

1. Show that the the dagger form of the unitary we found in class for the Fourier transform,  $U_{FT}^\dagger = (H_3(V_{32}H_2)(V_{31}V_{21}H_1)(V_{30}V_{20}V_{10}H_0)P)^\dagger$ , implements the inverse Fourier transform.

$$V_{ij} = e^{i\eta} \frac{u_i u_j}{x^{i-j}}$$

$$P^\dagger = P$$

$$V_j^t = e^{-i\pi \frac{n_i n_j}{2(n_i-1)}}$$

$$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

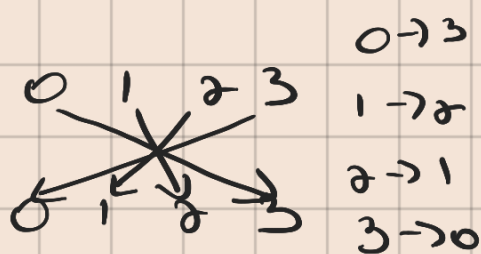
$$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}^{\dagger} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

$$H^\dagger = H$$

גאלר ביזנאס נה ג'אלר אסזר יטק

$$U_{QFT}^\dagger = P H_0 V_{10}^\dagger V_{20}^\dagger V_{30}^\dagger H_1 V_{21}^\dagger V_{31}^\dagger H_2 V_{32}^\dagger H_3$$

מהו המשפט של פאלי-וויינברג?



$$= H_3 V_{23}^\dagger \underbrace{V_{13}^\dagger V_{03}^\dagger}_{V_{10}^\dagger} H_8 \underbrace{V_{12}^\dagger V_{02}^\dagger}_{V_{10}^\dagger} H_1 V_{01}^\dagger H_0 P$$

$$= H_3 V_{23} H_2 V_{13} V_{03} V_{12} V_{02} H_1 \hat{V}_{01} H_0 P$$

$$= H_3 V_{23}^+ H_2 V_{13}^+ V_{12}^+ H_1 V_{03}^+ V_{02}^+ V_{01}^+ H_0 P$$

$$U_{QFT}^\dagger \text{ --- } |^1_1\rangle^1\langle^1_2| \otimes |0\rangle\langle^1_1| \quad V_{ij} = V_{ji}$$

(a) Find an operator  $U$  for which the operator  $U_f$  used in Shor's algorithm can be written as  $U_f = \sum_j |j\rangle\langle j| \otimes U^j$ , where the  $|j\rangle\langle j|$  part acts on the first (input) register and the  $U^j$  part acts on the second (output) register. Hint: for the second register, choose a starting state  $|y\rangle = |1\rangle_n$ .

$$U_f |x\rangle_n |y\rangle_n = |x\rangle_n |y \oplus f(x)\rangle_n$$

$$f(x) = b^x \pmod{N}$$

$$U_f |x\rangle_n |1\rangle_n = |x\rangle_n |1 \oplus b^x \pmod{N}\rangle_n$$

שם אם  $U$  פונקציה, אז  $U$  יהיה

$$b^x \pmod{N} \quad b \pmod{N} - 1 \quad b^x \pmod{N}$$

בזמן  $U$  זה יהיה  $x$  - אבל לא מה-התחלה

$$U |1\rangle_n = |b \pmod{N}\rangle_n$$

$$U |y\rangle_n = |b \pmod{N} y\rangle_n$$

$$U^x |y\rangle_n = |b^x \pmod{N} y\rangle_n \rightarrow$$

(ב) פונקציה  $b \pmod{N}$  תמיד יהיה,  $N=13$ ,  $b=3$

$$3^0 \pmod{13} = 1 \quad 3^1 \pmod{13} = 3 \quad 3^2 \pmod{13} = 9$$

$$3^3 \pmod{13} = 1 \quad 3^4 \pmod{13} = 3 \quad \dots$$

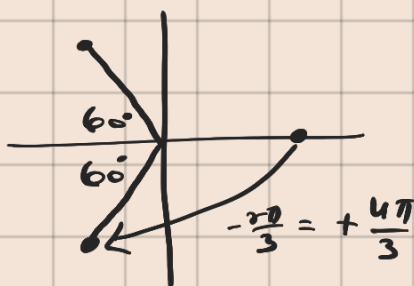
בזמן הפעולה  $U^x$  זה יהיה שלוש השברים

1, 3, 9, 13, 19, 25, 31, 37, 43, 49, 55, 61, 67, 73, 79, 85, 91, 97, 103, 109, 115, 121, 127, 133, 139, 145, 151, 157, 163, 169, 175, 181, 187, 193, 199, 205, 211, 217, 223, 229, 235, 241, 247, 253, 259, 265, 271, 277, 283, 289, 295, 301, 307, 313, 319, 325, 331, 337, 343, 349, 355, 361, 367, 373, 379, 385, 391, 397, 403, 409, 415, 421, 427, 433, 439, 445, 451, 457, 463, 469, 475, 481, 487, 493, 499, 505, 511, 517, 523, 529, 535, 541, 547, 553, 559, 565, 571, 577, 583, 589, 595, 601, 607, 613, 619, 625, 631, 637, 643, 649, 655, 661, 667, 673, 679, 685, 691, 697, 703, 709, 715, 721, 727, 733, 739, 745, 751, 757, 763, 769, 775, 781, 787, 793, 799, 805, 811, 817, 823, 829, 835, 841, 847, 853, 859, 865, 871, 877, 883, 889, 895, 901, 907, 913, 919, 925, 931, 937, 943, 949, 955, 961, 967, 973, 979, 985, 991, 997, 1003, 1009, 1015, 1021, 1027, 1033, 1039, 1045, 1051, 1057, 1063, 1069, 1075, 1081, 1087, 1093, 1099, 1105, 1111, 1117, 1123, 1129, 1135, 1141, 1147, 1153, 1159, 1165, 1171, 1177, 1183, 1189, 1195, 1201, 1207, 1213, 1219, 1225, 1231, 1237, 1243, 1249, 1255, 1261, 1267, 1273, 1279, 1285, 1291, 1297, 1303, 1309, 1315, 1321, 1327, 1333, 1339, 1345, 1351, 1357, 1363, 1369, 1375, 1381, 1387, 1393, 1399, 1405, 1411, 1417, 1423, 1429, 1435, 1441, 1447, 1453, 1459, 1465, 1471, 1477, 1483, 1489, 1495, 1501, 1507, 1513, 1519, 1525, 1531, 1537, 1543, 1549, 1555, 1561, 1567, 1573, 1579, 1585, 1591, 1597, 1603, 1609, 1615, 1621, 1627, 1633, 1639, 1645, 1651, 1657, 1663, 1669, 1675, 1681, 1687, 1693, 1699, 1705, 1711, 1717, 1723, 1729, 1735, 1741, 1747, 1753, 1759, 1765, 1771, 1777, 1783, 1789, 1795, 1801, 1807, 1813, 1819, 1825, 1831, 1837, 1843, 1849, 1855, 1861, 1867, 1873, 1879, 1885, 1891, 1897, 1903, 1909, 1915, 1921, 1927, 1933, 1939, 1945, 1951, 1957, 1963, 1969, 1975, 1981, 1987, 1993, 1999, 2005, 2011, 2017, 2023, 2029, 2035, 2041, 2047, 2053, 2059, 2065, 2071, 2077, 2083, 2089, 2095, 2101, 2107, 2113, 2119, 2125, 2131, 2137, 2143, 2149, 2155, 2161, 2167, 2173, 2179, 2185, 2191, 2197, 2203, 2209, 2215, 2221, 2227, 2233, 2239, 2245, 2251, 2257, 2263, 2269, 2275, 2281, 2287, 2293, 2299, 2305, 2311, 2317, 2323, 2329, 2335, 2341, 2347, 2353, 2359, 2365, 2371, 2377, 2383, 2389, 2395, 2401, 2407, 2413, 2419, 2425, 2431, 2437, 2443, 2449, 2455, 2461, 2467, 2473, 2479, 2485, 2491, 2497, 2503, 2509, 2515, 2521, 2527, 2533, 2539, 2545, 2551, 2557, 2563, 2569, 2575, 2581, 2587, 2593, 2599, 2605, 2611, 2617, 2623, 2629, 2635, 2641, 2647, 2653, 2659, 2665, 2671, 2677, 2683, 2689, 2695, 2701, 2707, 2713, 2719, 2725, 2731, 2737, 2743, 2749, 2755, 2761, 2767, 2773, 2779, 2785, 2791, 2797, 2803, 2809, 2815, 2821, 2827, 2833, 2839, 2845, 2851, 2857, 2863, 2869, 2875, 2881, 2887, 2893, 2899, 2905, 2911, 2917, 2923, 2929, 2935, 2941, 2947, 2953, 2959, 2965, 2971, 2977, 2983, 2989, 2995, 3001, 3007, 3013, 3019, 3025, 3031, 3037, 3043, 3049, 3055, 3061, 3067, 3073, 3079, 3085, 3091, 3097, 3103, 3109, 3115, 3121, 3127, 3133, 3139, 3145, 3151, 3157, 3163, 3169, 3175, 3181, 3187, 3193, 3199, 3205, 3211, 3217, 3223, 3229, 3235, 3241, 3247, 3253, 3259, 3265, 3271, 3277, 3283, 3289, 3295, 3301, 3307, 3313, 3319, 3325, 3331, 3337, 3343, 3349, 3355, 3361, 3367, 3373, 3379, 3385, 3391, 3397, 3403, 3409, 3415, 3421, 3427, 3433, 3439, 3445, 3451, 3457, 3463, 3469, 3475, 3481, 3487, 3493, 3499, 3505, 3511, 3517, 3523, 3529, 3535, 3541, 3547, 3553, 3559, 3565, 3571, 3577, 3583, 3589, 3595, 3601, 3607, 3613, 3619, 3625, 3631, 3637, 3643, 3649, 3655, 3661, 3667, 3673, 3679, 3685, 3691, 3697, 3703, 3709, 3715, 3721, 3727, 3733, 3739, 3745, 3751, 3757, 3763, 3769, 3775, 3781, 3787, 3793, 3799, 3805, 3811, 3817, 3823, 3829, 3835, 3841, 3847, 3853, 3859, 3865, 3871, 3877, 3883, 3889, 3895, 3901, 3907, 3913, 3919, 3925, 3931, 3937, 3943, 3949, 3955, 3961, 3967, 3973, 3979, 3985, 3991, 3997, 4003, 4009, 4015, 4021, 4027, 4033, 4039, 4045, 4051, 4057, 4063, 4069, 4075, 4081, 4087, 4093, 4099, 4105, 4111, 4117, 4123, 4129, 4135, 4141, 4147, 4153, 4159, 4165, 4171, 4177, 4183, 4189, 4195, 4201, 4207, 4213, 4219, 4225, 4231, 4237, 4243, 4249, 4255, 4261, 4267, 4273, 4279, 4285, 4291, 4297, 4303, 4309, 4315, 4321, 4327, 4333, 4339, 4345, 4351, 4357, 4363, 4369, 4375, 4381, 4387, 4393, 4399, 4405, 4411, 4417, 4423, 4429, 4435, 4441, 4447, 4453, 4459, 4465, 4471, 4477, 4483, 4489, 4495, 4501, 4507, 4513, 4519, 4525, 4531, 4537, 4543, 4549, 4555, 4561, 4567, 4573, 4579, 4585, 4591, 4597, 4603, 4609, 4615, 4621, 4627, 4633, 4639, 4645, 4651, 4657, 4663, 4669, 4675, 4681, 4687, 4693, 4699, 4705, 4711, 4717, 4723, 4729, 4735, 4741, 4747, 4753, 4759, 4765, 4771, 4777, 4783, 4789, 4795, 4801, 4807, 4813, 4819, 4825, 4831, 4837, 4843, 4849, 4855, 4861, 4867, 4873, 4879, 4885, 4891, 4897, 4903, 4909, 4915, 4921, 4927, 4933, 4939, 4945, 4951, 4957, 4963, 4969, 4975, 4981, 4987, 4993, 4999, 5005, 5011, 5017, 5023, 5029, 5035, 5041, 5047, 5053, 5059, 5065, 5071, 5077, 5083, 5089, 5095, 5101, 5107, 5113, 5119, 5125, 5131, 5137, 5143, 5149, 5155, 5161, 5167, 5173, 5179, 5185, 5191, 5197, 5203, 5209, 5215, 5221, 5227, 5233, 5239, 5245, 5251, 5257, 5263, 5269, 5275, 5281, 5287, 5293, 5299, 5305, 5311, 5317, 5323, 5329, 5335, 5341, 5347, 5353, 5359, 5365, 5371, 5377, 5383, 5389, 5395, 5401, 5407, 5413, 5419, 5425, 5431, 5437, 5443, 5449, 5455, 5461, 5467, 5473, 5479, 5485, 5491, 5497, 5503, 5509, 5515, 5521, 5527, 5533, 5539, 5545, 5551, 5557, 5563, 5569, 5575, 5581, 5587, 5593, 5599, 5605, 5611, 5617, 5623, 5629, 5635, 5641, 5647, 5653, 5659, 5665, 5671, 5677, 5683, 5689, 5695, 5701, 5707, 5713, 5719, 5725, 5731, 5737, 5743, 5749, 5755, 5761, 5767, 5773, 5779, 5785, 5791, 5797, 5803, 5809, 5815, 5821, 5827, 5833, 5839, 5845, 5851, 5857, 5863, 5869, 5875, 5881, 5887, 5893, 5899, 5905, 5911, 5917, 5923, 5929, 5935, 5941, 5947, 5953, 5959, 5965, 5971, 5977, 5983, 5989, 5995, 6001, 6007, 6013, 6019, 6025, 6031, 6037, 6043, 6049, 6055, 6061, 6067, 6073, 6079, 6085, 6091, 6097, 6103, 6109, 6115, 6121, 6127, 6133, 6139, 6145, 6151, 6157, 6163, 6169, 6175, 6181, 6187, 6193, 6199, 6205, 6211, 6217, 6223, 6229, 6235, 6241, 6247, 6253, 6259, 6265, 6271, 6277, 6283, 6289, 6295, 6301, 6307, 6313, 6319, 6325, 6331, 6337, 6343, 6349, 6355, 6361, 6367, 6373, 6379, 6385, 6391, 6397, 6403, 6409, 6415, 6421, 6427, 6433, 6439, 6445, 6451, 6457, 6463, 6469, 6475, 6481, 6487, 6493, 6499, 6505, 6511, 6517, 6523, 6529, 6535, 6541, 6547, 6553, 6559, 6565, 6571, 6577, 6583, 6589, 6595, 6601, 6607, 6613, 6619, 6625, 6631, 6637, 6643, 6649, 6655, 6661, 6667, 6673, 6679, 6685, 6691, 6697, 6703, 6709, 6715, 6721, 6727, 6733, 6739, 6745, 6751, 6757, 6763, 6769, 6775, 6781, 6787, 6793, 6799, 6805, 6811, 6817, 6823, 6829, 6835, 6841, 6847, 6853, 6859, 6865, 6871, 6877, 6883, 6889, 6895, 6901, 6907, 6913, 6919, 6925, 6931, 6937, 6943, 6949, 6955, 6961, 6967, 6973, 6979, 6985, 6991, 6997, 7003, 7009, 7015, 7021, 7027, 7033, 7039, 7045, 7051, 7057, 7063, 7069, 7075, 7081, 7087, 7093, 7099, 7105, 7111, 7117, 7123, 7129, 7135, 7141, 7147, 7153, 7159, 7165, 7171, 7177, 7183, 7189, 7195, 7201, 7207, 7213, 7219, 7225, 7231, 7237, 7243, 7249, 7255, 7261, 7267, 7273, 7279, 7285, 7291, 7297, 7303, 7309, 7315, 7321, 7327, 7333, 7339, 7345, 7351, 7357, 7363, 7369, 7375, 7381, 7387, 7393, 7399, 7405, 7411, 7417, 7423, 7429, 7435, 7441, 7447, 7453, 7459, 7465, 7471, 7477, 7483, 7489, 7495, 7501, 7507, 7513, 7519, 7525, 7531, 7537, 7543, 7549, 7555, 7561, 7567, 7573, 7579, 7585, 7591, 7597, 7603, 7609, 7615, 7621, 7627, 7633, 7639, 7645, 7651, 7657, 7663, 7669, 7675, 7681, 7687, 7693, 7699, 7705, 7711, 7717, 7723, 7729, 7735, 7741, 7747, 7753, 7759, 7765, 7771, 7777, 7783, 7789, 7795, 7801, 7807, 7813, 7819, 7825, 7831, 7837, 7843, 7849, 7855, 7861, 7867, 7873, 7879, 7885, 7891, 7897, 7903, 7909, 7915, 7921, 7927, 7933, 7939, 7945, 7951, 7957, 7963, 7969, 7975, 7981, 7987, 7993, 7999, 8005, 8011, 8017, 8023, 8029, 8035, 8041, 8047, 8053, 8059, 8065, 8071, 8077, 8083, 8089, 8095, 8101, 8107, 8113, 8119, 8125, 8131, 8137, 8143, 8149, 8155, 8161, 8167, 8173, 8179, 8185, 8191, 8197, 8203, 8209, 8215, 8221, 8227, 8233, 8239, 8245, 8251, 8257, 8263, 8269, 8275, 8281, 8287, 8293, 8299, 8305, 8311, 8317, 8323, 8329, 8335, 8341, 8347, 8353, 8359, 8365, 8371, 8377, 8383, 8389, 8395, 8401, 8407, 8413, 8419, 8425, 8431, 8437, 8443, 8449, 8455, 8461, 8467, 8473, 8479, 8485, 8491, 8497, 8503, 8509, 8515, 8521, 8527, 8533, 8539, 8545, 8551, 8557, 8563, 8569, 8575, 8581, 8587, 8593, 8599, 8605, 8611, 8617, 8623, 8629, 8635, 8641, 8647, 8653, 8659, 8665, 8671, 8677, 8683, 8689, 8695, 8701, 8707, 8713, 8719, 8725, 8731, 8737, 8743, 8749, 8755, 8761, 8767, 8773, 8779, 8785, 8791, 8797, 8803, 8809, 8815, 8821, 8827, 8833, 8839, 8845, 8851, 8857, 8863, 8869, 8875, 8881, 8887, 8893, 8899, 8905, 8911, 8917, 8923, 8929, 8935, 8941, 8947, 8953, 8959, 8965, 8971, 8977, 8983, 8989, 8995, 9001, 9007, 9013, 9019, 9025, 9031, 9037, 9043, 9049, 9055, 9061, 9067, 9073, 9079, 9085, 9091, 9097, 9103, 9109, 9115, 9121, 9127, 9133, 9139, 9145, 9151, 9157, 9163, 9169, 9175, 9181, 9187, 9193, 9199, 9205, 9211, 9217, 9223, 9229, 9235, 9241, 9247, 9253, 9259, 9265, 9271, 9277, 9283, 9289, 9295, 9301, 9307, 9313, 9319, 9325, 9331, 9337, 9343, 9349, 9355, 9361, 9367, 9373, 9379, 9385, 9391, 9397, 9403, 9409, 9415, 9421, 9427, 9433, 9439, 9445, 9451, 9457, 9463, 9469, 9475, 9481, 9487, 9493, 9499, 9505, 9511, 9517, 9523, 9529, 9535, 9541, 9547, 9553, 9559, 9565, 9571, 9577, 9583, 9589, 9595, 9601, 9607, 9613, 9619, 9625, 9631, 9637, 9643, 9649, 9655, 9661, 9667, 9673, 9679, 9685, 9691, 9697, 9703, 9709, 9715, 9721, 9727, 9733, 9739, 9745, 9751, 9757, 9763, 9769, 9775, 9781, 9787, 9793, 9799, 9805, 9811, 9817, 9823, 9829, 9835, 9841, 9847, 9853, 9859, 9865, 9871, 9877, 9883, 9889, 9895, 9901, 9907, 9913, 9919, 9925, 9931, 9937, 9943, 9949, 9955, 9961, 9967, 9973, 9979, 9985, 9991, 9997, 10003, 10009, 10015, 10021, 10027, 10033, 10039, 10045, 10051, 10057, 10063, 10069, 10075, 10081, 10087, 10093, 10099, 10105, 10111, 10117, 10123, 10129, 10135, 10141, 10147, 10153, 10159, 10165, 10171, 10177, 10183, 10189, 10195, 10201, 10207, 10213, 10219, 10225, 10231, 10237, 10243, 10249, 10255, 10261, 10267, 10273, 10279, 10285, 10291, 10297, 10303, 10309, 10315, 10321, 10327, 10333, 10339, 10345, 10351, 10357, 10363, 10369, 10375, 10381, 10387, 10393, 10399, 10405, 10411, 10417, 10423, 10429, 10435, 10441, 10447, 10453, 10459, 10465, 10471, 10477, 10483, 10489, 10495, 10501, 10507, 10513, 10519, 10525, 10531, 10537, 10543, 10549, 10555, 10561, 10567, 10573, 10579, 10585, 10591, 10597, 10603, 10609, 10615, 10621, 10627, 10633, 10639, 10645, 10651, 10657, 10663, 10669, 10675, 10681, 10687, 10693, 10699, 10705, 10711, 10717, 10723, 10729, 10735, 10741, 10747, 10753, 10759, 10765, 10771, 10777, 10783, 10789, 10795, 10801, 10807, 10813, 10819, 10825, 10831, 10837, 10843, 10849, 10855, 10861, 10867, 10873, 10879, 10885, 10891, 10897, 10903, 10909, 10915, 10921, 10927, 10933, 10939, 10945, 10951, 10957, 10963, 10969, 10975, 10981, 10987, 10993, 10999, 11005, 11011, 11017, 11023, 11029, 11035, 11041, 11047, 11053, 11059, 11065, 11071, 11077, 11083, 11089, 11095, 11101, 11107, 11113, 11119, 11125, 11131, 11137, 11143, 11149, 11155, 11161, 11167, 11173, 11179, 11185, 11191, 11197, 11203, 11209, 11215, 11221, 11227, 11233, 11239, 11245, 11251, 11257, 11263,

לאחר  $\psi$  מחלק את המרחב לרשת' מרחבים סגורים  
 רשת הפאזר  $\psi$  סגור  $r=3$

$$U(|1\rangle\lambda_1 + |3\rangle\lambda_3 + |a\rangle\lambda_a) = (|1\rangle\lambda_1 + |3\rangle\lambda_3 + |a\rangle\lambda_a) \equiv |\psi_0\rangle$$

$$\lambda_0 = 1 = e^{2\pi i \cdot 0} \Rightarrow \varphi_0 = 0$$



$$\begin{aligned} U & (e^{i\frac{2\pi}{3}}|1\rangle + e^{-i\frac{2\pi}{3}}|3\rangle + |a\rangle) \\ &= (e^{i\frac{2\pi}{3}}|3\rangle + e^{-i\frac{2\pi}{3}}|a\rangle + |1\rangle) \\ &= e^{-i\frac{2\pi}{3}} (e^{i\frac{2\pi}{3}}|1\rangle + e^{i\frac{4\pi}{3}}|3\rangle + |a\rangle) = \lambda_1 |\psi_1\rangle \\ \lambda_1 &= e^{-i\frac{2\pi}{3}} \Rightarrow \varphi_1 = -\frac{1}{3} \end{aligned}$$

$$|\psi_2\rangle = (e^{-i\frac{2\pi}{3}}|1\rangle + e^{i\frac{2\pi}{3}}|3\rangle + |a\rangle)$$

$$\lambda_2 = e^{i\frac{2\pi}{3}} \Rightarrow \varphi_2 = \frac{1}{3}$$

באמצעות  $\varphi_i$  נחלק את המרחב לרשת'  $PE$  ונראה שיש

$$\varphi_i = \frac{q}{r} \quad q = 0, \pm 1, \pm 2, \dots$$

$$\begin{aligned} -\frac{2\pi}{3} &= \frac{4\pi}{3} & \text{של } \psi & \text{על ידי } \psi \\ \downarrow & \quad \downarrow & & \\ \varphi = -\frac{1}{3} & \quad \varphi = \frac{2}{3} & & \frac{2\pi}{3} = \frac{1}{3} \end{aligned}$$

$$q = 0, 1, 2 \quad \text{כל } \psi \text{ ו-} \psi^2$$

$$q = 0, 1, \dots, r-1 \quad \text{כל } \psi \text{ ו-} \psi^2$$

$$|0\rangle\lambda_0 |1\rangle\lambda_1 \quad \circ \sim \psi_1 \text{ ו-} \psi_2$$

$$\frac{1}{\sqrt{2}} \sum_{k=0}^{2-1} |x\rangle\lambda_k |1\rangle\lambda_1 \quad \circ \quad H_1^{\otimes 2} \psi_{\text{ע}}$$

$$\frac{1}{\sqrt{2}} \sum_{k=0}^{2-1} |x\rangle\lambda_k |0\rangle\lambda_0 \quad \circ \quad \sum |x\rangle\lambda_k |0\rangle\lambda_0 \psi_{\text{ע}}$$

רפסל פור"ה א" פור"ה הפיק ארזאים - הישן

ואז נקט  $\varphi_i = \frac{q}{r}$  סבב' פ'.

לסוף ארזאין מנה שותף אפר מ"ג אגד

מהוא ר ארזאין זיך ארפסל מרז אקט פ

אחר ארזאין מנה שותף.