3a.

Consider pixel P1 (223, 197) with intensity 148 on image_1

and its corresponding pixel P2 (92, 144) with intensity 120 on image_2

Let A be the 16 X 16 block around pixel P1

80 52 30 233 134 169 140 144 90 185 16 225 70 26 57 200
119 126 85 5 202 147 220 130 254 31 236 226 92 21 61 202
137 254 61 49 200 137 50 252 80 10 12 186 147 226 245 166
228 198 119 240 14 188 235 141 220 21 233 234 58 108 164 121
43 134 192 48 127 47 9 234 14 231 235 203 190 155 231 130
124 251 40 143 206 83 228 69 99 126 162 134 83 94 1 243
75 225 151 203 228 163 120 42 244 236 222 203 221 239 251 103
252 79 43 83 111 2 91 206 67 107 253 10 101 29 186 155
68 86 31 228 78 15 19 213 102 115 139 113 18 215 64 114
83 183 92 200 70 183 160 156 187 201 254 11 228 19 100 197
41 0 146 121 252 210 210 78 158 36 66 56 251 62 99 29
252 2 59 143 68 180 47 92 48 220 71 30 108 155 247 185
115 236 235 182 140 94 43 113 183 91 77 143 98 0 246 30
162 217 239 63 53 221 194 153 104 154 53 166 128 120 157 17
122 167 175 77 111 132 191 215 118 203 56 41 245 1 109 138
73 55 52 162 121 183 138 92 210 148 17 17 134 182 18 122

Calculating orientation of each pixel:

Y1
X1 p X2
Y2

Orientation of the pixel p = $\tan^{-1}((Y1-Y2)/(X2-X1))$

Rounding the orientations to the nearest angles corresponding to the 8 directions i.e, 0, 45, 90, 135,….., 360 degrees.

The orientations of all the pixels in the above A block are

183 225 204 175 153 89 190 241 233 209 85 174 246 79 254 94
161 99 204 166 69 68 147 101 235 119 105 155 63 203 223 182

247 249 63 99 90 86 183 163 105 72 133 194 156 87 233 72

204 202 89 63 123 208 211 71 135 131 69 188 229 112 110 169

225 183 218 251 244 89 75 167 230 235 124 84 179 239 200 206

70 247 171 82 181 169 115 251 186 227 224 84 121 112 71 90

73 149 176 166 201 81 76 191 159 219 77 192 145 91 159 210

101 80 135 86 162 114 81 157 102 156 74 70 234 212 154 78

82 225 66 137 84 99 146 211 70 101 156 168 66 66 165 190

127 145 217 107 249 156 63 129 113 242 63 122 93 143 150 217

199 246 204 231 73 68 203 82 113 163 144 155 208 211 235 132

216 220 182 90 131 167 222 171 125 240 178 182 187 198 136 120

166 175 230 221 175 119 64 134 137 65 205 142 121 76 73 210

129 77 123 227 146 228 118 209 253 93 207 88 172 241 84 142

88 114 134 147 229 216 177 235 250 77 124 72 221 181 192 211

162 92 234 210 187 223 61 173 175 96 230 234 177 199 213 71

Dividing this orientation matrix O1 into sixteen 4X4 blocks and calculating the frequencies of each of the 8 directions.

So, from each 4 X 4 block, we will get a histogram of frequencies in all the 8 directions

If we combine the frequencies from all the sixteen 4 X 4 blocks we will get a 128 size vector which is called SIFT feature. (8 * 16 = 128)

SIFT feature for the pixel P1 is

S1 = [2 1 8 9 6 7 9 2 2 9 2 5 8 2 9 8 1 8 4 6 1 5 3 5 5 1 9 6 1 7 8 9 1 7 6 4 6 2 6 5 3 6 1 3 8 9 3 5 6 2 9 1 4 3 2 7 4 6 7 9 6 4 4 7 5 2 6 4 2 7 4 5 8 4 6 1 7 9 7 3 3 4 4 2 7 4 5 5 9 1 3 1 1 3 7 5 3 1 5 9 6 3 4 6 4 6 9 8 4 3 3 6 5 1 1 2 8 1 9 1 1 5 8 3 2 5 5 8]

Let B be the 16 X 16 block around pixel P1

105 167 62 56 74 166 179 79 106 131 156 162 63 170 86 235
139 90 236 183 203 218 194 238 135 71 199 116 50 230 213 100
246 252 153 196 97 120 206 183 199 166 122 210 166 65 168 221
85 170 240 145 72 254 49 140 92 81 171 44 214 199 76 221
124 108 52 92 112 234 81 223 214 71 214 236 112 214 113 175
114 240 141 52 107 105 205 202 108 157 174 154 92 231 175 250
140 147 59 149 194 67 62 221 219 148 126 165 247 74 203 184
86 240 241 105 77 108 86 143 224 53 170 218 241 68 195 43
147 192 108 64 154 230 64 217 45 173 203 100 87 101 128 191
107 133 99 100 102 223 67 201 161 68 130 133 211 198 175 85
212 75 204 147 215 47 131 73 45 249 49 74 154 78 178 223
64 243 204 96 80 242 94 248 95 49 96 214 224 185 135 138
133 149 129 83 74 201 50 66 118 141 82 50 78 87 132 233
234 160 189 252 251 137 250 104 238 220 170 225 162 208 178 210
72 210 62 237 224 243 70 203 80 165 74 207 245 221 223 123
229 232 216 47 42 149 127 173 123 101 217 212 55 216 184 196

Calculating orientation of each pixel:

Y1
X1 p X2
Y2

Orientation of the pixel p = $\tan^{-1}((Y1-Y2)/(X2-X1))$

Rounding the orientations to the nearest angles corresponding to the 8 directions i.e, 0, 45, 90, 135,….., 360 degrees.

The orientations of all the pixels in the above B block are

187 218 238 68 108 226 252 65 175 61 142 197 189 46 249 171
255 211 236 93 44 56 132 135 66 73 191 101 237 148 174 43
77 45 163 119 125 199 251 102 45 214 63 108 69 157 212 57
114 255 56 150 225 172 119 60 232 122 202 51 82 122 170 181
63 163 197 218 234 253 60 51 222 65 110 61 169 96 154 49
183 91 198 84 80 192 112 202 194 103 105 192 145 180 76 135
75 84 121 73 245 164 211 245 209 163 85 122 236 126 213 107

199 116 238 182 78 208 141 205 71 235 230 178 41 72 62 96

221 152 66 154 76 239 57 200 125 135 146 198 98 212 54 196

116 45 160 89 161 88 175 161 235 161 211 228 249 116 193 182

112 92 113 191 82 140 212 79 59 232 92 223 56 236 192 125

142 141 151 195 115 176 93 86 94 196 159 157 96 190 217 218

46 129 64 241 250 50 44 148 58 45 65 213 150 154 154 195

61 149 208 230 202 71 232 88 219 75 241 161 168 145 219 126

130 229 219 85 180 194 170 136 203 212 59 120 83 69 49 144

155 171 207 241 61 161 48 210 123 47 237 179 100 202 166 250

Dividing this orientation matrix O2 into sixteen 4X4 blocks and calculating the frequencies of each of the 8 directions.

So, from each 4 X 4 block, we will get a histogram of frequencies in all the 8 directions
If we combine the frequencies from all the sixteen 4 X 4 blocks the we will get a 128 size vector which is called SIFT feature. (8 * 16 = 128)

SIFT feature for the pixel P2 is

S2 = [5 6 1 2 7 3 4 8 8 7 7 6 3 8 3 9 7 2 2 5 6 5 4 7 6 8 4 3 6 5 4 4 7 8 3 1 7 8 8 7 3 4 4 8 4 9 3 6 9 9 6 6 3 5 3 1 3 7 4 5 8 5 8 7 8 1 3 2 9 9 3 5 7 5 6 8 1 2 1 8 3 6 1 1 3 2 9 5 9 5 8 9 1 7 1 7 5 1 2 3 1 7 7 2 9 5 9 2 3 6 2 9 6 9 4 6 8 5 9 4 9 2 9 6 5 5 1 6]

Sum of squared difference (SSD) between the SIFT vectors (S1 & S2) for the pixels P1 and P2:

=> 1 + 0 + 1 +…….. + 4 + 1
=> 38