Q1

Given x = 2, y = 1

Feedforward propagation:

First layer:

$$z^{(1)} = (\begin{smallmatrix} 1 \\ 2 \end{smallmatrix})^T * W^{(1)} = (\begin{smallmatrix} 0.7 \\ 1 \end{smallmatrix})^T$$

$$a^{(1)} = tanh(z^{(1)}) = (\begin{smallmatrix} tanh(0.7) \\ tanh(1) \end{smallmatrix})^T \approx (\begin{smallmatrix} 0.604368 \\ 0.761594 \end{smallmatrix})^T$$

Hidden layer:

$$z^{(2)} = (\begin{smallmatrix} 1 \\ a^{(1)} \end{smallmatrix})^T * W^{(2)}$$

$$a^{(2)} = tanh(z^{(2)}) \approx -0.901546$$

Output layer:

$$z^{(3)} = (\begin{smallmatrix} 1 \\ a^{(2)} \end{smallmatrix})^T * W^{(3)}$$

$$h(x) = tanh(z^{(3)}) \approx -0.665761$$

Now start backpropagation:

since the activation functions are all tanh, we use squared error cost function.

Errors:

Output Layer:

$$\delta^{(3)} = \frac{\partial J(w)}{\partial z^{(3)}} = 2(h(x) - y)(1 - (h(x))^2) \approx -1.854864$$

Second Layer:

$$\delta^{(2)} = \delta^{(3)} * W_{2,1}^{(3)} * [1 - a^{(2)^2}] \approx -0.694518$$

First Layer:

$$\delta^{(1)} = \delta^{(2)} * W_{2:3,1}^{(2)} * [1 - a^{(1)^2}] \approx (\begin{smallmatrix} -0.440838 \\ 0.875040 \end{smallmatrix})$$

Now we can compute the partial derivatives needed for the gradient

First Layer

$$\frac{\partial J(w)}{\partial W^{(1)}} = \delta^{(1)} * \left(\begin{array}{c} 1 \\ x \end{array}\right)^T = \left[\begin{array}{cc} -0.440838 & -0.881677 \\ 0.875040 & 1.750080 \end{array}\right]$$

Second Layer

$$\frac{\partial J(w)}{\partial W^{(2)}} = \delta^{(2)} * \left(\begin{array}{c} 1 \\ a^{(2)} \end{array}\right)^T = \left(\begin{array}{c} -0.6945185 \\ -0.4197446 \\ -0.5289412 \end{array}\right)$$

Third Layer:

$$\frac{\partial J(w)}{\partial W^{(3)}} = \delta^{(3)} * \left(\begin{array}{c} 1 \\ a^{(3)} \end{array}\right)^T = \left(\begin{array}{c} -1.8548644 \\ 1.6722449 \end{array}\right)$$

Q2

```
In [1]:  import numpy as np
         import matplotlib.pyplot as plt
         from sklearn import datasets
         X, y = datasets.make_blobs(centers=4, random_state=2, n_samples=500)
         plt.scatter(X[:, 0], X[:, 1], c=y)
         plt.title("Hand-made Example")
         plt.show()
```

Hand-made Example
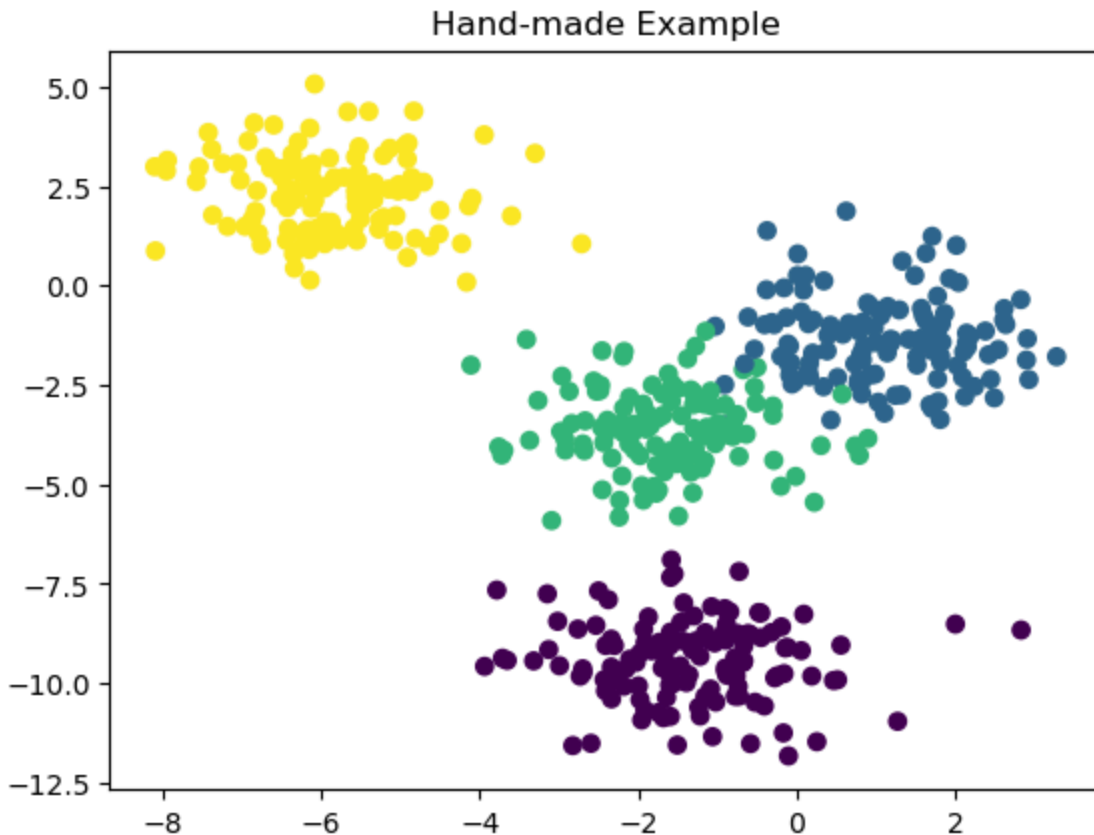

```
In [5]:   import torch
```

```
In [3]:   from sklearn.model_selection import train_test_split
          X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, ran

          # to pytorch tensor
          X_train = torch.tensor(X_train, dtype=torch.float32)
          X_test = torch.tensor(X_test, dtype=torch.float32)
          y_train = torch.tensor(y_train, dtype=torch.long)
          y_test = torch.tensor(y_test, dtype=torch.long)
```

```
In [4]:   X.shape, y.shape
```

```
Out[4]:   ((500, 2), (500,))
```

```
In [5]:   # define nn
          class MLP(torch.nn.Module):
              def __init__(self, input_size, hidden_size, num_classes):
                  super(MLP, self).__init__()
                  self.layer1 = torch.nn.Linear(input_size, hidden_size)
                  self.layer2 = torch.nn.Linear(hidden_size, hidden_size)
                  self.output_layer = torch.nn.Linear(hidden_size, num_classes)

              def forward(self, x):
                  x = self.layer1(x)
                  x = torch.tanh(self.layer2(x))
                  x = torch.softmax(self.output_layer(x), dim=-1)
                  return x
```

In [6]:
```python
# Model parameters
input_size = 2
hidden_size = 128
num_classes = 4
num_epochs = 1024
learning_rate = 0.001

# Initialize the model
model = MLP(input_size, hidden_size, num_classes)

# This criterion computes the cross entropy loss between input logits and ta
loss_fn = torch.nn.CrossEntropyLoss()

# We will use Stochastic Gradient Descent
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate, momentum=0
```

In [7]:
```python
# use summary writer to track the train and test loss for each epoch
from torch.utils.tensorboard import SummaryWriter
writer = SummaryWriter()

for epoch in range(num_epochs):
    # Forward pass
    y_pred = model(X_train)
    loss = loss_fn(y_pred, y_train)

    # Zero gradients for each batch
    optimizer.zero_grad()

    # Backward pass
    loss.backward()

    # Update gradients
    optimizer.step()

    # Test the model
    y_pred_test = model(X_test)
    loss_test = loss_fn(y_pred_test, y_test)

    # Log the loss
    writer.add_scalar('Loss/train', loss, epoch)
    writer.add_scalar('Loss/test', loss_test, epoch)

    # Print the loss for each epoch
    print(f"Epoch {epoch}: train loss: {loss.item()}, test loss: {loss_test.
```

```
Epoch 0: train loss: 1.431787133216858, test loss: 1.4364352226257324
Epoch 1: train loss: 1.4304388761520386, test loss: 1.4338222742080688
Epoch 2: train loss: 1.4278721809387207, test loss: 1.4300851821899414
Epoch 3: train loss: 1.4242002964019775, test loss: 1.4253267049789429
Epoch 4: train loss: 1.4195235967636108, test loss: 1.419641375541687
Epoch 5: train loss: 1.413933515548706, test loss: 1.4131152629852295
Epoch 6: train loss: 1.4075137376785278, test loss: 1.40583074092865
Epoch 7: train loss: 1.4003444910049438, test loss: 1.3978681564331055
Epoch 8: train loss: 1.3925038576126099, test loss: 1.3893072605133057
Epoch 9: train loss: 1.384070634841919, test loss: 1.3802293539047241
Epoch 10: train loss: 1.375124454498291, test loss: 1.3707187175750732
Epoch 11: train loss: 1.365749478340149, test loss: 1.360862374305725
Epoch 12: train loss: 1.3560329675674438, test loss: 1.3507510423660278
Epoch 13: train loss: 1.3460654020309448, test loss: 1.3404769897460938
Epoch 14: train loss: 1.3359402418136597, test loss: 1.3301326036453247
Epoch 15: train loss: 1.325751543045044, test loss: 1.3198071718215942
Epoch 16: train loss: 1.3155899047851562, test loss: 1.3095831871032715
Epoch 17: train loss: 1.305539608001709, test loss: 1.2995332479476929
Epoch 18: train loss: 1.2956756353378296, test loss: 1.2897169589996338
Epoch 19: train loss: 1.2860597372055054, test loss: 1.2801786661148071
Epoch 20: train loss: 1.276738166809082, test loss: 1.2709472179412842
Epoch 21: train loss: 1.26774263381958, test loss: 1.2620348930358887
Epoch 22: train loss: 1.2590885162353516, test loss: 1.2534409761428833
Epoch 23: train loss: 1.2507768869400024, test loss: 1.245151400566101
Epoch 24: train loss: 1.2427968978881836, test loss: 1.2371430397033691
Epoch 25: train loss: 1.2351279258728027, test loss: 1.2293846607208252
Epoch 26: train loss: 1.2277417182922363, test loss: 1.221840739250183
Epoch 27: train loss: 1.220605731010437, test loss: 1.214472770690918
Epoch 28: train loss: 1.2136834859848022, test loss: 1.2072408199310303
Epoch 29: train loss: 1.2069374322891235, test loss: 1.2001066207885742
Epoch 30: train loss: 1.200331449508667, test loss: 1.1930344104766846
Epoch 31: train loss: 1.193830966949463, test loss: 1.1859924793243408
Epoch 32: train loss: 1.187404751777649, test loss: 1.1789560317993164
Epoch 33: train loss: 1.1810275316238403, test loss: 1.1719074249267578
Epoch 34: train loss: 1.174680233001709, test loss: 1.1648386716842651
Epoch 35: train loss: 1.1683518886566162, test loss: 1.1577527523040771
Epoch 36: train loss: 1.1620410680770874, test loss: 1.1506645679473877
Epoch 37: train loss: 1.155755877494812, test loss: 1.143599033355713
Epoch 38: train loss: 1.1495144367218018, test loss: 1.1365916728973389
Epoch 39: train loss: 1.143343448638916, test loss: 1.1296850442886353
Epoch 40: train loss: 1.1372761726379395, test loss: 1.1229254007339478
Epoch 41: train loss: 1.1313499212265015, test loss: 1.116359829902649
Epoch 42: train loss: 1.1256024837493896, test loss: 1.110032081604004
Epoch 43: train loss: 1.120069980621338, test loss: 1.103980302810669
Epoch 44: train loss: 1.114783525466919, test loss: 1.0982334613800049
Epoch 45: train loss: 1.1097666025161743, test loss: 1.0928106307983398
Epoch 46: train loss: 1.1050351858139038, test loss: 1.087720513343811
Epoch 47: train loss: 1.1005953550338745, test loss: 1.0829604864120483
Epoch 48: train loss: 1.0964443683624268, test loss: 1.0785179138183594
Epoch 49: train loss: 1.092571020126342, test loss: 1.0743725299835205
Epoch 50: train loss: 1.0889568328857422, test loss: 1.070497989654541
Epoch 51: train loss: 1.085578441619873, test loss: 1.0668634176254272
Epoch 52: train loss: 1.0824092626571655, test loss: 1.0634371042251587
Epoch 53: train loss: 1.0794211626052856, test loss: 1.0601871013641357
Epoch 54: train loss: 1.0765857696533203, test loss: 1.05708312988281254
Epoch 55: train loss: 1.0738768577575684, test loss: 1.0540977716445923
```

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Epoch 56: train loss: 1.0712696313858032, test loss: 1.0512064695358276
Epoch 57: train loss: 1.0687427520751953, test loss: 1.048388123512268
Epoch 58: train loss: 1.0662777423858643, test loss: 1.04562555674362183
Epoch 59: train loss: 1.0638591051101685, test loss: 1.0429047346115112
Epoch 60: train loss: 1.0614745616912842, test loss: 1.0402146577835083
Epoch 61: train loss: 1.0591148138046265, test loss: 1.0375474691390991
Epoch 62: train loss: 1.0567727088928223, test loss: 1.0348975658416748
Epoch 63: train loss: 1.0544438362121582, test loss: 1.0322619676589966
Epoch 64: train loss: 1.0521254539489746, test loss: 1.029639482498169
Epoch 65: train loss: 1.0498168468475342, test loss: 1.0270298719406128
Epoch 66: train loss: 1.0475186109542847, test loss: 1.0244351625442505
Epoch 67: train loss: 1.0452322959899902, test loss: 1.0218578577041626
Epoch 68: train loss: 1.0429604053497314, test loss: 1.0193008184432983
Epoch 69: train loss: 1.0407061576843262, test loss: 1.0167675018310547
Epoch 70: train loss: 1.0384726524353027, test loss: 1.0142618417739868
Epoch 71: train loss: 1.0362639427185059, test loss: 1.0117875337600708
Epoch 72: train loss: 1.0340828895568848, test loss: 1.009347677230835
Epoch 73: train loss: 1.0319329500198364, test loss: 1.0069453716278076
Epoch 74: train loss: 1.02981698513031, test loss: 1.0045831203460693
Epoch 75: train loss: 1.027737021446228, test loss: 1.0022624731063843
Epoch 76: train loss: 1.025694727897644, test loss: 0.9999845623970032
Epoch 77: train loss: 1.023691177368164, test loss: 0.9977501034736633
Epoch 78: train loss: 1.0217267274856567, test loss: 0.9955589175224304
Epoch 79: train loss: 1.0198006629943848, test loss: 0.9934101104736328
Epoch 80: train loss: 1.0179123878479004, test loss: 0.9913025498390198
Epoch 81: train loss: 1.0160605907440186, test loss: 0.9892343878746033
Epoch 82: train loss: 1.0142436027526855, test loss: 0.9872041344642639
Epoch 83: train loss: 1.0124592781066895, test loss: 0.9852093458175659
Epoch 84: train loss: 1.0107054710388184, test loss: 0.9832480549812317
Epoch 85: train loss: 1.0089800357818604, test loss: 0.9813182950019836
Epoch 86: train loss: 1.0072808265686035, test loss: 0.979417622089386
Epoch 87: train loss: 1.0056060552597046, test loss: 0.9775449633598328
Epoch 88: train loss: 1.0039535760879517, test loss: 0.9756982326507568
Epoch 89: train loss: 1.0023220777511597, test loss: 0.973876416683197
Epoch 90: train loss: 1.0007102489471436, test loss: 0.9720785021781921
Epoch 91: train loss: 0.9991170763969421, test loss: 0.9703035950660706
Epoch 92: train loss: 0.9975417852401733, test loss: 0.9685513377189636
Epoch 93: train loss: 0.995983898639679, test loss: 0.9668214321136475
Epoch 94: train loss: 0.9944433569908142, test loss: 0.9651136994361877
Epoch 95: train loss: 0.9929198622703552, test loss: 0.9634279012680054
Epoch 96: train loss: 0.991413414478302, test loss: 0.9617642164230347
Epoch 97: train loss: 0.9899240732192993, test loss: 0.9601227641105652
Epoch 98: train loss: 0.9884520173072815, test loss: 0.9585034847259521
Epoch 99: train loss: 0.9869973659515381, test loss: 0.9569063782691956
Epoch 100: train loss: 0.9855603575706482, test loss: 0.9553313255310059
Epoch 101: train loss: 0.9841408729553223, test loss: 0.9537783861160278
Epoch 102: train loss: 0.9827388525009155, test loss: 0.9522472620010376
Epoch 103: train loss: 0.9813545346260071, test loss: 0.9507377743721008
Epoch 104: train loss: 0.979987621307373, test loss: 0.9492495556013489
Epoch 105: train loss: 0.9786379933357239, test loss: 0.9477823376655579
Epoch 106: train loss: 0.9773052334785461, test loss: 0.9463356733322144
Epoch 107: train loss: 0.9759894013404846, test loss: 0.9449091553688049
Epoch 108: train loss: 0.9746898412704468, test loss: 0.9435024857521057
Epoch 109: train loss: 0.9734064340591431, test loss: 0.9421150088310242
Epoch 110: train loss: 0.9721388220787048, test loss: 0.9407463669776917
Epoch 111: train loss: 0.9708864688873291, test loss: 0.9393962025642395
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Epoch 112: train loss: 0.9696492552757263, test loss: 0.9380638599395752
Epoch 113: train loss: 0.9684266448020935, test loss: 0.936749279499054
Epoch 114: train loss: 0.9672186374664307, test loss: 0.9354517459869385
Epoch 115: train loss: 0.9660245776176453, test loss: 0.9341713786125183
Epoch 116: train loss: 0.9648443460464478, test loss: 0.9329072833061218
Epoch 117: train loss: 0.9636777639389038, test loss: 0.9316596388816833
Epoch 118: train loss: 0.9625244140625, test loss: 0.9304280877113342
Epoch 119: train loss: 0.9613842964172363, test loss: 0.929212212562561
Epoch 120: train loss: 0.9602571129798889, test loss: 0.9280120730400085
Epoch 121: train loss: 0.9591426253318787, test loss: 0.9268272519111633
Epoch 122: train loss: 0.9580408334732056, test loss: 0.9256576299667358
Epoch 123: train loss: 0.9569514989852905, test loss: 0.9245027899742126
Epoch 124: train loss: 0.9558745622634888, test loss: 0.9233630299568176
Epoch 125: train loss: 0.9548097252845764, test loss: 0.9222379326820374
Epoch 126: train loss: 0.9537568688392639, test loss: 0.9211271405220032
Epoch 127: train loss: 0.9527159929275513, test loss: 0.9200307726860046
Epoch 128: train loss: 0.9516867995262146, test loss: 0.9189483523368835
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Epoch 137: train loss: 0.9429258704185486, test loss: 0.9098079800605774
Epoch 138: train loss: 0.9420052170753479, test loss: 0.9088554382324219
Epoch 139: train loss: 0.9410948157310486, test loss: 0.9079148173332214
Epoch 140: train loss: 0.9401940107345581, test loss: 0.9069859385490417
Epoch 141: train loss: 0.9393030405044556, test loss: 0.9060683250427246
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Epoch 143: train loss: 0.9375492334365845, test loss: 0.9042671918869019
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Epoch 146: train loss: 0.9349879622459412, test loss: 0.9016466736793518
Epoch 147: train loss: 0.9341520667076111, test loss: 0.900794267654419
Epoch 148: train loss: 0.9333248138427734, test loss: 0.8999519944190979
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Epoch 156: train loss: 0.9270071387290955, test loss: 0.8935609459877014
Epoch 157: train loss: 0.9262531399726868, test loss: 0.8928031325340271
Epoch 158: train loss: 0.9255066514015198, test loss: 0.8920539021492004
Epoch 159: train loss: 0.9247677326202393, test loss: 0.8913131952285767
Epoch 160: train loss: 0.9240362644195557, test loss: 0.8905807733535767
Epoch 161: train loss: 0.9233119487762451, test loss: 0.8898566365242004
Epoch 162: train loss: 0.9225947856903076, test loss: 0.8891404867172241
Epoch 163: train loss: 0.9218847155570984, test loss: 0.8884322643280029
Epoch 164: train loss: 0.9211814999580383, test loss: 0.8877318501472473
Epoch 165: train loss: 0.920485258102417, test loss: 0.8870392441749573
Epoch 166: train loss: 0.9197956919670105, test loss: 0.8863541483879089
Epoch 167: train loss: 0.9191129207611084, test loss: 0.8856765627861023
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Epoch 168: train loss: 0.9184366464614868, test loss: 0.8850062489509583
Epoch 169: train loss: 0.9177669286727905, test loss: 0.8843432068824768
Epoch 170: train loss: 0.9171038269996643, test loss: 0.8836872577667236
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Epoch 173: train loss: 0.9151515960693359, test loss: 0.8817611932754517
Epoch 174: train loss: 0.9145131707191467, test loss: 0.8811327219009399
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Epoch 177: train loss: 0.9126334190368652, test loss: 0.8792866468429565
Epoch 178: train loss: 0.9120185971260071, test loss: 0.8786841630935669
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Epoch 180: train loss: 0.910805881023407, test loss: 0.8774976134300232
Epoch 181: train loss: 0.9102079272270203, test loss: 0.8769136667251587
Epoch 182: train loss: 0.9096154570579529, test loss: 0.8763356804847717
Epoch 183: train loss: 0.9090284109115601, test loss: 0.875763475894928
Epoch 184: train loss: 0.9084467887878418, test loss: 0.8751972317695618
Epoch 185: train loss: 0.9078702330589294, test loss: 0.874636709690094
Epoch 186: train loss: 0.9072992205619812, test loss: 0.8740818500518799
Epoch 187: train loss: 0.9067331552505493, test loss: 0.8735326528549194
Epoch 188: train loss: 0.9061723351478577, test loss: 0.8729888796806335
Epoch 189: train loss: 0.9056164622306824, test loss: 0.8724507689476013
Epoch 190: train loss: 0.9050655961036682, test loss: 0.8719177842140198
Epoch 191: train loss: 0.9045195579528809, test loss: 0.8713902831077576
Epoch 192: train loss: 0.9039785861968994, test loss: 0.870867908000946
Epoch 193: train loss: 0.9034422039985657, test loss: 0.8703508973121643
Epoch 194: train loss: 0.9029107689857483, test loss: 0.8698387742042542
Epoch 195: train loss: 0.9023838639259338, test loss: 0.8693318367004395
Epoch 196: train loss: 0.9018617272377014, test loss: 0.8688297867774963
Epoch 197: train loss: 0.9013442397117615, test loss: 0.8683326840400696
Epoch 198: train loss: 0.9008310437202454, test loss: 0.8678403496742249
Epoch 199: train loss: 0.9003225564956665, test loss: 0.8673529028892517
Epoch 200: train loss: 0.8998184204101562, test loss: 0.866870105266571
Epoch 201: train loss: 0.8993186950683594, test loss: 0.8663920760154724
Epoch 202: train loss: 0.8988232612609863, test loss: 0.8659185767173767
Epoch 203: train loss: 0.8983321189880371, test loss: 0.8654496073722839
Epoch 204: train loss: 0.8978452086448669, test loss: 0.8649852275848389
Epoch 205: train loss: 0.8973625898361206, test loss: 0.8645251393318176
Epoch 206: train loss: 0.896884024143219, test loss: 0.8640694618225098
Epoch 207: train loss: 0.8964096307754517, test loss: 0.8636181354522705
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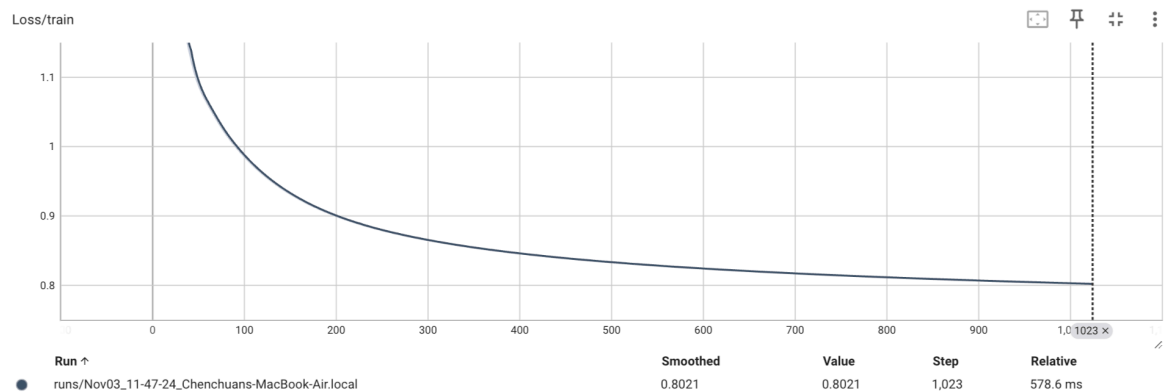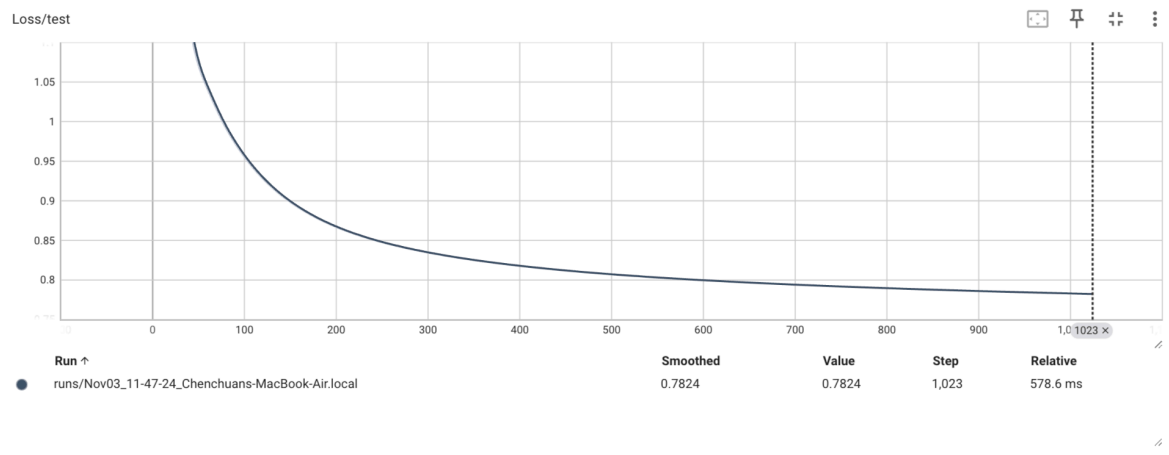
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Epoch 978: train loss: 0.8036746382713318, test loss: 0.7836562395095825
Epoch 979: train loss: 0.8036374449729919, test loss: 0.7836273312568665
Epoch 980: train loss: 0.8036001324653625, test loss: 0.7835984230041504
Epoch 981: train loss: 0.80356293691670227, test loss: 0.7835693955421448
Epoch 982: train loss: 0.8035259246826172, test loss: 0.7835405468940735
Epoch 983: train loss: 0.8034889101982117, test loss: 0.7835118174552917
Epoch 984: train loss: 0.8034518957138062, test loss: 0.7834829688072205
Epoch 985: train loss: 0.8034150004386902, test loss: 0.7834543585777283
Epoch 986: train loss: 0.8033780455589294, test loss: 0.7834256887435913
Epoch 987: train loss: 0.803341269493103, test loss: 0.7833970785140991
Epoch 988: train loss: 0.8033044934272766, test loss: 0.7833685874938965
Epoch 989: train loss: 0.8032678365707397, test loss: 0.7833399176597595
Epoch 990: train loss: 0.8032311201095581, test loss: 0.7833115458488464
Epoch 991: train loss: 0.8031947612762451, test loss: 0.7832830548286438
Epoch 992: train loss: 0.803158164024353, test loss: 0.7832546830177307
Epoch 993: train loss: 0.8031217455863953, test loss: 0.7832263708114624
Epoch 994: train loss: 0.8030853271484375, test loss: 0.7831981182098389
Epoch 995: train loss: 0.8030489087104797, test loss: 0.7831698060035706
Epoch 996: train loss: 0.8030126094818115, test loss: 0.783141553401947
Epoch 997: train loss: 0.8029763102531433, test loss: 0.783113420009613
Epoch 998: train loss: 0.8029401898384094, test loss: 0.7830852270126343
Epoch 999: train loss: 0.8029041290283203, test loss: 0.7830572724342346
Epoch 1000: train loss: 0.802868127822876, test loss: 0.7830290794372559
Epoch 1001: train loss: 0.8028320074081421, test loss: 0.7830011248588562
Epoch 1002: train loss: 0.8027960062026978, test loss: 0.7829731106758118
Epoch 1003: train loss: 0.8027601838111877, test loss: 0.7829451560974121
Epoch 1004: train loss: 0.8027243614196777, test loss: 0.7829173803329468
Epoch 1005: train loss: 0.8026884198188782, test loss: 0.7828894853591919
Epoch 1006: train loss: 0.8026527166366577, test loss: 0.7828617095947266
Epoch 1007: train loss: 0.8026171922683716, test loss: 0.782833993434906
```

```
Epoch 1008: train loss: 0.8025814294815063, test loss: 0.7828063368797302
Epoch 1009: train loss: 0.8025459051132202, test loss: 0.7827785611152649
Epoch 1010: train loss: 0.8025104403495789, test loss: 0.7827509045600891
Epoch 1011: train loss: 0.8024749755859375, test loss: 0.7827233672142029
Epoch 1012: train loss: 0.8024395108222961, test loss: 0.7826959490776062
Epoch 1013: train loss: 0.802042248725891, test loss: 0.7826683521270752
Epoch 1014: train loss: 0.8023689985275269, test loss: 0.7826409935951233
Epoch 1015: train loss: 0.802333652973175, test loss: 0.7826134562492371
Epoch 1016: train loss: 0.8022984862327576, test loss: 0.7825860381126404
Epoch 1017: train loss: 0.8022633194923401, test loss: 0.7825587391853333
Epoch 1018: train loss: 0.8022282123565674, test loss: 0.7825313806533813
Epoch 1019: train loss: 0.8021932244300842, test loss: 0.7825042009353638
Epoch 1020: train loss: 0.8021582961082458, test loss: 0.7824769616127014
Epoch 1021: train loss: 0.8021233081817627, test loss: 0.7824499011039734
Epoch 1022: train loss: 0.8020884990692139, test loss: 0.7824227213859558
Epoch 1023: train loss: 0.8020536303520203, test loss: 0.782395601272583
```

In [3]:
```python
from IPython.display import Image
Image(filename='/Users/chuan/Desktop/c815_course_hws/hw8/losses.png', width=
```

Out[3]:

Loss/test

Run ↑		Smoothed	Value	Step	Relative
●	runs/Nov03_11-47-24_Chenchuans-MacBook-Air.local	0.7824	0.7824	1,023	578.6 ms

Loss/train

Run ↑		Smoothed	Value	Step	Relative
●	runs/Nov03_11-47-24_Chenchuans-MacBook-Air.local	0.8021	0.8021	1,023	578.6 ms

In [8]:
```python
# Plot the decision boundary

# set min and max values and give it some padding
x_min, x_max = -10, 10
y_min, y_max = -15, 10
xx, yy = np.meshgrid(np.arange(x_min, x_max, 0.01),
                     np.arange(y_min, y_max, 0.01))

# convert the grid to a tensor and predict class labels for each point
```
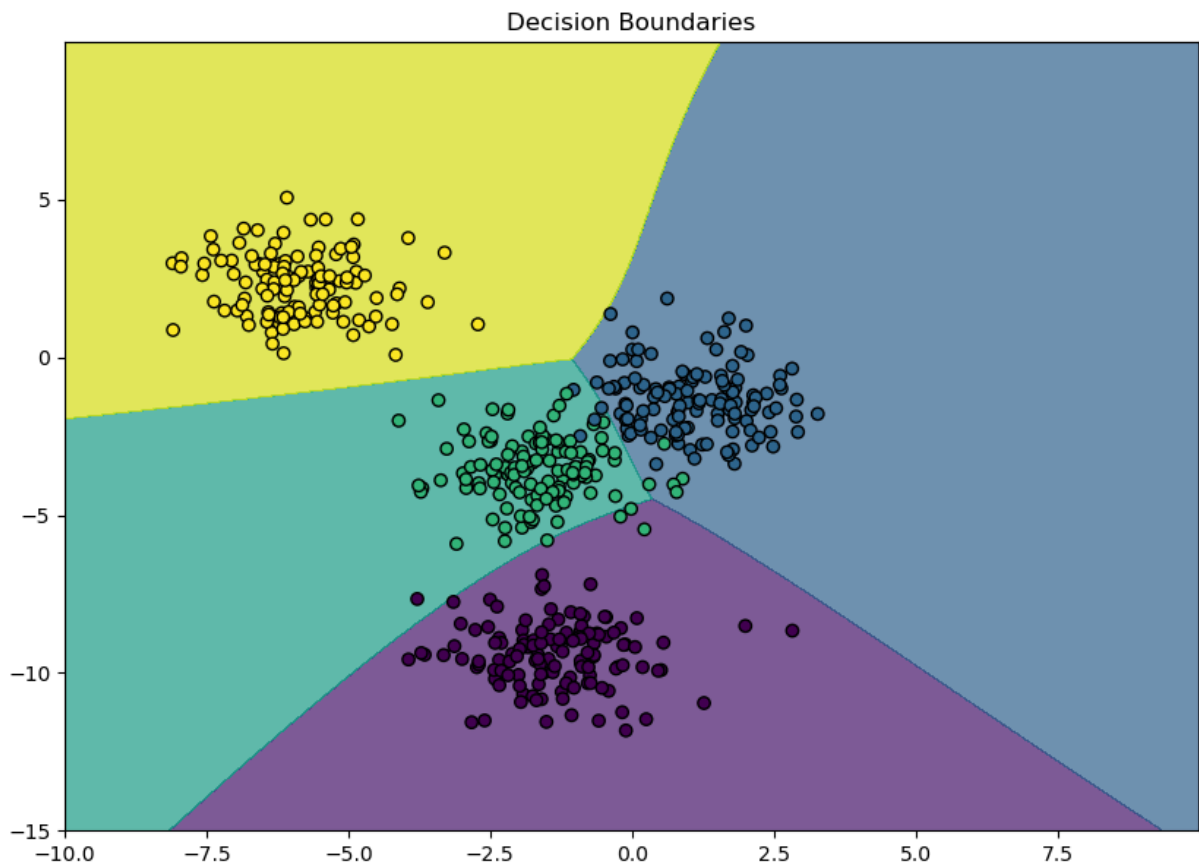
```python
grid = torch.Tensor(np.c_[xx.ravel(), yy.ravel()])
model.eval()  # set model to evaluation mode
# disable gradient computation
with torch.no_grad():
    Z = model(grid).argmax(dim=1)
# convert the predictions back to numpy array
Z = Z.numpy().reshape(xx.shape)

plt.figure(figsize=(10, 7))
plt.contourf(xx, yy, Z, alpha=0.7)
plt.scatter(X[:, 0], X[:, 1], c=y, edgecolors='k')
plt.xlim(xx.min(), xx.max())
plt.ylim(yy.min(), yy.max())
plt.title('Decision Boundaries')
plt.show()
```


Decision Boundaries

In [ ]: