VIF
43	application_type_INDIVIDUAL	138.14
2	int_rate	118.98
14	purpose_debt_consolidation	49.23
1	term	26.81
13	purpose_credit_card	18.10

In [234]:
```
X.drop(columns=['application_type_INDIVIDUAL'],axis=1,inplace=True)
calc_vif(X)[:5]
```

Out[234]:

	Feature	VIF
2	int_rate	101.93
14	purpose_debt_consolidation	25.69
1	term	23.82
9	total_acc	12.51
5	open_acc	12.07

In [235]:
```
X.drop(columns=['int_rate'], axis=1, inplace=True)
calc_vif(X)[:5]
```

Out[235]:

	Feature	VIF
1	term	22.85
13	purpose_debt_consolidation	20.25
8	total_acc	12.51
4	open_acc	11.99
12	purpose_credit_card	7.88

In [236]:
```
X.drop(columns=['term'], axis=1, inplace=True)
calc_vif(X)[:5]
```

Out[236]:

	Feature	VIF
12	purpose_debt_consolidation	15.61
7	total_acc	12.44
3	open_acc	11.99
6	revol_util	7.51
11	purpose_credit_card	6.19

In [237]:
```
X.drop(columns=['purpose_debt_consolidation'], axis=1, inplace=True)
calc_vif(X)[:5]
```

Out[237]:

	Feature	VIF
7	total_acc	12.31
3	open_acc	11.47
6	revol_util	6.66
0	loan_amnt	5.58
1	annual_inc	3.03

In [238]:
```
X.drop(columns=['open_acc'], axis=1, inplace=True)
calc_vif(X)[:5]
```

Out[238]:

	Feature	VIF
5	revol_util	6.61
6	total_acc	6.06
0	loan_amnt	5.55
1	annual_inc	3.03
32	grade_C	2.85

In [239]:
```
X=scaler.fit_transform(X)

kfold=KFold(n_splits=5)
accuracy=np.mean(cross_val_score(Log_R,X,y,cv=kfold,scoring='accuracy',n_jobs=-1))
print("Cross Validation accuracy : {:.3f}".format(accuracy))
```

```
Cross Validation accuracy : 0.888
```

In [ ]: