

## **MLFA Assignment 7 - REPORT**

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**Roll Number : 20EE10069**

### **EXPERIMENT - 1 :**

#### **PART - A :**

##### **For EXPT 1 Training CNN Vanilla :**

Epoch 1/50: Training loss = 1.6685851167659371  
Epoch 2/50: Training loss = 1.1781220904418401  
Epoch 3/50: Training loss = 0.9523161497651315  
Epoch 4/50: Training loss = 0.748025751539639  
Epoch 5/50: Training loss = 0.5514515426998235  
Epoch 6/50: Training loss = 0.3447064970981102  
Epoch 7/50: Training loss = 0.19567749744319185  
Epoch 8/50: Training loss = 0.11284139689666275  
Epoch 9/50: Training loss = 0.08948245811827328  
Epoch 10/50: Training loss = 0.06908801162843498  
Epoch 11/50: Training loss = 0.05138712408667316  
Epoch 12/50: Training loss = 0.04706910719420305  
Epoch 13/50: Training loss = 0.05350353748404554  
Epoch 14/50: Training loss = 0.036668221504256436  
Epoch 15/50: Training loss = 0.040462359847805024  
Epoch 16/50: Training loss = 0.04171504631248892  
Epoch 17/50: Training loss = 0.03009126974241238  
Epoch 18/50: Training loss = 0.03664235981675435  
Epoch 19/50: Training loss = 0.03542914988986236  
Epoch 20/50: Training loss = 0.026821600306513056  
Epoch 21/50: Training loss = 0.03577839368740477  
Epoch 22/50: Training loss = 0.03799221669299984  
Epoch 23/50: Training loss = 0.036084481562506786  
Epoch 24/50: Training loss = 0.019418793869720372  
Epoch 25/50: Training loss = 0.02715897165376655  
Epoch 26/50: Training loss = 0.032280785626760324  
Epoch 27/50: Training loss = 0.028293895070697656  
Epoch 28/50: Training loss = 0.02151317881807514  
Epoch 29/50: Training loss = 0.023527959507191554  
Epoch 30/50: Training loss = 0.01938994671366586  
Epoch 31/50: Training loss = 0.03087488005421248  
Epoch 32/50: Training loss = 0.021909999392679607  
Epoch 33/50: Training loss = 0.025505008347028374  
Epoch 34/50: Training loss = 0.017030169716347198  
Epoch 35/50: Training loss = 0.019867811301825283  
Epoch 36/50: Training loss = 0.026078466320652704  
Epoch 37/50: Training loss = 0.014155698203949772  
Epoch 38/50: Training loss = 0.02664984459513608  
Epoch 39/50: Training loss = 0.018063931326781  
Epoch 40/50: Training loss = 0.019124552275218087  
Epoch 41/50: Training loss = 0.014438967458364477  
Epoch 42/50: Training loss = 0.020136975276115236  
Epoch 43/50: Training loss = 0.02485425502289923

Epoch 44/50: Training loss = 0.015939905895312242  
Epoch 45/50: Training loss = 0.0179281213008371  
Epoch 46/50: Training loss = 0.01806515391633314  
Epoch 47/50: Training loss = 0.019206179869426555  
Epoch 48/50: Training loss = 0.01582488967242356  
Epoch 49/50: Training loss = 0.016144630504232756  
Epoch 50/50: Training loss = 0.018735572573971192

**Test set accuracy with CNNVanilla = 65.55 %**

**Total params: 4,256,330**

**Trainable params: 4,256,330**

**Non-trainable params: 0**

**PART - B :**

**For EXPT 1 Training CNN Resnet :**

Epoch 1/50: Training loss = 1.3754086299818389  
Epoch 2/50: Training loss = 0.8799446660036944  
Epoch 3/50: Training loss = 0.6891434746129173  
Epoch 4/50: Training loss = 0.5080836086857076  
Epoch 5/50: Training loss = 0.3199453761382979  
Epoch 6/50: Training loss = 0.16971941087014822  
Epoch 7/50: Training loss = 0.09080422542305017  
Epoch 8/50: Training loss = 0.06703729248054478  
Epoch 9/50: Training loss = 0.04432466764915354  
Epoch 10/50: Training loss = 0.039986168314721814  
Epoch 11/50: Training loss = 0.04067016154888789  
Epoch 12/50: Training loss = 0.03834847982602232  
Epoch 13/50: Training loss = 0.024101945607238735  
Epoch 14/50: Training loss = 0.02986342301687264  
Epoch 15/50: Training loss = 0.026429112090691164  
Epoch 16/50: Training loss = 0.022084197103121907  
Epoch 17/50: Training loss = 0.02748622947279839  
Epoch 18/50: Training loss = 0.03056602914846141  
Epoch 19/50: Training loss = 0.021635443774023454  
Epoch 20/50: Training loss = 0.02579816830776898  
Epoch 21/50: Training loss = 0.021934930955021813  
Epoch 22/50: Training loss = 0.01187818588710352  
Epoch 23/50: Training loss = 0.019955655457143083  
Epoch 24/50: Training loss = 0.019443035558132187  
Epoch 25/50: Training loss = 0.01800418723367478  
Epoch 26/50: Training loss = 0.027926035656603242  
Epoch 27/50: Training loss = 0.02004536039110425  
Epoch 28/50: Training loss = 0.01698572925120896  
Epoch 29/50: Training loss = 0.018004464108214182  
Epoch 30/50: Training loss = 0.014821073278542417  
Epoch 31/50: Training loss = 0.011602988983510414  
Epoch 32/50: Training loss = 0.016664613040083334  
Epoch 33/50: Training loss = 0.01603446071266615  
Epoch 34/50: Training loss = 0.02703287456260652  
Epoch 35/50: Training loss = 0.014020339819265301  
Epoch 36/50: Training loss = 0.011323073973471764  
Epoch 37/50: Training loss = 0.010009245534501115

Epoch 38/50: Training loss = 0.013759591739638994  
Epoch 39/50: Training loss = 0.0134546298454088  
Epoch 40/50: Training loss = 0.020805492430535734  
Epoch 41/50: Training loss = 0.016140830430751003  
Epoch 42/50: Training loss = 0.012251182241313045  
Epoch 43/50: Training loss = 0.00538756259518369  
Epoch 44/50: Training loss = 0.008284968326307183  
Epoch 45/50: Training loss = 0.019997905044132198  
Epoch 46/50: Training loss = 0.020236312915399974  
Epoch 47/50: Training loss = 0.014245346737063338  
Epoch 48/50: Training loss = 0.006290919962636081  
Epoch 49/50: Training loss = 0.008335712877127737  
Epoch 50/50: Training loss = 0.014998416998126658

**Test set accuracy with CNNResnet = 70.42 %**

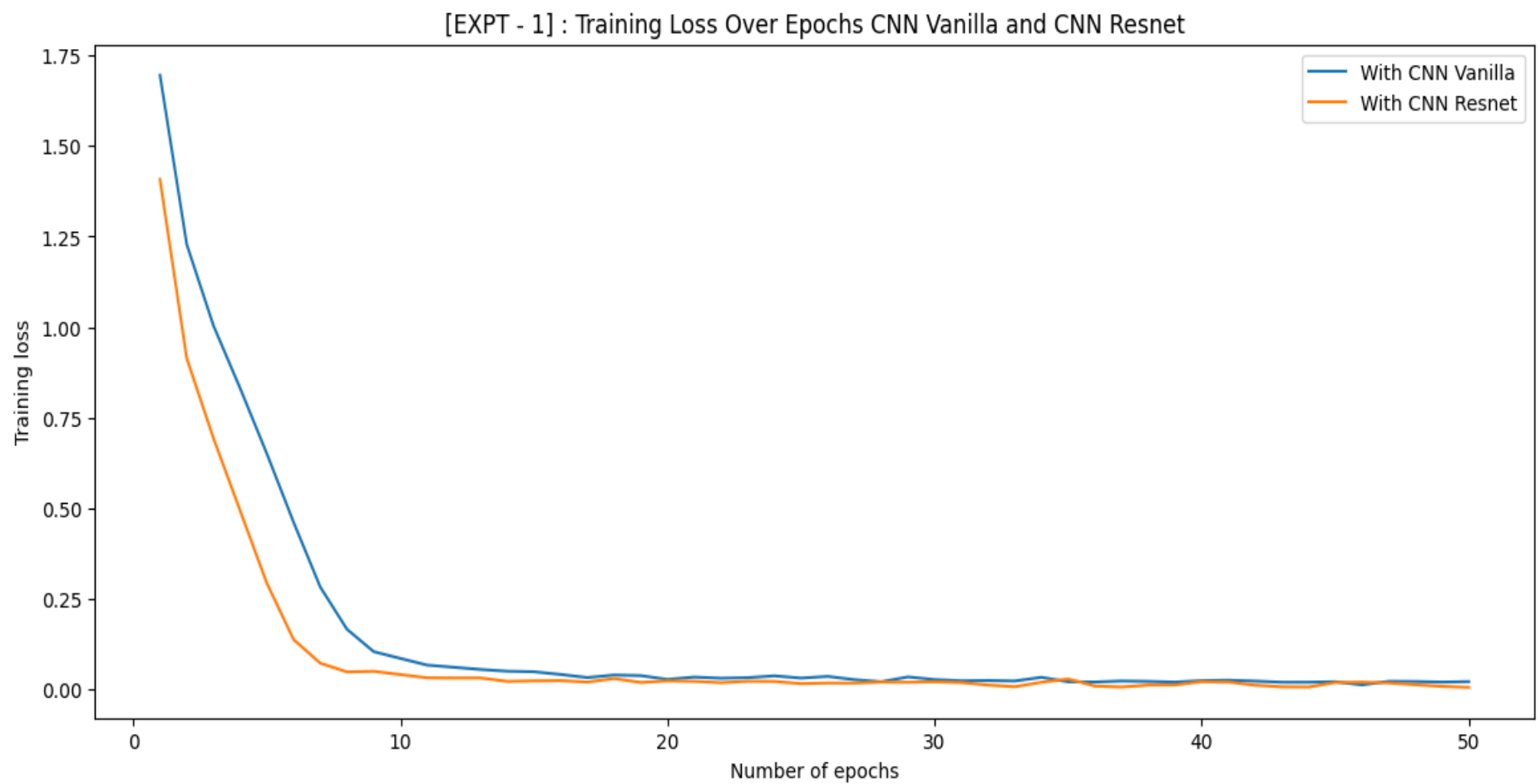
**Total params: 4,256,330**

**Trainable params: 4,256,330**

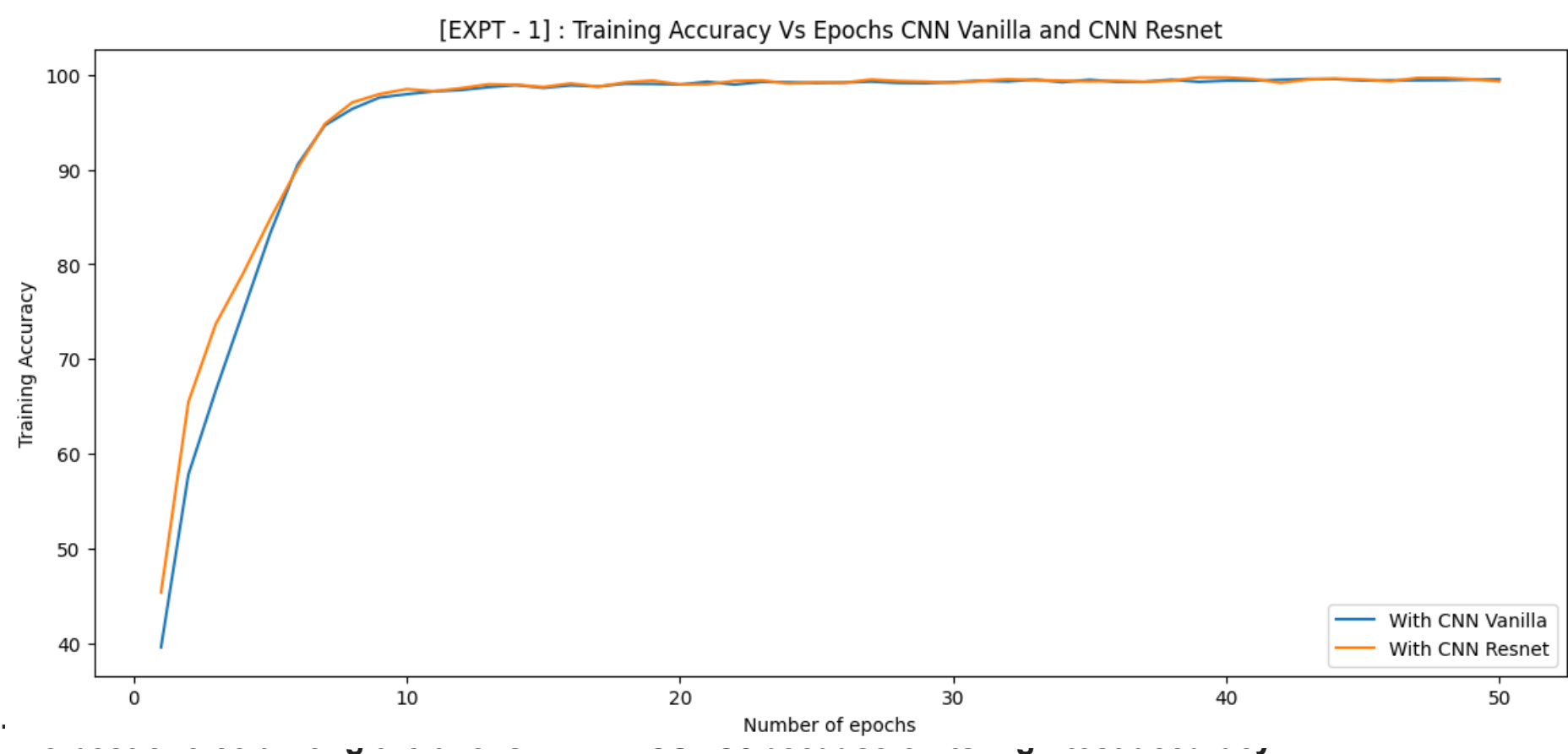
**Non-trainable params: 0**

**Hence, the number of parameters for both CNN Vanilla and CNN Resnet are same.**

**Training Loss Vs Epochs for CNN Vanilla and CNN Resnet :**



## Training Accuracy Vs Epochs for CNN Vanilla and CNN Resnet :



## EXPERIMENT - 2 :

### [EXPT - 2] : Training CNNResnet without Data Normalization

```
Epoch 1/50 (No Normalization): Training loss = 1.6265083636556352
Epoch 2/50 (No Normalization): Training loss = 1.1353123838804207
Epoch 3/50 (No Normalization): Training loss = 0.9205230839398443
Epoch 4/50 (No Normalization): Training loss = 0.7488764281175575
Epoch 5/50 (No Normalization): Training loss = 0.5935991150992257
Epoch 6/50 (No Normalization): Training loss = 0.44017449903244876
Epoch 7/50 (No Normalization): Training loss = 0.2720049321651459
Epoch 8/50 (No Normalization): Training loss = 0.15705229718314143
Epoch 9/50 (No Normalization): Training loss = 0.09616249885258017
Epoch 10/50 (No Normalization): Training loss = 0.07653402219697529
Epoch 11/50 (No Normalization): Training loss = 0.06440181287993886
Epoch 12/50 (No Normalization): Training loss = 0.049410567462102185
Epoch 13/50 (No Normalization): Training loss = 0.0387855410571115
Epoch 14/50 (No Normalization): Training loss = 0.040140841997285584
Epoch 15/50 (No Normalization): Training loss = 0.03846070417012943
Epoch 16/50 (No Normalization): Training loss = 0.0277568472606339
Epoch 17/50 (No Normalization): Training loss = 0.0408986032636342
Epoch 18/50 (No Normalization): Training loss = 0.034426152545778195
Epoch 19/50 (No Normalization): Training loss = 0.025941462535173536
Epoch 20/50 (No Normalization): Training loss = 0.025906611211379344
Epoch 21/50 (No Normalization): Training loss = 0.03219688217730585
Epoch 22/50 (No Normalization): Training loss = 0.03454807317312047
Epoch 23/50 (No Normalization): Training loss = 0.01895228646842915
Epoch 24/50 (No Normalization): Training loss = 0.030096978979061682
Epoch 25/50 (No Normalization): Training loss = 0.02616230182454218
Epoch 26/50 (No Normalization): Training loss = 0.0248956524372595
Epoch 27/50 (No Normalization): Training loss = 0.022274684828554034
Epoch 28/50 (No Normalization): Training loss = 0.02492197791627627
Epoch 29/50 (No Normalization): Training loss = 0.02319700563711361
Epoch 30/50 (No Normalization): Training loss = 0.019829038635124356
Epoch 31/50 (No Normalization): Training loss = 0.020208372995827575
Epoch 32/50 (No Normalization): Training loss = 0.025648324216991588
Epoch 33/50 (No Normalization): Training loss = 0.017957197613919115
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Epoch 34/50 (No Normalization): Training loss = 0.02156379352245309  
Epoch 35/50 (No Normalization): Training loss = 0.014583955609479596  
Epoch 36/50 (No Normalization): Training loss = 0.01651334803719525  
Epoch 37/50 (No Normalization): Training loss = 0.025165656339781056  
Epoch 38/50 (No Normalization): Training loss = 0.017401968208569273  
Epoch 39/50 (No Normalization): Training loss = 0.019684037528350018  
Epoch 40/50 (No Normalization): Training loss = 0.01737361813376287  
Epoch 41/50 (No Normalization): Training loss = 0.015662852539300765  
Epoch 42/50 (No Normalization): Training loss = 0.019873900832584585  
Epoch 43/50 (No Normalization): Training loss = 0.010381609589135874  
Epoch 44/50 (No Normalization): Training loss = 0.018094857662265207  
Epoch 45/50 (No Normalization): Training loss = 0.012623500554675085  
Epoch 46/50 (No Normalization): Training loss = 0.014994580669736024  
Epoch 47/50 (No Normalization): Training loss = 0.020164740854536886  
Epoch 48/50 (No Normalization): Training loss = 0.017166149271212575  
Epoch 49/50 (No Normalization): Training loss = 0.025485172215611578  
Epoch 50/50 (No Normalization): Training loss = 0.013767433024756373

**[EXPT - 2] : Test set accuracy for CNNResnet without Data Normalization = 67.61 %**

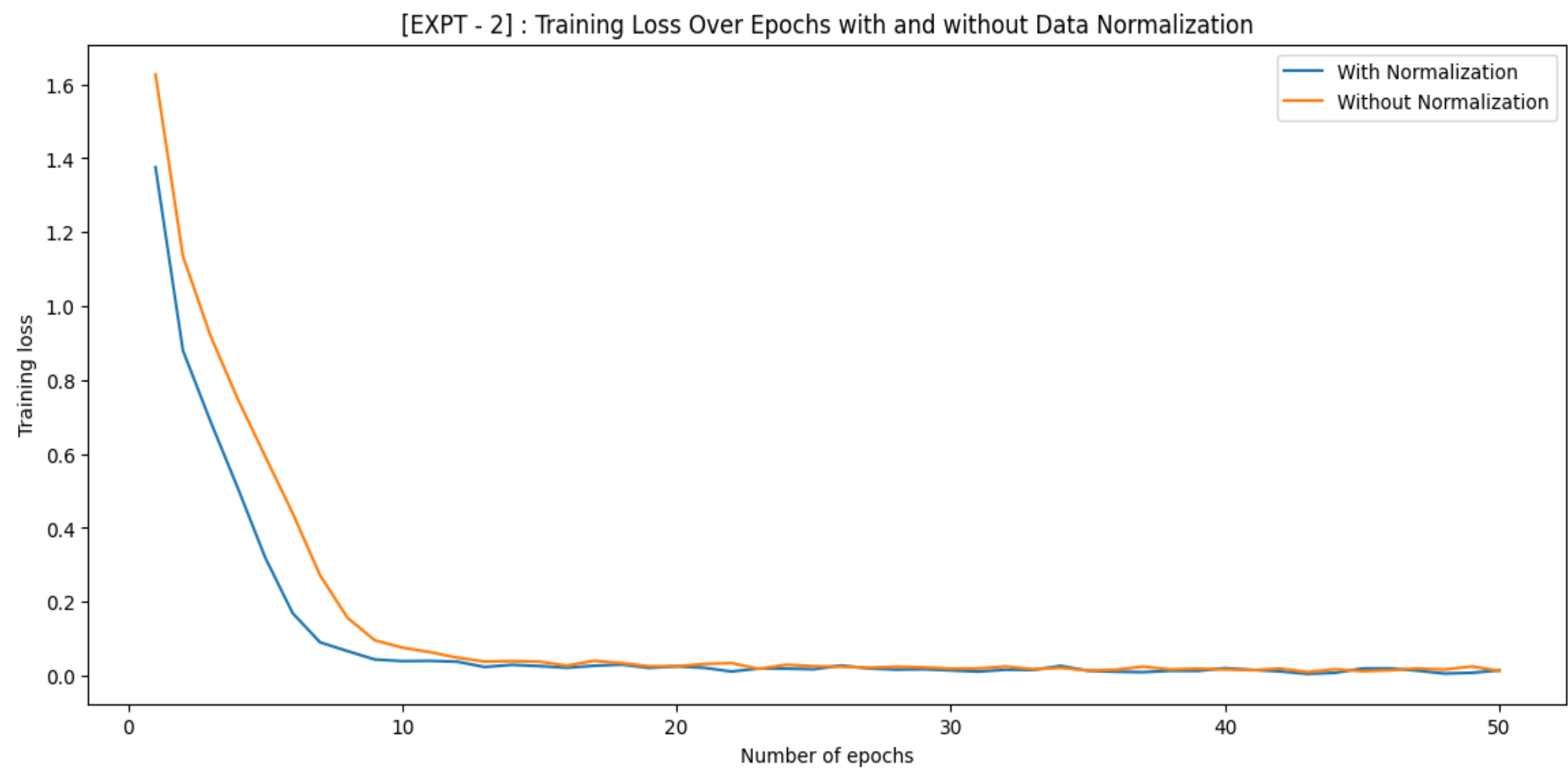
**[EXPT - 2] : Training CNNResnet with Data Normalization**

Epoch 1/50: Training loss = 1.3754086299818389  
Epoch 2/50: Training loss = 0.8799446660036944  
Epoch 3/50: Training loss = 0.6891434746129173  
Epoch 4/50: Training loss = 0.5080836086857076  
Epoch 5/50: Training loss = 0.3199453761382979  
Epoch 6/50: Training loss = 0.16971941087014822  
Epoch 7/50: Training loss = 0.09080422542305017  
Epoch 8/50: Training loss = 0.06703729248054478  
Epoch 9/50: Training loss = 0.04432466764915354  
Epoch 10/50: Training loss = 0.039986168314721814  
Epoch 11/50: Training loss = 0.04067016154888789  
Epoch 12/50: Training loss = 0.03834847982602232  
Epoch 13/50: Training loss = 0.024101945607238735  
Epoch 14/50: Training loss = 0.02986342301687264  
Epoch 15/50: Training loss = 0.026429112090691164  
Epoch 16/50: Training loss = 0.022084197103121907  
Epoch 17/50: Training loss = 0.02748622947279839  
Epoch 18/50: Training loss = 0.03056602914846141  
Epoch 19/50: Training loss = 0.021635443774023454  
Epoch 20/50: Training loss = 0.02579816830776898  
Epoch 21/50: Training loss = 0.021934930955021813  
Epoch 22/50: Training loss = 0.01187818588710352  
Epoch 23/50: Training loss = 0.019955655457143083  
Epoch 24/50: Training loss = 0.019443035558132187  
Epoch 25/50: Training loss = 0.01800418723367478  
Epoch 26/50: Training loss = 0.027926035656603242  
Epoch 27/50: Training loss = 0.02004536039110425  
Epoch 28/50: Training loss = 0.01698572925120896  
Epoch 29/50: Training loss = 0.018004464108214182  
Epoch 30/50: Training loss = 0.014821073278542417  
Epoch 31/50: Training loss = 0.011602988983510414  
Epoch 32/50: Training loss = 0.016664613040083334  
Epoch 33/50: Training loss = 0.01603446071266615  
Epoch 34/50: Training loss = 0.02703287456260652  
Epoch 35/50: Training loss = 0.014020339819265301

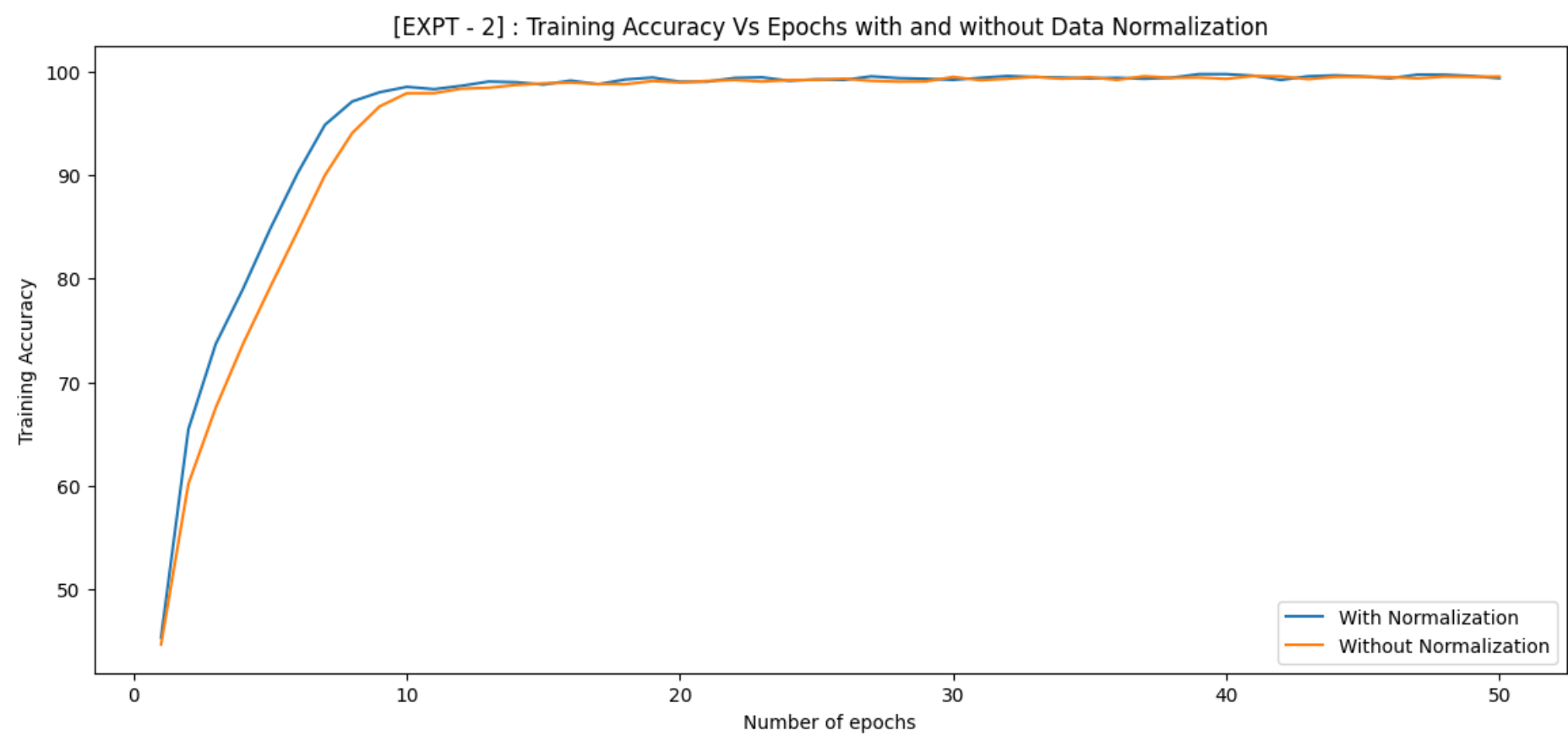
Epoch 36/50: Training loss = 0.011323073973471764  
Epoch 37/50: Training loss = 0.010009245534501115  
Epoch 38/50: Training loss = 0.013759591739638994  
Epoch 39/50: Training loss = 0.0134546298454088  
Epoch 40/50: Training loss = 0.020805492430535734  
Epoch 41/50: Training loss = 0.016140830430751003  
Epoch 42/50: Training loss = 0.012251182241313045  
Epoch 43/50: Training loss = 0.00538756259518369  
Epoch 44/50: Training loss = 0.008284968326307183  
Epoch 45/50: Training loss = 0.019997905044132198  
Epoch 46/50: Training loss = 0.020236312915399974  
Epoch 47/50: Training loss = 0.014245346737063338  
Epoch 48/50: Training loss = 0.006290919962636081  
Epoch 49/50: Training loss = 0.008335712877127737  
Epoch 50/50: Training loss = 0.014998416998126658

[EXPT - 2] : Test set accuracy for CNNResnet with Data Normalization = 70.42 %

Training Loss Vs Epochs for CNN Resnet with and without Data Normalization :



## Training Accuracy Vs Epochs for CNN Resnet with and without Data Normalization :



The best choice among the two is **CNNResnet with Data Normalization** because of its high test accuracy.

## EXPERIMENT - 3 :

[EXPT - 3, PART - A ] : Training CNNResnet with SGD Optimizer, Data Normalization

```
Epoch 1/50: Training loss = 2.2181620257241383
Epoch 2/50: Training loss = 2.0928041874145973
Epoch 3/50: Training loss = 2.006269728650852
Epoch 4/50: Training loss = 1.9393505277682324
Epoch 5/50: Training loss = 1.8846374403457253
Epoch 6/50: Training loss = 1.8386602657181876
Epoch 7/50: Training loss = 1.8011896902201128
Epoch 8/50: Training loss = 1.769271302588132
Epoch 9/50: Training loss = 1.7417179346084595
Epoch 10/50: Training loss = 1.7175745818079735
Epoch 11/50: Training loss = 1.6953512971498528
Epoch 12/50: Training loss = 1.673471135144331
Epoch 13/50: Training loss = 1.6533226638424152
Epoch 14/50: Training loss = 1.6352920459241282
Epoch 15/50: Training loss = 1.6172039143893184
Epoch 16/50: Training loss = 1.5996237567492895
Epoch 17/50: Training loss = 1.5827383526733942
Epoch 18/50: Training loss = 1.5660207581763366
Epoch 19/50: Training loss = 1.5494427072758576
Epoch 20/50: Training loss = 1.5344125950823024
Epoch 21/50: Training loss = 1.5182346859756781
Epoch 22/50: Training loss = 1.5019790061882563
Epoch 23/50: Training loss = 1.487730694060423
Epoch 24/50: Training loss = 1.4725390131376228
Epoch 25/50: Training loss = 1.4582364200329294
Epoch 26/50: Training loss = 1.444051159279687
Epoch 27/50: Training loss = 1.4302282765203593
Epoch 28/50: Training loss = 1.4167364695850684
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Epoch 29/50: Training loss = 1.4040458366578938  
Epoch 30/50: Training loss = 1.3912735228635826  
Epoch 31/50: Training loss = 1.378776521098857  
Epoch 32/50: Training loss = 1.3681506392907123  
Epoch 33/50: Training loss = 1.3561285052980696  
Epoch 34/50: Training loss = 1.3440892447014243  
Epoch 35/50: Training loss = 1.3343195142794628  
Epoch 36/50: Training loss = 1.323497612257393  
Epoch 37/50: Training loss = 1.312506766951814  
Epoch 38/50: Training loss = 1.3030605115452591  
Epoch 39/50: Training loss = 1.2933331344808852  
Epoch 40/50: Training loss = 1.2840810077530997  
Epoch 41/50: Training loss = 1.275409314705401  
Epoch 42/50: Training loss = 1.2678247963895604  
Epoch 43/50: Training loss = 1.258094070517287  
Epoch 44/50: Training loss = 1.249455111367362  
Epoch 45/50: Training loss = 1.240953515987007  
Epoch 46/50: Training loss = 1.2319378208140939  
Epoch 47/50: Training loss = 1.2236226091579514  
Epoch 48/50: Training loss = 1.2141974446724872  
Epoch 49/50: Training loss = 1.20690099013095  
Epoch 50/50: Training loss = 1.1991177882466997

**[EXPT - 3, PART - A] : Test set accuracy with CNNResnet with SGD Optimizer, Data Normalization = 53.56 %**

**[EXPT - 3, PART - B] : Training CNNResnet with Mini-Batch Gradient Descent with no momentum, Data Normalization**

Epoch 1/50: Training loss = 2.2405163463281124  
Epoch 2/50: Training loss = 2.126503182917225  
Epoch 3/50: Training loss = 2.0361731964714673  
Epoch 4/50: Training loss = 1.9634196308194374  
Epoch 5/50: Training loss = 1.9044215204764385  
Epoch 6/50: Training loss = 1.8575908675485728  
Epoch 7/50: Training loss = 1.8197976180485316  
Epoch 8/50: Training loss = 1.7880808844858287  
Epoch 9/50: Training loss = 1.7610327175685339  
Epoch 10/50: Training loss = 1.7359742059999583  
Epoch 11/50: Training loss = 1.7119139664027156  
Epoch 12/50: Training loss = 1.6894403574418049  
Epoch 13/50: Training loss = 1.6666992112081878  
Epoch 14/50: Training loss = 1.6429871430202407  
Epoch 15/50: Training loss = 1.619980810248122  
Epoch 16/50: Training loss = 1.5975579424780242  
Epoch 17/50: Training loss = 1.5739139415779893  
Epoch 18/50: Training loss = 1.5515732819936714  
Epoch 19/50: Training loss = 1.5275266997668209  
Epoch 20/50: Training loss = 1.5072810096400124  
Epoch 21/50: Training loss = 1.4864103727194728  
Epoch 22/50: Training loss = 1.4656323814878658  
Epoch 23/50: Training loss = 1.4466413247342012  
Epoch 24/50: Training loss = 1.428415844026877  
Epoch 25/50: Training loss = 1.4115159170968192  
Epoch 26/50: Training loss = 1.3938190906631702  
Epoch 27/50: Training loss = 1.3778150635106223  
Epoch 28/50: Training loss = 1.3628379282902698  
Epoch 29/50: Training loss = 1.3482618039968062  
Epoch 30/50: Training loss = 1.3347107397050273  
Epoch 31/50: Training loss = 1.3224846215880648  
Epoch 32/50: Training loss = 1.3093024699055418  
Epoch 33/50: Training loss = 1.2977853837061901



Epoch 34/50: Training loss = 1.2866646945476532  
Epoch 35/50: Training loss = 1.2757224586545204  
Epoch 36/50: Training loss = 1.266333597655199  
Epoch 37/50: Training loss = 1.2553602566524429  
Epoch 38/50: Training loss = 1.2463220978269771  
Epoch 39/50: Training loss = 1.2363673849981658  
Epoch 40/50: Training loss = 1.2290199490226046  
Epoch 41/50: Training loss = 1.2193733137481066  
Epoch 42/50: Training loss = 1.211245237564554  
Epoch 43/50: Training loss = 1.204154838712848  
Epoch 44/50: Training loss = 1.1976025019373213  
Epoch 45/50: Training loss = 1.1890770367213659  
Epoch 46/50: Training loss = 1.1822816613985567  
Epoch 47/50: Training loss = 1.1745995553780575  
Epoch 48/50: Training loss = 1.166220566143795  
Epoch 49/50: Training loss = 1.1602840019123895  
Epoch 50/50: Training loss = 1.153152168101194

**[EXPT - 3, PART - B ] : Test set accuracy with CNNResnet with Mini-Batch Gradient Descent with no momentum, Data Normalization = 55.96 %**

**[EXPT - 3, PART - C] : Training CNNResnet with Mini-Batch Gradient Descent with momentum 0.9, Data Normalization**

Epoch 1/50: Training loss = 1.962206398345986  
Epoch 2/50: Training loss = 1.6676983000064383  
Epoch 3/50: Training loss = 1.5084655801860654  
Epoch 4/50: Training loss = 1.3867073496993707  
Epoch 5/50: Training loss = 1.3004442982527675  
Epoch 6/50: Training loss = 1.232142599261537  
Epoch 7/50: Training loss = 1.1687051568712508  
Epoch 8/50: Training loss = 1.110826881260288  
Epoch 9/50: Training loss = 1.0703168380625394  
Epoch 10/50: Training loss = 1.0208181936521918  
Epoch 11/50: Training loss = 0.9783799547930153  
Epoch 12/50: Training loss = 0.929372424069716  
Epoch 13/50: Training loss = 0.8830126578710518  
Epoch 14/50: Training loss = 0.8349523957894773  
Epoch 15/50: Training loss = 0.7862394309165527  
Epoch 16/50: Training loss = 0.7343276270798275  
Epoch 17/50: Training loss = 0.6942617677304209  
Epoch 18/50: Training loss = 0.6347520205439353  
Epoch 19/50: Training loss = 0.5746939043913569  
Epoch 20/50: Training loss = 0.5201009919448775  
Epoch 21/50: Training loss = 0.4502379863846059  
Epoch 22/50: Training loss = 0.38108123572809355  
Epoch 23/50: Training loss = 0.327840510679751  
Epoch 24/50: Training loss = 0.2580388422523226  
Epoch 25/50: Training loss = 0.20136287952868306  
Epoch 26/50: Training loss = 0.15785504782534376  
Epoch 27/50: Training loss = 0.11024565567091411  
Epoch 28/50: Training loss = 0.08363236271187055  
Epoch 29/50: Training loss = 0.07420943380922687  
Epoch 30/50: Training loss = 0.049547126355143835  
Epoch 31/50: Training loss = 0.03524673886939275  
Epoch 32/50: Training loss = 0.03824379525565523  
Epoch 33/50: Training loss = 0.030863062518990923  
Epoch 34/50: Training loss = 0.00807182434043486  
Epoch 35/50: Training loss = 0.0037492453999703333  
Epoch 36/50: Training loss = 0.0020343538341635117  
Epoch 37/50: Training loss = 0.0017171920249262368  
Epoch 38/50: Training loss = 0.0008754093364494073  
Epoch 39/50: Training loss = 0.0007943856894877283

Epoch 40/50: Training loss = 0.0005410167032838514  
Epoch 41/50: Training loss = 0.0004553300428337285  
Epoch 42/50: Training loss = 0.0004058122356916417  
Epoch 43/50: Training loss = 0.00037178794898826877  
Epoch 44/50: Training loss = 0.00038432281723303  
Epoch 45/50: Training loss = 0.000314128744414157  
Epoch 46/50: Training loss = 0.0002922660253772141  
Epoch 47/50: Training loss = 0.00027245186185832516  
Epoch 48/50: Training loss = 0.0002576273926729764  
Epoch 49/50: Training loss = 0.00024116563716753653  
Epoch 50/50: Training loss = 0.00022758381631004395

**[EXPT - 3, PART - C] : Test set accuracy with CNNResnet with Mini-Batch Gradient Descent  
with momentum 0.9, Data Normalization = 67.89 %**

**[EXPT - 3, PART - D] : Training CNNResnet with ADAM Optimizer, Data Normalization**

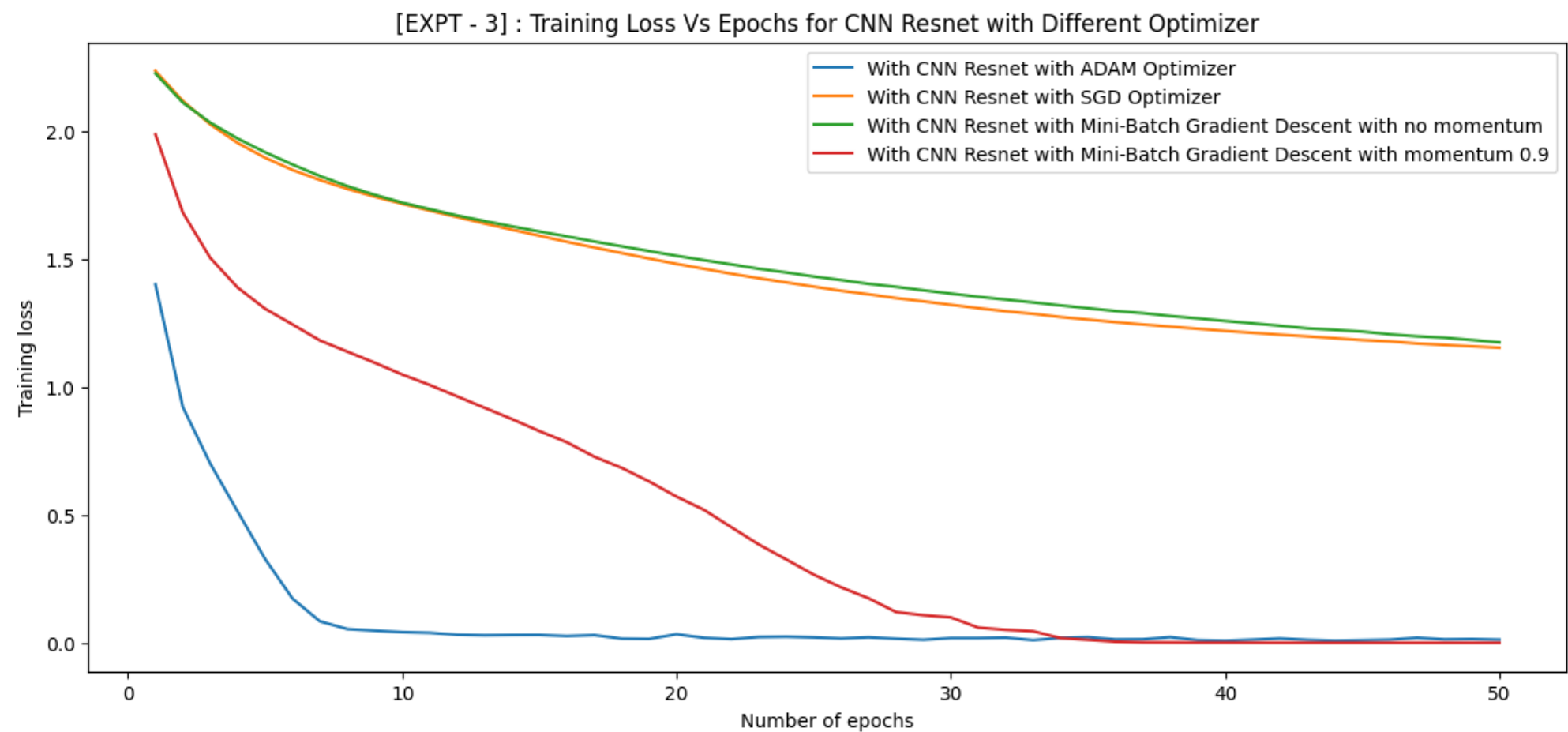
Epoch 1/50: Training loss = 1.3754086299818389  
Epoch 2/50: Training loss = 0.8799446660036944  
Epoch 3/50: Training loss = 0.6891434746129173  
Epoch 4/50: Training loss = 0.5080836086857076  
Epoch 5/50: Training loss = 0.3199453761382979  
Epoch 6/50: Training loss = 0.16971941087014822  
Epoch 7/50: Training loss = 0.09080422542305017  
Epoch 8/50: Training loss = 0.06703729248054478  
Epoch 9/50: Training loss = 0.04432466764915354  
Epoch 10/50: Training loss = 0.039986168314721814  
Epoch 11/50: Training loss = 0.04067016154888789  
Epoch 12/50: Training loss = 0.03834847982602232  
Epoch 13/50: Training loss = 0.024101945607238735  
Epoch 14/50: Training loss = 0.02986342301687264  
Epoch 15/50: Training loss = 0.026429112090691164  
Epoch 16/50: Training loss = 0.022084197103121907  
Epoch 17/50: Training loss = 0.02748622947279839  
Epoch 18/50: Training loss = 0.03056602914846141  
Epoch 19/50: Training loss = 0.021635443774023454  
Epoch 20/50: Training loss = 0.02579816830776898  
Epoch 21/50: Training loss = 0.021934930955021813  
Epoch 22/50: Training loss = 0.01187818588710352  
Epoch 23/50: Training loss = 0.019955655457143083  
Epoch 24/50: Training loss = 0.019443035558132187  
Epoch 25/50: Training loss = 0.01800418723367478  
Epoch 26/50: Training loss = 0.027926035656603242  
Epoch 27/50: Training loss = 0.02004536039110425  
Epoch 28/50: Training loss = 0.01698572925120896  
Epoch 29/50: Training loss = 0.018004464108214182  
Epoch 30/50: Training loss = 0.014821073278542417  
Epoch 31/50: Training loss = 0.011602988983510414  
Epoch 32/50: Training loss = 0.016664613040083334  
Epoch 33/50: Training loss = 0.01603446071266615  
Epoch 34/50: Training loss = 0.02703287456260652  
Epoch 35/50: Training loss = 0.014020339819265301  
Epoch 36/50: Training loss = 0.011323073973471764  
Epoch 37/50: Training loss = 0.010009245534501115  
Epoch 38/50: Training loss = 0.013759591739638994  
Epoch 39/50: Training loss = 0.0134546298454088  
Epoch 40/50: Training loss = 0.020805492430535734  
Epoch 41/50: Training loss = 0.016140830430751003  
Epoch 42/50: Training loss = 0.012251182241313045  
Epoch 43/50: Training loss = 0.00538756259518369  
Epoch 44/50: Training loss = 0.008284968326307183  
Epoch 45/50: Training loss = 0.019997905044132198

Epoch 46/50: Training loss = 0.020236312915399974  
Epoch 47/50: Training loss = 0.014245346737063338  
Epoch 48/50: Training loss = 0.006290919962636081  
Epoch 49/50: Training loss = 0.008335712877127737  
Epoch 50/50: Training loss = 0.014998416998126658

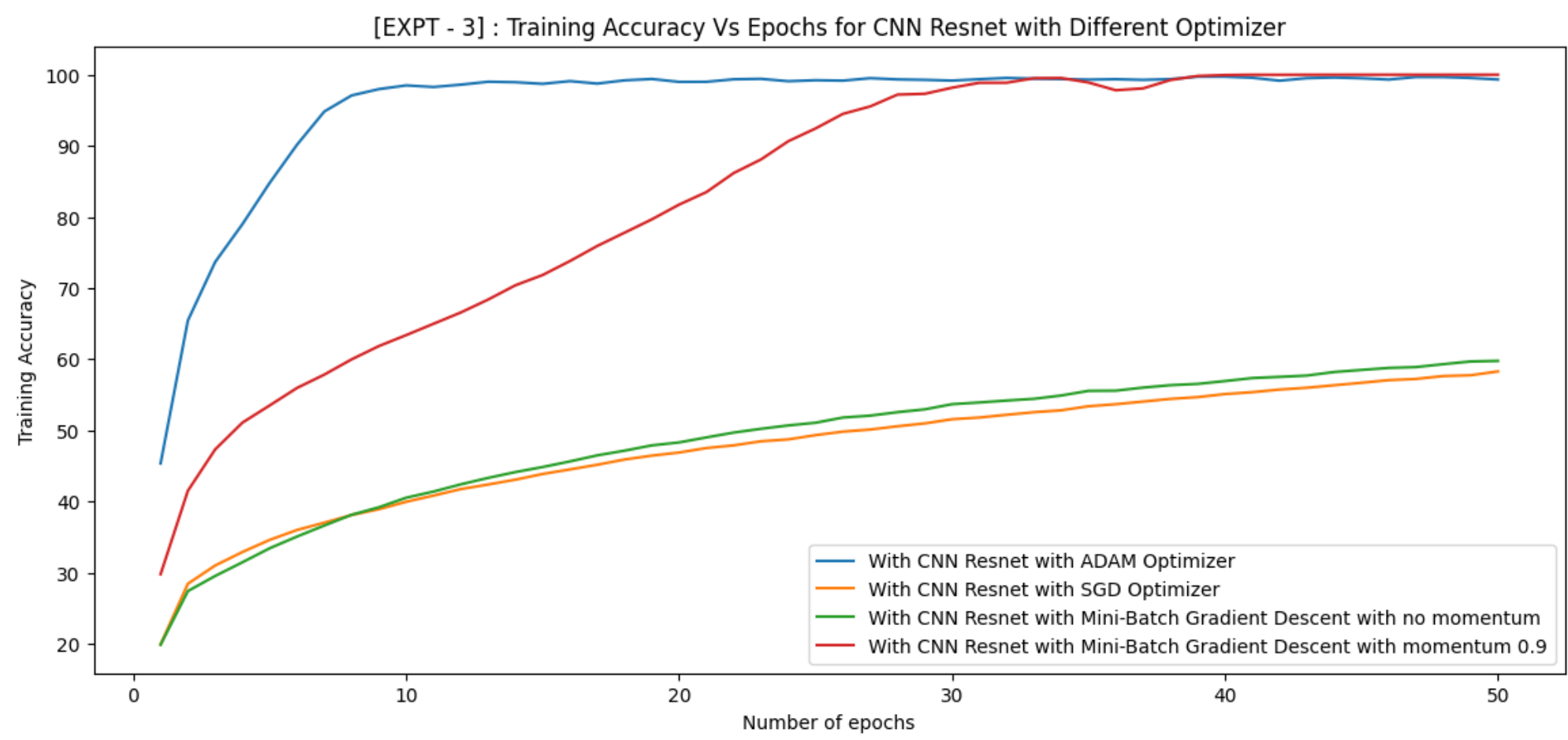
[EXPT - 3, PART - D ] : Test set accuracy with ADAM Optimizer, Data Normalization = 70.42 %

The best choice among the four is **CNNResnet with ADAM Optimizer** because of its high test accuracy.

**Training Loss Vs Epochs for CNN Resnet with Data Normalization for Different Optimizers :**



# Training Accuracy Vs Epochs for CNN Resnet with Data Normalization for Different Optimizers :



## EXPERIMENT - 4 :

[EXPT - 4, PART - A] : Training CNNResnet - Four level Resnet block with two fully-connected layer

Epoch 1/50: Training loss = 1.4549924390656608  
Epoch 2/50: Training loss = 0.9392709245487135  
Epoch 3/50: Training loss = 0.7048959750301984  
Epoch 4/50: Training loss = 0.5102155938440439  
Epoch 5/50: Training loss = 0.3154763782358899  
Epoch 6/50: Training loss = 0.15274592519414668  
Epoch 7/50: Training loss = 0.08402017678837387  
Epoch 8/50: Training loss = 0.05530861050498729  
Epoch 9/50: Training loss = 0.04504655071591236  
Epoch 10/50: Training loss = 0.03454727785927909  
Epoch 11/50: Training loss = 0.03887274389972492  
Epoch 12/50: Training loss = 0.035005135340521076  
Epoch 13/50: Training loss = 0.030207856009448215  
Epoch 14/50: Training loss = 0.025847132624202997  
Epoch 15/50: Training loss = 0.021167393064611042  
Epoch 16/50: Training loss = 0.01794842510942693  
Epoch 17/50: Training loss = 0.024970327066827794  
Epoch 18/50: Training loss = 0.02565890309111006  
Epoch 19/50: Training loss = 0.023306483008461644  
Epoch 20/50: Training loss = 0.022016855435474415  
Epoch 21/50: Training loss = 0.022987390742447152  
Epoch 22/50: Training loss = 0.020043746683489988  
Epoch 23/50: Training loss = 0.017404217159551358  
Epoch 24/50: Training loss = 0.01794463677013445  
Epoch 25/50: Training loss = 0.025226782915320208  
Epoch 26/50: Training loss = 0.018779917813752  
Epoch 27/50: Training loss = 0.015393795781740348  
Epoch 28/50: Training loss = 0.015049895540275374  
Epoch 29/50: Training loss = 0.021192337564496816

Epoch 30/50: Training loss = 0.01537659194389339  
Epoch 31/50: Training loss = 0.010386178900911805  
Epoch 32/50: Training loss = 0.015467927947091604  
Epoch 33/50: Training loss = 0.013196777811033974  
Epoch 34/50: Training loss = 0.01523594469501998  
Epoch 35/50: Training loss = 0.0198349283060192  
Epoch 36/50: Training loss = 0.013934862314977646  
Epoch 37/50: Training loss = 0.016402032137230724  
Epoch 38/50: Training loss = 0.010745415664206696  
Epoch 39/50: Training loss = 0.017808456732642038  
Epoch 40/50: Training loss = 0.011061694303453823  
Epoch 41/50: Training loss = 0.00986076145681163  
Epoch 42/50: Training loss = 0.00988822975334039  
Epoch 43/50: Training loss = 0.017294194361038163  
Epoch 44/50: Training loss = 0.013104474858014978  
Epoch 45/50: Training loss = 0.008522037877903168  
Epoch 46/50: Training loss = 0.011563525652027052  
Epoch 47/50: Training loss = 0.0051238565415866215  
Epoch 48/50: Training loss = 0.008123468599794195  
Epoch 49/50: Training loss = 0.026821397904221122  
Epoch 50/50: Training loss = 0.01294820190927641

**[EXPT - 4, PART - A] : Test set accuracy with CNNResnet\_DeepConv = 70.08 %**

**For CNNResnet\_DeepConv :**

**Total params: 4,274,826**

**Trainable params: 4,274,826**

**Non-trainable params: 0**

**[EXPT - 4, PART - B] : Training CNNResnet - Three level Resnet blocks with four fully-connected layers**

Epoch 1/50: Training loss = 1.4301838233154647  
Epoch 2/50: Training loss = 0.9021082873247108  
Epoch 3/50: Training loss = 0.6605468310263692  
Epoch 4/50: Training loss = 0.4352152095157273  
Epoch 5/50: Training loss = 0.23054210963297864  
Epoch 6/50: Training loss = 0.09980326159191984  
Epoch 7/50: Training loss = 0.07585576382864799  
Epoch 8/50: Training loss = 0.053365337401058296  
Epoch 9/50: Training loss = 0.045071005932891706  
Epoch 10/50: Training loss = 0.03886134829847332  
Epoch 11/50: Training loss = 0.033604143617427626  
Epoch 12/50: Training loss = 0.03253421692263183  
Epoch 13/50: Training loss = 0.03297610383252708  
Epoch 14/50: Training loss = 0.03552883243834486  
Epoch 15/50: Training loss = 0.02598322310713025  
Epoch 16/50: Training loss = 0.02040291947849589  
Epoch 17/50: Training loss = 0.02389342560936526  
Epoch 18/50: Training loss = 0.02777442053359534  
Epoch 19/50: Training loss = 0.02178689857353266  
Epoch 20/50: Training loss = 0.02414768900216215  
Epoch 21/50: Training loss = 0.022500174833409374  
Epoch 22/50: Training loss = 0.018914209647586437  
Epoch 23/50: Training loss = 0.024515815928865852  
Epoch 24/50: Training loss = 0.019654427905096576  
Epoch 25/50: Training loss = 0.021194837831509567  
Epoch 26/50: Training loss = 0.022082453804762977  
Epoch 27/50: Training loss = 0.019760829482669467  
Epoch 28/50: Training loss = 0.013970850596836368

Epoch 29/50: Training loss = 0.01718789824772845  
Epoch 30/50: Training loss = 0.018834787688208555  
Epoch 31/50: Training loss = 0.017566802145702984  
Epoch 32/50: Training loss = 0.010171611019711922  
Epoch 33/50: Training loss = 0.018833334125312313  
Epoch 34/50: Training loss = 0.018536731916745857  
Epoch 35/50: Training loss = 0.016982856480706465  
Epoch 36/50: Training loss = 0.018282935538267413  
Epoch 37/50: Training loss = 0.014461437111057587  
Epoch 38/50: Training loss = 0.011887015096994108  
Epoch 39/50: Training loss = 0.015445600109642885  
Epoch 40/50: Training loss = 0.013451516038764325  
Epoch 41/50: Training loss = 0.014571547715381805  
Epoch 42/50: Training loss = 0.009714129351926445  
Epoch 43/50: Training loss = 0.017892340360457618  
Epoch 44/50: Training loss = 0.014778973071417791  
Epoch 45/50: Training loss = 0.010109545918622847  
Epoch 46/50: Training loss = 0.010375794647262985  
Epoch 47/50: Training loss = 0.016506778914659587  
Epoch 48/50: Training loss = 0.011903474853838537  
Epoch 49/50: Training loss = 0.010262949343643636  
Epoch 50/50: Training loss = 0.013970953603459247

[EXPT - 4, PART - B] : Test set accuracy with CNNResnet\_DeepFC = 69.52 %

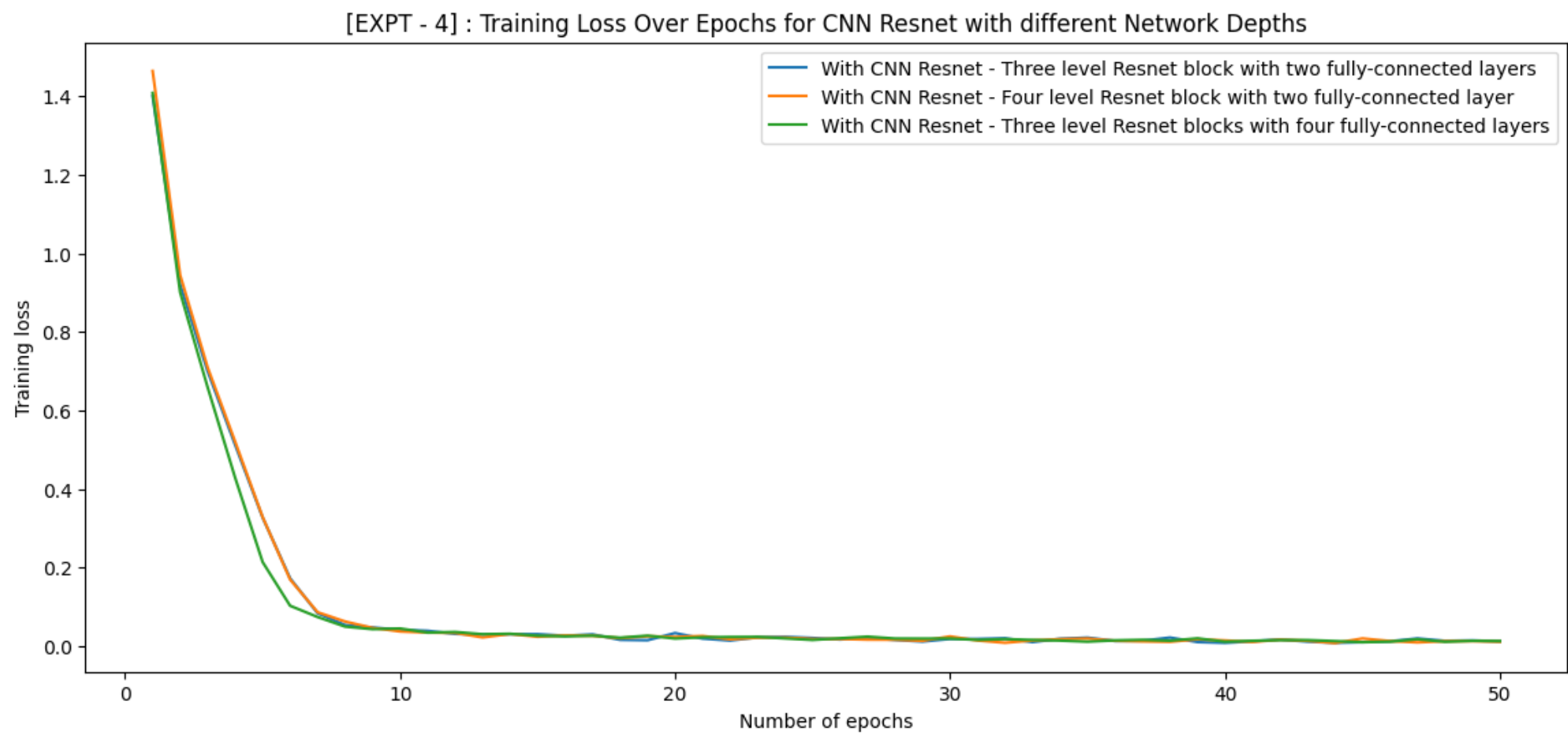
For CNNResnet\_DeepFC :

Total params: 9,104,714

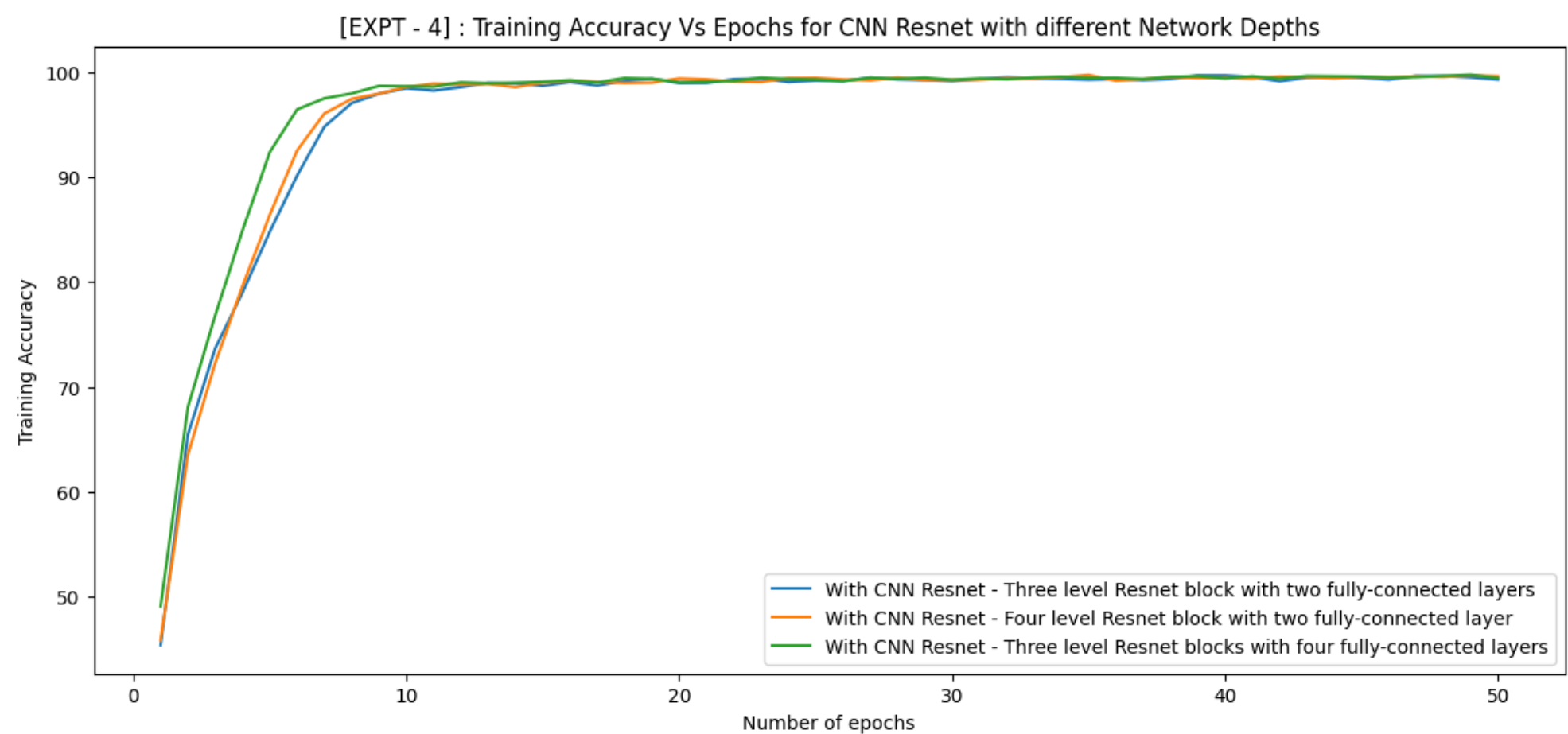
Trainable params: 9,104,714

Non-trainable params: 0

Training Loss Vs Epochs for CNN Resnet with Data Normalization for Different Optimizers :



Training Accuracy Vs Epochs for CNN Resnet with Data Normalization for Different Optimizers :



The best choice among the three is **CNNResnet with three level Resnet blocks with four fully-connected layers** as the training loss is minimum for this case and also accuracy on the test set is approximately the same (70 %) for all the models .

Best Choice:

The best choice will depend on the specific dataset and task.

However, for many image recognition tasks, especially those involving complex scenes or numerous classes, increasing the depth with convolutional layers is often more beneficial.

This is because convolutional layers are more suited to image data, capable of capturing spatial hierarchies and patterns.

**In Case A (More Conv Layers):** Likely to perform better on complex image tasks.

**In Case B (More Fully Connected Layers):** Could be better when the complexity lies in the classification decision boundary rather than feature extraction.