STAT 33B Homework 4

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This homework is due **Apr 2, 2021** by 11:59pm PT.

Homeworks are graded for correctness.

As you work, write your answers in this notebook. Answer questions with complete sentences, and put code in code chunks. You can make as many new code chunks as you like.

Please do not delete the exercises already in this notebook, because it may interfere with our grading tools.

You need to submit your work in two places:

- Submit this Rmd file with your edits on bCourses.
- Knit and submit the generated PDF file on Gradescope.

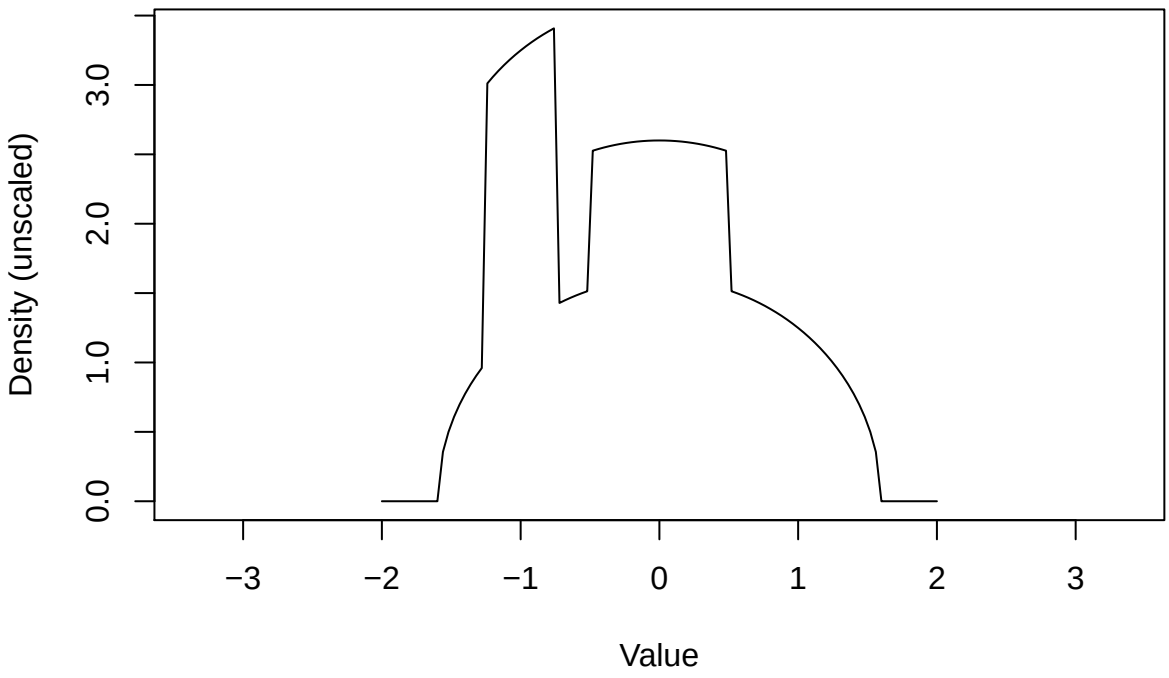
Rejection Sampling

In Homework 1, you saw that R provides functions to sample from a variety of well-known distributions. In particular, we used `runif()` to generate samples from a (continuous) uniform distribution.

What if you want to sample from a distribution that's not well-known?

For example, suppose you want to sample from this distribution on -1.6 to 1.6:

```
dhand = function(x) {
  y = numeric(length(x))
  i = -1.6 < x & x < 1.6
  y[i] = sqrt(2.56 - x[i]^2) + dunif(x[i], -1.25, -0.75) +
    dunif(x[i], -0.5, 0.5)

  y
}

curve(dhand, -2, 2, xlab = "Value", ylab = "Density (unscaled)", asp = 1)
```



Let's call this distribution the "hand" distribution, since it resembles the silhouette of a person (or robot) raising their hand.

One way to sample from distributions that are not well-known by using a statistical technique called *rejection sampling*.

The idea is to choose a rectangle that completely encloses the target density curve, and then uniformly sample points within the rectangle. If a point falls below the density curve, then the point is accepted and its x-coordinate is a new sample value. If a point falls above the density curve, then it is rejected (and discarded). This produces the correct distribution because relatively more points will be accepted in places where the density curve is taller.

The bottom side of the enclosing rectangle should always be on the line `y = 0`.

The exact steps in rejection sampling are:

1. Uniformly sample (x, y) coordinates for a candidate point.
2. Test whether the y coordinate is below the target density curve. If it is, then the x coordinate is a new sample value. If it isn't, then the x coordinate is discarded.
3. Repeat steps 1-2 until the desired number of sample values is reached.

Part 1

What's an appropriate enclosing rectangle for the hand distribution's density curve?

Show the rectangle by:

1. Using the call to `curve` above

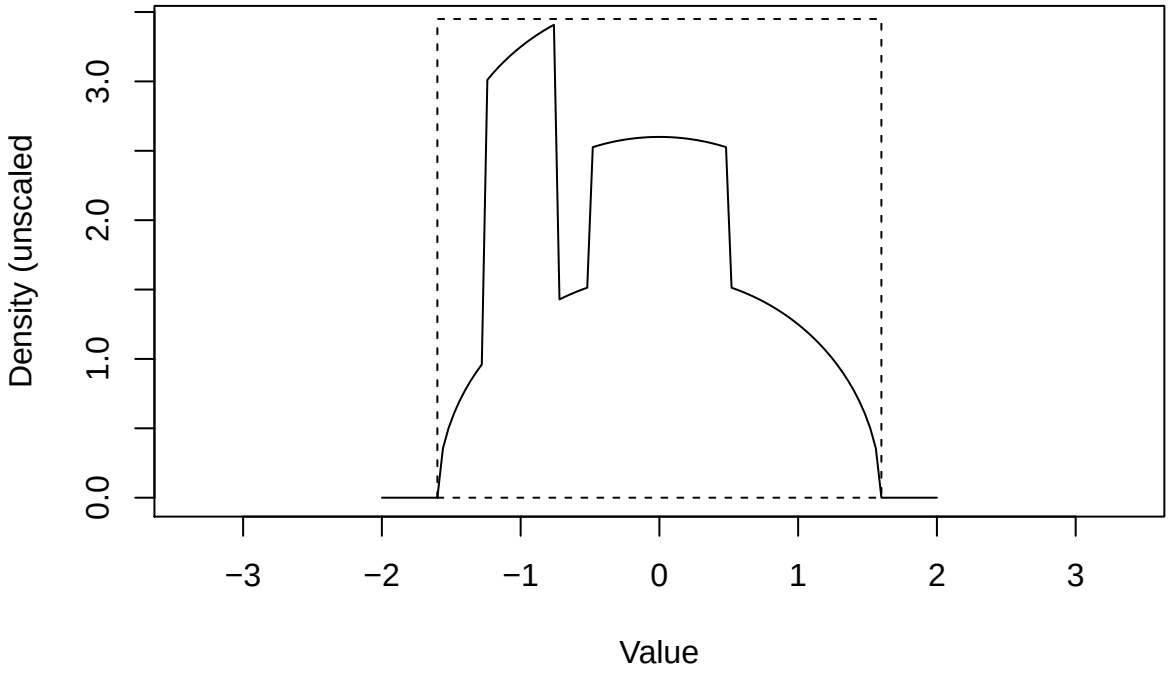
2. Followed by a call to `rect` (a base R plotting function), to superimpose the rectangle on our density curve plot.

Use the argument `lty = "dashed"` in the call to `rect` so that the rectangle is visually distinct from the curve.

There are many possible answers to this question, but smaller rectangles are more efficient for rejection sampling.

YOUR ANSWER GOES HERE:

```
curve(dhand, -2, 2, xlab = "Value", ylab = "Density (unscaled", asp = 1)
rect(-1.6, 0, 1.6, 3.45, lty = "dashed")
```



Part 2

Write a function `rhand` that uses rejection sampling to return a vector of `n` samples from the hand distribution. Your function should have a parameter `n` with default argument `100`.

Use the `dhand()` function provided above as the target density curve.

Test that your function runs without error for `n` equal to 10, 100, and 1000.

Hint: Consider pre-allocation, vector operations, and other ways that may increase the efficiency of your code.

Think about: Will you generate 1 observation at a time, or more? If considering pre-allocation vs not using pre-allocation, how will run times compare between small **n** *and large* **n***?*

YOUR ANSWER GOES HERE:

```
rhand = function(n = 100) {
   sample = numeric(n)
   while (n > 0) {
      x = runif(1, -1.6, 1.6)
      y = runif(1, 0, 3.45)
      if (dhand(x) > y) {
         sample[n] = x
         n = n - 1
      }
   }
   sample
}

rhand(10)
```

```
##  [1]  0.55442991 -0.84134540 -0.92410999 -0.92848246  0.07080948  0.54382766
##  [7]  0.45206755 -1.09295344  0.03045839  1.41284478
```

```
rhand()
```

```
##   [1] -0.449076132  1.018582825 -0.082861597 -0.767746834 -0.304709504
##   [6]  0.770387706  0.589917705 -0.565787480 -1.017662670 -1.114158032
##  [11] -0.589224662  0.405858199 -1.578316111  0.075992776 -0.311484610
##  [16] -0.630910403 -0.356180669 -1.054677654 -0.404483191  0.154740679
##  [21]  1.010905570  0.152435221  0.439471539 -1.074473476 -1.208335038
##  [26] -1.161089610  0.024270459 -1.351678987  0.423002043 -1.023861658
##  [31] -1.360986484 -0.287735891  1.414538425  0.603798633 -1.007025668
##  [36]  0.388591609  0.086897643  0.672300430  1.242391612 -0.202366298
##  [41] -1.157019769  0.016330950 -0.358553006  1.454976687 -0.788958088
##  [46] -0.265638874 -0.214999694  1.372529361  0.157387777 -0.755865446
##  [51] -0.084168904 -0.017328534  0.073094222  0.342349196  0.001367667
##  [56]  0.353827935  0.256549818  0.352370396  0.292166088 -1.314889182
##  [61] -0.879081386 -1.057418943  1.509932788 -0.775631230  0.368457688
##  [66]  0.825279239 -0.317370705 -0.132175887  0.468954916 -1.527702083
##  [71] -1.235670695 -0.517236115  0.369295587  0.140157422 -0.797762979
##  [76]  0.296302851  0.778613783  0.100977378  0.357351173  0.483931931
##  [81] -0.464992982  0.775731088  1.010511088  0.958395464  0.731913451
##  [86]  0.859780227 -0.137793542  0.254447352 -1.337672982 -0.460321373
##  [91] -0.092922060 -1.003036166  0.297930980 -0.513388038  0.260094252
##  [96] -0.517621307 -0.934910471 -0.208175189 -1.127748541  0.259025258
```

```
rhand(1000)
```

```
##    [1]  0.3884690806 -1.0939820170 -0.6532969929 -0.8010065414  1.1017525591
##    [6]  0.0471262425 -0.7272890575 -0.1296014689 -1.2492397517  0.5933604077
##   [11] -0.8976578467  1.3745214075  0.2025280863  0.3900722750  0.2261804663
##   [16] -1.2714767985 -0.6012822025  0.1342581414  1.5278084680 -0.9702987120
##   [21] -0.6832672238 -0.2719849832 -1.2382133253 -1.1799454287  0.5867273211
```

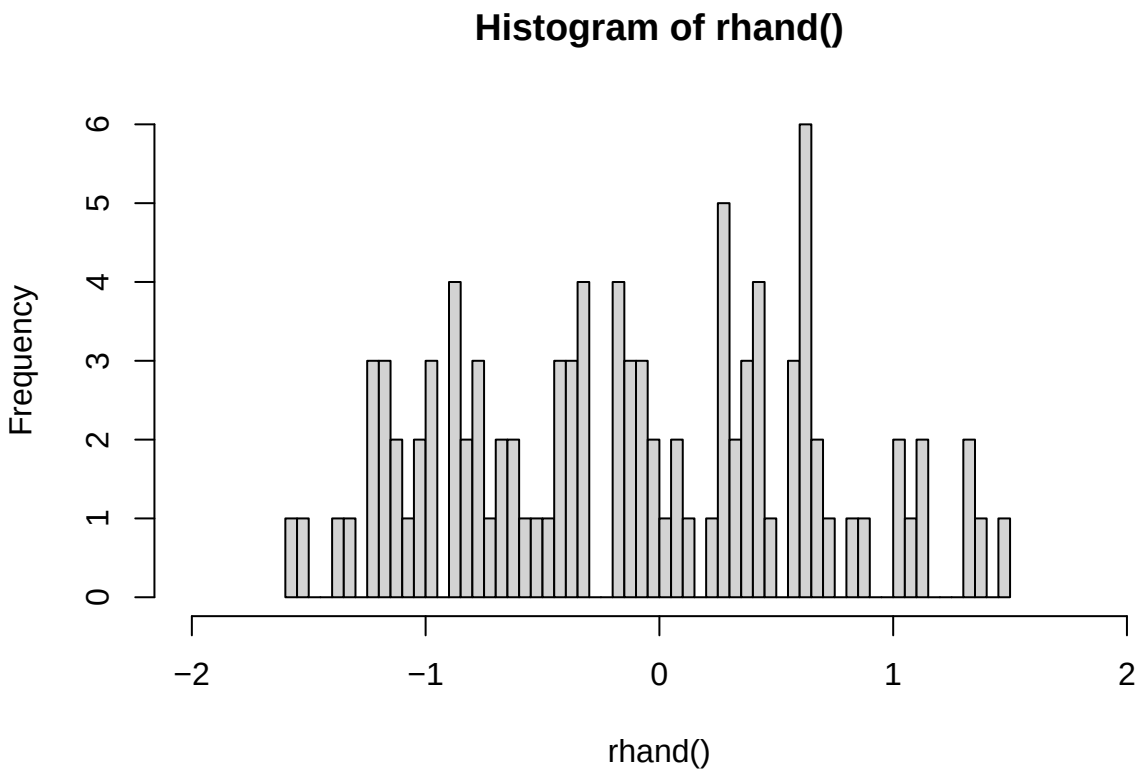
```
##   [26] -0.9228711478 -0.7527799845  0.5672154233 -1.1274525128 -0.7790021546
##   [31] -0.8151146002  0.4410484068 -0.1894476883 -0.3692769662  0.4535670288
##   [36]  0.3756786391 -0.0669629179 -0.8020068899 -0.1222465657 -0.2323676057
##   [41] -0.4807995372  0.2837709136  0.9308026582 -1.0296672896  0.1217439838
##   [46] -0.8767980881 -0.3112325564 -1.1087538928  0.4571158573  0.2056947157
##   [51] -0.4967374176 -0.1030467115  0.7764218435  0.7715362407 -0.3706393525
##   [56] -0.0029160440  1.2202345744  0.7456276163 -0.2964883581 -1.1498811357
##   [61] -0.0301620334  0.0527880393 -0.0818105534 -0.5752169840  0.3540186681
##   [66]  0.8381540857  0.9384515576 -1.0624927305 -0.9566995777 -0.3621432826
##   [71]  0.5730483629  0.3528904609  0.8945544243  1.1989003569  0.8922746919
##   [76] -0.4041496783  0.3198011562  0.0026751041 -0.9992293321 -1.4377820291
##   [81] -0.3729999132  0.4708814003 -0.9995466255 -0.8691518836  0.1833598547
##   [86] -1.0857864372  0.3323422290 -1.2284894109 -1.3987902209 -0.4381198771
##   [91] -1.3464411147 -0.1994565509 -0.2585715771 -1.0317151919 -1.3113894790
##   [96] -1.1005656444  0.5834581248 -0.1858768068  0.1659886032  0.4670167617
##  [101] -1.0084507883  1.2641216911  0.4752912834 -0.4369257398  1.3876322925
##  [106] -0.6571341842  0.7943477809  1.0427241020  0.3128329746  0.4922095552
##  [111]  0.7159014858 -1.1497010320  1.0237118691  0.9755790107  0.4092315070
##  [116]  0.2332743086 -1.2360531218 -1.2184494369 -0.8452797934 -0.3627371408
##  [121] -0.1297359429  1.1972405657  0.8597987041  1.5768874891  0.2169007100
##  [126] -1.3787348241  0.3437857404  1.2540699646 -0.6663783498 -1.1872480385
##  [131] -0.2460084029  0.6993923411  0.1815347858  0.0920198545 -0.7539322831
##  [136] -1.1719020583 -0.4525923967 -0.5870287642  0.3505205743  1.0881026827
##  [141]  0.2689647742 -0.9691420481  0.7315845840 -0.8975674890 -0.1872688927
##  [146] -1.0968104862 -0.0337892152  0.2955193855  0.0391387716 -0.4320138797
##  [151]  1.2390645005  0.4688141793 -1.4584870860  1.4718902148  0.6647121869
##  [156] -0.9474796697 -1.0807930581 -1.3442252927  0.4532299802 -1.0422539175
##  [161] -0.9785657696 -0.7176411875  1.0685262814 -0.2983659357 -1.0468768440
##  [166]  0.6129207022 -0.6810087070  1.4534639806  0.3353695475  0.4396303289
##  [171]  0.3604578286  0.3843795076 -0.9776332773  0.7324680284  0.2590675287
##  [176] -1.0771316141 -0.9543450512 -0.3469031408 -0.8051237494  0.4780437239
##  [181]  0.2800801605 -1.4484855823 -0.2436490260 -0.4530664682  0.4833481699
##  [186]  0.7343821406 -1.1876970641  1.1096255764  0.1572953194  1.4397751056
##  [191]  0.7862319849  0.5119845375  0.3302597597 -0.8933618575 -0.4299314924
##  [196] -0.8830146894  0.3151381105  1.1128683329 -1.5199611448  0.9871560305
##  [201] -1.3111988425  0.8212758891  1.3909937590 -1.1920596458  0.6005971603
##  [206]  0.1867776521 -0.4131059930 -0.3783682689  0.0618116088  0.1009306163
##  [211] -1.4893430933 -0.2002587825  0.3471845336 -0.7407118119 -0.9117806941
##  [216]  0.7015067905  0.4306961522  1.1078096345 -0.9352916673  0.1984458506
##  [221] -1.3102379754  0.5171374992  0.5810036995 -0.2709831610  0.0952585004
##  [226] -1.0362793192  0.1869757578 -0.7160968892 -0.8461456947 -1.1832347706
##  [231] -0.2938320063 -1.2300228626 -0.2812764190  0.0888332918  0.5935700879
##  [236] -0.1422799066 -0.3554012671 -0.1685465567 -0.4424162902  0.4457336590
##  [241] -0.3134190805 -1.0088868558  0.3600572668  0.2820486553  0.6128351487
##  [246]  0.2411162965 -0.1308814444 -1.0034066513 -0.2164768368 -1.1487620212
##  [251] -0.9979484029 -0.4939537540 -0.9618533008  0.0199721396 -0.7958444692
##  [256] -0.9484723583 -1.3172811158 -0.8850081757 -0.9843939498 -0.2321292087
##  [261]  0.1743195906 -0.5813901186  0.3438392021  0.2875749603  0.0022950351
##  [266] -1.1340626195  0.4251925975 -0.9442299381  1.2162975639 -0.8354272738
##  [271] -0.3984436005  0.9492650434 -0.6915763393 -0.1912069306  0.7156667441
##  [276] -0.9522154458 -0.3172855973  1.4209962286  0.7886462897 -1.0775550306
##  [281] -0.9643348835 -0.1269996025 -0.4673646100  1.4756787792  1.0238256514
##  [286] -0.3969490446  0.5612037368  0.8033436961 -1.1870489158  0.5383068629
##  [291] -1.2645291112 -0.5749280274 -0.0812513843  0.4589417905 -0.9309671812
```

```
##  [296]  1.2901672535 -1.2264201179  0.5598187730  0.7686196819 -0.1839254588
##  [301] -0.6362089381  0.1466151230  0.8818953998 -0.1970236987 -0.4494733736
##  [306] -1.0306792080  1.2074653417  0.2267823212  0.0591038749 -0.9655700289
##  [311] -1.1269978747  0.8483635947 -0.4600557275  0.5678214289 -1.1282953613
##  [316] -0.4843553655 -1.0763939664 -0.3096615866  0.2534604423  1.1709837794
##  [321]  0.2227750435 -1.0445095092 -1.3822434232 -0.5801376469 -0.8500083208
##  [326]  1.4181714401 -0.8498982571 -0.7307594635  0.1300487146 -0.9440130383
##  [331] -0.8362141289 -0.6277626492  0.3153403699 -0.0781900160  1.0414300933
##  [336]  1.4857573994  0.6586159565 -0.8789020695 -0.7798712119 -0.8331887826
##  [341]  0.3153536543 -1.1827272289 -0.9713331819  0.0428596996  0.3918270960
##  [346] -0.3122766428 -0.8004742973 -0.1472229689 -0.0016486645 -0.1254426569
##  [351]  0.5326318756 -0.2598509811 -0.2658038855 -1.5542375214 -0.8074868187
##  [356]  1.3919583812 -1.0630263977 -1.3702945612  0.0106161632  0.0733579725
##  [361]  0.8873165250  0.6014940925 -0.8633816145 -0.8126663625 -0.4146598503
##  [366] -1.0155616239 -0.2162439324 -0.1475196064  0.6198067501 -1.2943940274
##  [371] -1.4992301524  0.0851660617  0.7430374585 -0.7806972392 -0.7712296017
##  [376] -0.9872901186 -0.1828483596 -0.7351640090 -0.1166189909 -0.4579325497
##  [381] -0.6822097756 -0.4523149841  0.4097964659  0.3773809738 -1.0669140622
##  [386]  0.2876472220  0.3852240942  0.3630341932 -0.5930386581 -0.8180364445
##  [391]  0.0892546780 -0.0150956504  0.1059571810  0.4694640040  0.6186930463
##  [396]  0.2799620859 -1.0609468155 -1.3382805482  0.1882042572 -0.8935951069
##  [401]  1.3772686116  0.2116419695  0.3881114818  1.2075290129 -0.9207325540
##  [406]  1.1732440121 -0.9722973295 -0.8637249216  0.3849699765 -1.1899655819
##  [411] -0.0170885697  1.3422115289 -0.4372085117  0.0108936086 -1.1294560447
##  [416]  0.3845263392 -1.5922069080  1.5707923144  0.2349813588 -0.8738005482
##  [421]  1.0517318241 -1.1097336642  0.9351641491 -0.8756082274  0.9852828287
##  [426] -0.2890480287  0.5531726226  0.4651920363 -0.5814419575  0.0829468116
##  [431]  0.0238824017 -0.7819290802  0.6396552369 -0.1074053012 -0.4966265850
##  [436] -0.9158525944 -0.5146803722 -0.4501450911 -0.8556860261  0.1633305110
##  [441]  0.2787585445  0.6008644752  1.2620757028 -0.7907368749  0.9103159495
##  [446]  0.2274153471 -0.8237756677 -0.3886728629 -1.1740447104  0.7421860844
##  [451] -0.9056848846 -1.4463921018  1.1647839047 -0.6504414722 -0.2609431632
##  [456] -1.1078447081  0.0182528809  0.1412655786  0.8543584123 -1.3559381843
##  [461]  0.3393971093  0.1376250476 -0.8460013360  0.3399517901  0.0477979012
##  [466]  0.4711629115 -1.0057788409 -0.2020365454  0.9816792347  1.3483676910
##  [471]  1.4748654924 -0.2055395290  1.2854772098  0.1656480148 -0.6537039347
##  [476] -0.2539033152 -0.3397971779 -1.4903180405  1.5084375352 -0.8095792010
##  [481] -1.3355002552 -1.4342136234 -0.9624860682  0.3169019476 -0.8637455933
##  [486] -0.0625537492 -0.9507281236 -1.2194771171  0.0717490770 -0.8724479705
##  [491]  0.0715220146 -0.1018793613 -0.2969241798  0.0526252553 -0.1944212489
##  [496]  0.8711712703 -0.5993719794 -0.8513384633 -0.9140149996 -0.6776304044
##  [501] -1.0280523665  0.4985108823 -1.0468550935  1.1133761473 -0.4576825432
##  [506]  0.8832151845  0.8522383973  1.2469011582  0.3860765286 -0.2907063141
##  [511] -0.1686399601 -1.2225570925 -0.1504985899 -1.1635559238 -0.3906644374
##  [516]  0.1028725691 -0.4222032383 -0.7579170063  0.3481200643  0.0772437617
##  [521]  0.9614755578 -0.8272066452 -0.8770519577  0.0370872416 -1.2461042896
##  [526]  0.4798588432  1.0783138059 -1.1539130889 -1.0451873943  0.5300137095
##  [531]  0.8984777942 -0.4507078804  0.5983926624 -0.1113730513 -0.8140057549
##  [536] -0.9673733003 -0.9375074580  0.1260812759 -1.4108545676 -0.8715071835
##  [541]  0.0925367042 -1.1750925772  0.4495710835 -0.8679969050 -1.1898397572
##  [546]  0.0444930121  0.3218286470  0.0581017986 -0.3342401139 -1.2452225626
##  [551] -0.2370323330  0.2900821328  0.1748372480 -0.0781325728  0.7801489927
##  [556] -0.4000897743 -0.4035645448 -0.8870919384 -0.1035667010  1.4011880130
##  [561] -0.9517146707 -0.8006539308 -0.1539071441  1.0515276812 -0.1426758610
```

```
##  [566] -1.4723761253  0.4461972229 -0.2750101708 -0.4884019226 -0.9883679025
##  [571] -0.8235076770 -1.2262804851  0.5112106182 -1.1082797661 -1.5492689341
##  [576]  1.3923939049 -0.8718922332 -0.9988633424  0.3260072045  0.6501248546
##  [581] -0.0168433279  0.0789940596  0.4722296052 -1.2238522671 -0.7818655267
##  [586]  1.2937902890  0.3879424185 -0.2194745526  0.9546132870 -0.8968433067
##  [591] -1.0509363823  0.2747517832 -1.1885585047  0.2957092576 -0.3613922045
##  [596] -0.0080845281  0.0004806578 -0.4781155303 -1.1439825170 -1.1962185338
##  [601]  0.8159285575 -0.1696170881  0.0612827279  0.1196787484 -0.3463988476
##  [606]  0.4819854014  1.1859740019 -0.4734792784 -0.3763041280 -0.8262819625
##  [611]  0.9288086928  1.0093393654 -0.3041952655 -0.7505700171  1.5194624417
##  [616] -0.2791875161 -0.5265677452  0.1932767659 -1.0407223724 -0.0773295216
##  [621]  0.0719812289 -0.4368984245  1.0020207025  0.3688814171 -1.1724449873
##  [626]  0.6177971311 -1.2063532636 -1.0783508554 -0.9890206665 -1.4237969778
##  [631] -0.0479950957 -0.4373900563  0.8189828187 -0.8226397015 -0.5129628532
##  [636]  0.5996109687 -1.2322646134  0.0436139233  0.5460300572  0.1588046581
##  [641]  0.7984858871  0.2970125660 -0.9510427356 -1.2634011373 -1.1291604146
##  [646] -0.1752450101 -0.1380529627  0.4915742941 -0.9191685751  1.1424991205
##  [651] -0.9846208140  0.5414467119 -0.3814927690 -0.8209537514 -0.9974424757
##  [656] -0.7366359703  1.4977697104  0.6558275342 -1.0609967917  0.2882346220
##  [661] -0.7231751740  0.2068637885 -0.8477170348 -1.0555033423 -1.1677122630
##  [666] -0.3082199596 -1.0746970356 -0.3950087547 -1.1229799345  0.6913138241
##  [671] -0.6157853626  0.1008998729 -1.2694705777 -0.4229831934  0.2735868424
##  [676] -0.4716529883  0.3603268996 -1.1080389373  0.4862636805  1.3142458886
##  [681]  0.9722212903  0.9274891853 -0.0597282030 -0.1268309429 -0.7926310390
##  [686] -0.4278373003  0.9953507103  0.0193362728  0.3998170644  0.1341350310
##  [691] -0.3542546347 -0.3573366143  0.4003343642  0.4239231490 -0.2739331491
##  [696] -0.2096020818  0.4524216287  0.8246853583  0.9499007829 -0.3872180261
##  [701]  1.4537439875  1.0163125604 -0.5440581769 -0.9146851800  1.1409113936
##  [706] -0.9909892105 -0.2536073387 -0.3078643888 -0.7654097050 -1.0597461477
##  [711] -0.3968238376  1.2329048775  1.3909922242 -0.1025742561  1.5021123946
##  [716] -1.2379010610 -0.2932799451 -0.5253402524 -0.8129431285 -0.8856830329
##  [721]  0.5320112370 -1.1901298307  0.7676612869 -1.2443373226 -0.0071580991
##  [726]  0.1513645753  1.2181417033  1.2846801378  0.8986508742 -0.5007538095
##  [731] -0.8476698764  0.2361636192 -0.8962297350 -1.1772351325 -0.2569730021
##  [736] -1.0953027733 -0.9926201276 -1.1206131086 -0.1420652680 -1.1862340771
##  [741]  0.3468024738 -1.0260543540 -0.3570588857  0.3537334450 -1.0526023813
##  [746]  0.2048130527 -0.3837211460 -0.3637114145  0.6068274692  0.6324103162
##  [751] -0.9498956546  0.0448984370  1.0628081881  0.9585840128 -1.1236698866
##  [756]  0.3005907364  1.2859913655 -0.7245075926 -1.2135805160 -0.7396559604
##  [761]  1.1990536928  1.1806852378  0.3416258879  0.6445102051 -0.9621983081
##  [766]  0.1084589534 -0.8187979423  0.1007053681 -0.5697173901  0.1352169819
##  [771] -1.0538917728 -1.1369731702 -0.7046800435 -1.5465884060  0.7320093647
##  [776] -1.0681909986 -0.9312284142 -0.5073671117 -0.0257949002 -0.4181481950
##  [781]  0.7655492298 -0.7581970267 -0.6723461628  1.3077610917 -0.1520711340
##  [786] -0.9706683122 -1.0461106762  0.7845858909 -0.4281531788  0.0649524353
##  [791] -0.3872924358  0.7034746669 -0.3757382989 -0.3316582859 -0.7873135231
##  [796]  1.2331804760 -1.1040037505 -1.0120955601  0.0933919616 -0.3591822043
##  [801]  1.4700287372 -1.0966257952 -1.4002678350  0.2730333142 -1.0453896247
##  [806]  0.1599125028 -0.9176804475 -0.3356559217 -0.6293657862 -0.2542514175
##  [811]  0.2347720392 -0.4539779842 -0.5430778287 -0.0829678580 -0.0888527900
##  [816] -1.0138447598  0.5997449562 -0.2412549749 -0.5165074170 -0.8460519411
##  [821]  0.9425730623 -0.9428000815 -1.2090863898  0.8711422883  0.4257961281
##  [826] -0.8123476312 -1.5514000542  0.0860925600  0.8456171729 -1.1587469280
##  [831] -0.6930455983  0.1870679185 -0.7480223618 -0.1163171485 -0.9958266646
```

```
##  [836]  0.1702811942  1.1209560409 -0.6106285103  0.5273296736 -0.2867628992
##  [841] -0.4542689182  0.0949535817  0.2086607881 -0.9553704411 -0.9382921383
##  [846] -1.2148447983 -0.1427560449 -0.8145181865  1.5606276222  0.5795228265
##  [851] -0.8316951402 -1.4939147942 -0.1483906463 -0.8855823949  0.4786229581
##  [856]  0.1522558168 -0.6878758937  0.1331516549 -0.7935124047 -0.1216278173
##  [861] -1.0134188525 -0.7661890857 -0.7995014869  0.0629164755  0.9695152745
##  [866]  0.0338747159 -1.2330053411  0.0794263385  0.7620073661  0.0714719087
##  [871]  0.1313289024  0.7808820300 -1.0793445192 -0.6069508158  1.1129778542
##  [876] -0.0746259406 -0.2228290245  1.4280458629  0.5663285337 -1.2170984164
##  [881] -0.2165171497  0.6954068601 -0.8633253939  0.0464235306 -0.4190377481
##  [886] -1.4935154065 -0.1007076286  0.1563133895  0.0219920650 -0.9685240187
##  [891]  0.1972196139  0.5791247249  0.6897813126 -0.2506120905  1.1111250229
##  [896]  1.3468980476  0.9573500067  0.9239666812 -0.9848215058  0.4570149161
##  [901]  0.0117086701 -1.1773282491 -0.4753037989  1.3630443804 -0.9015987650
##  [906]  0.9196336120  0.1570924915 -0.6121232241  0.3915463850 -1.1222005680
##  [911] -0.3892091379  0.1538216174 -0.0532930061  0.8222304456  0.5047386721
##  [916]  0.1560143493  0.7733915642 -1.1729251847 -0.7733143680 -0.1631358445
##  [921] -0.0866887331 -0.3173388749 -0.7179451801  0.7878044263  0.3328621060
##  [926]  0.0193379082 -0.4678864501 -0.9791675605 -0.4460019626  0.0817302294
##  [931] -0.2405043252 -1.0561992131  0.0679871216  1.1054983392  0.0595647484
##  [936]  0.0113708362  1.0741592661  0.6289516084  1.0995929033 -0.2190660365
##  [941] -0.7756894201 -0.4850097008 -0.2380406037  0.0118676372 -0.8000255026
##  [946] -0.9857009992  0.6352931648 -1.2720877402  1.2117862761 -0.3038875043
##  [951]  1.0943165764 -0.8168141328 -0.3049288124 -0.1016927838 -0.8871587753
##  [956] -1.0020286053  0.3986806221 -0.5904467911 -1.0184588343 -0.1801337853
##  [961] -1.4101196483 -0.6944458038  1.2328531958 -0.7931802325 -0.3596183099
##  [966] -0.3788172908  0.5670234039  0.6288488656 -0.9879844695  0.7917497009
##  [971] -0.9024592809  0.1323035792 -0.4110654972 -0.0695816569  0.0989546023
##  [976] -1.1519353196  0.1486635692 -0.4357507758 -1.1439630613 -1.0472748652
##  [981] -0.0930787086 -1.2526938982 -1.2134162620 -0.0961501464  0.6218982287
##  [986] -1.3967180729  0.8108021215  1.5672737777 -0.1287495255 -0.1514123350
##  [991]  0.4930065550  0.0882807530  0.3112006873 -0.8960419811  1.4858913049
##  [996]  0.2989195026  0.0759217843 -0.9800795637  0.2881012529 -0.9336218737
```

```
hist(rhand(), xlim = c(-2, 2), breaks = 50)
```



Part 3

1. Use your `rhand` function to sample 100 points from the hand distribution and plot a histogram of these values. Make sure to call `set.seed` first so that your result is reproducible.

   Hint: You can use base R graphics to plot a histogram for a sample `x` *with* `hist(x, xlim = c(-2, 2))`*.*

2. How does the shape of your estimated density curve compare to the shape of the actual density curve for the hand distribution (see above)?

3. Repeat Parts 1-2 with a sample of 1,000,000 points. Comment on how the new estimated density curve compares to the one from Part 1.

   Note 1: Sampling this many points may take 10-60 seconds (it can take as short as 1 second though). Anything substantially longer than 10-60 seconds means your function is doing something very inefficient and you should consider rewriting your function.

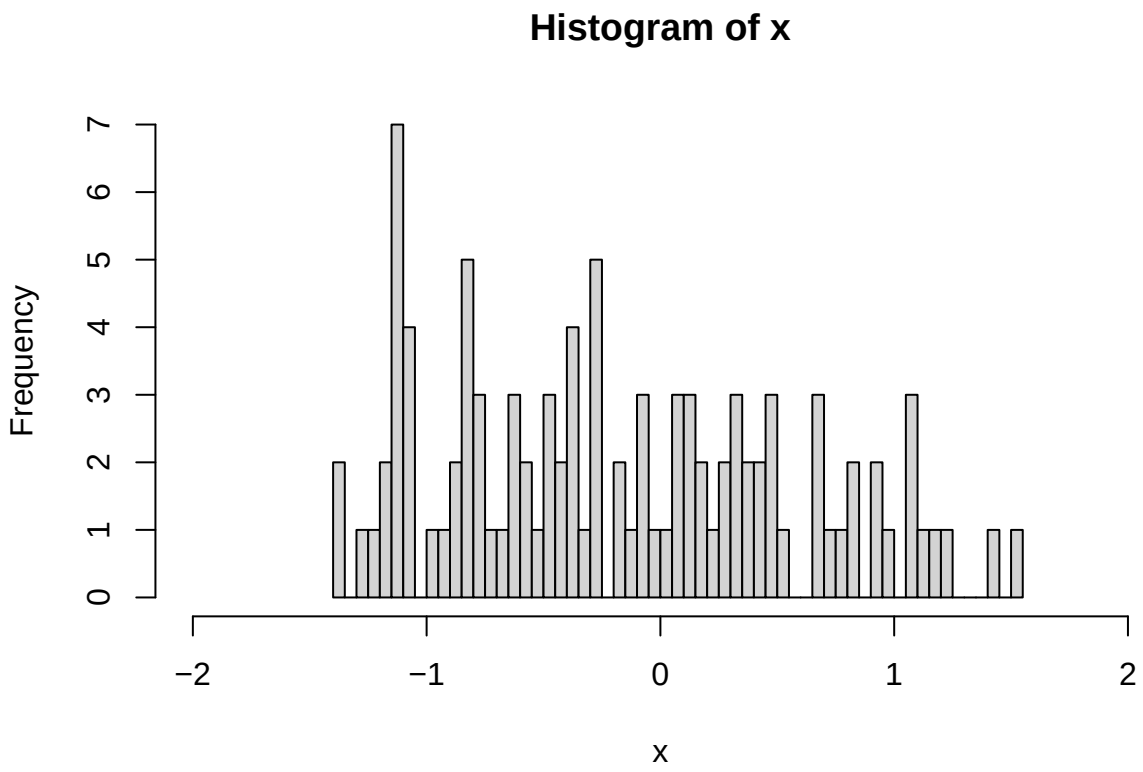
   Note 2: Your estimated density curve in this part should look flatter than the actual density curve, but have the same general shape. If it has a different shape, there may be a bug in your `rhand` *function.*

   Hint: Modify the call to `hist()` *and supply a value for the breaks parameter, e.g.,* `hist(x, xlim = c(-2, 2), breaks = 50)`*.*

4. Based on the sample from Part 3, what are the approximate mean and standard deviation of the hand distribution?

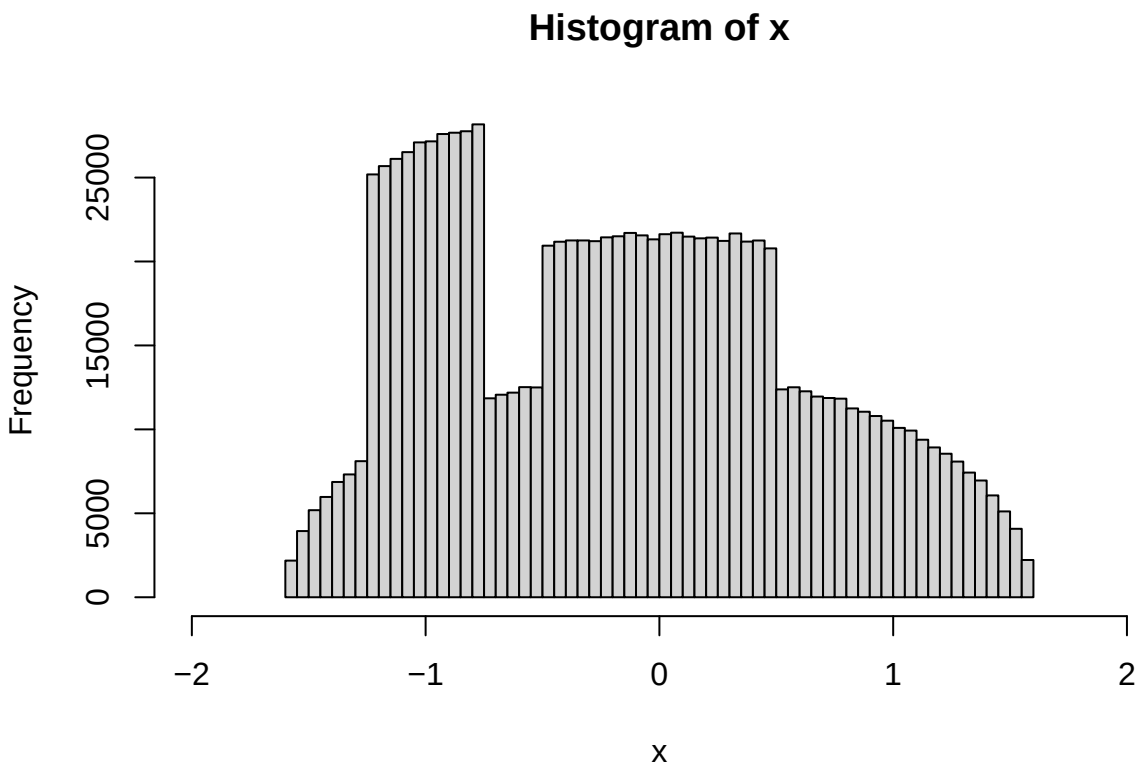
YOUR ANSWER GOES HERE:

```
set.seed(123)

x = rhand()
hist(x, xlim = c(-2, 2), breaks = 50)
```



> The estimated histogram doesn't resemble the actual histogram for the hand distribution. Although the x-axis is the same range, the y-axis is not, along with the shape of the histogram.

```
set.seed(123)

x = rhand(1e6)
hist(x, xlim = c(-2, 2), breaks = 50)
```



> The estimated histogram doesn't resemble the histogram from Part 1 of this problem. Although the x-axis is the same range, the y-axis is not, and the shape of the histogram definitely doesn't resemble each other.

```
cat("The mean is", mean(x), "while the standard deviation is",
      sd(x))
```

```
## The mean is -0.1662812 while the standard deviation is 0.7640995
```