Problem 1

a)

unformPhase:

```
function phase = uniformPhase(mean,var)

phase = unifrnd(-pi,pi)

end
```

constantMag:

```
function mag = constantMag(mean,var)

mag = mean

end
```

normalMag:

```
function mag = normalMag(mean,var)

mag = normrnd(mean,sqrt(var))

end
```

normalPhase:

```
function Phase = normalPhase(mean,var)

phase = normrnd(mean,sqrt(var))

end
```

b)

randomPhasor:

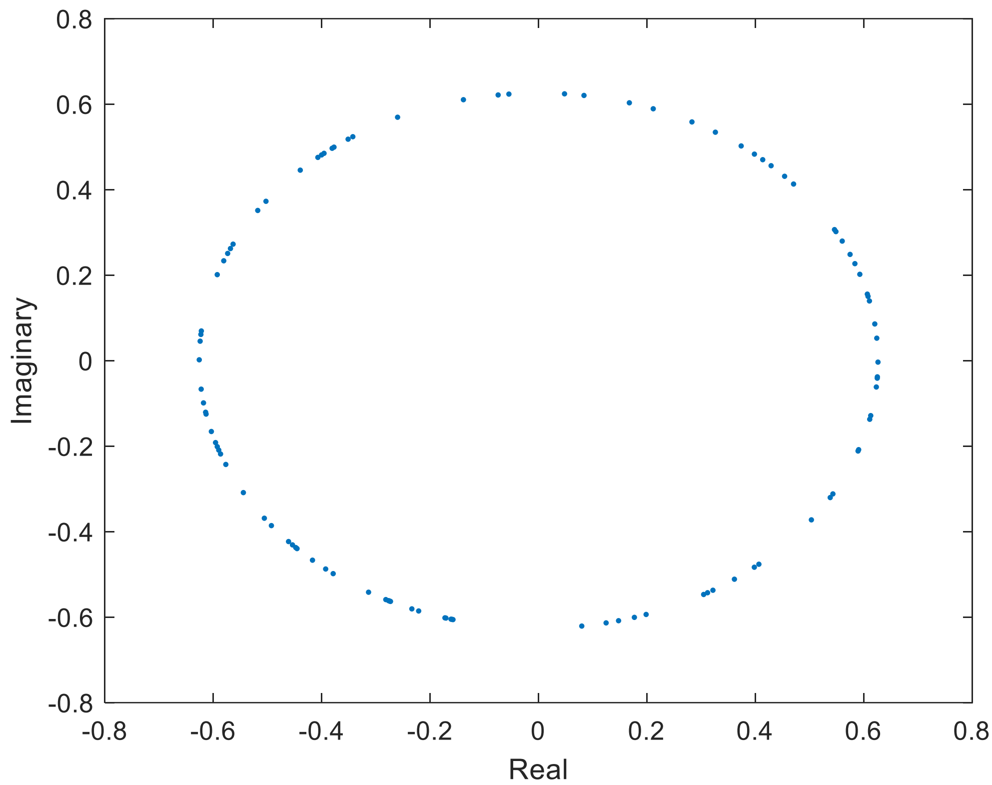
```
function phasor = randomPhasor(magDist,magMean,magVar,phaseDist,phaseMean,phaseVar)

mag = magDist(magMean,magVar)
phase = phaseDist(phaseMean,phaseVar)
phasor = mag*exp(1*j*phase)

end
```

c)

onepartc.m:

```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 100;
phasor = zeros(N,1);

magMean = rand;
magVar = rand;
phaseMean = rand;
phaseVar = rand;

for i = 1:N

    phasor(i) = randomPhasor(magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

plot(real(phasor),imag(phasor),'.')
```

Problem 1 (continued)



d)

randomPhasorSum:

```
function phasorsum =
randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar)

for i = 1:N

    phasor(i) = randomPhasor(magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

phasorsum = sum(phasor)/sqrt(N);S

end
```

Problem 2

a)

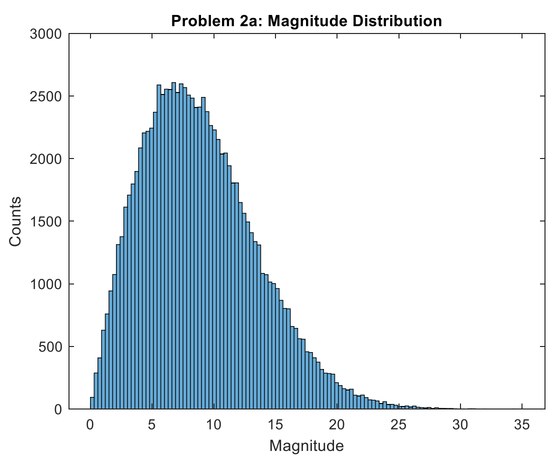
twoparta.m:

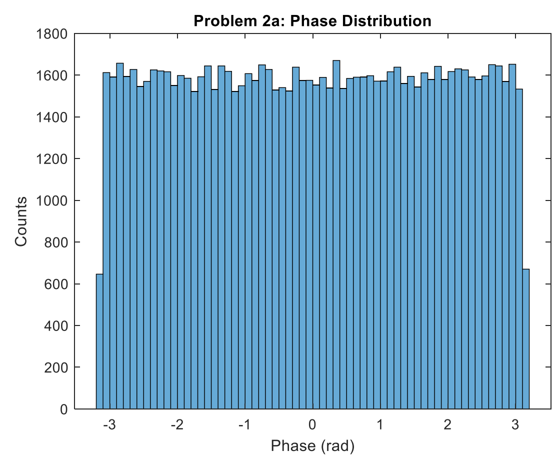
```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

mag = abs(phasor);
phase = angle(phasor);
```

Problem 2 (continued)

a) (continued)

```
figure(1);
maghist = histogram(mag);
title('Problem 2a: Magnitude Distribution');
xlabel('Magnitude');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

figure(2);
phasehist = histogram(phase);
title('Problem 2a: Phase Distribution');
xlabel('Phase (rad)');ylabel('Counts');

phaseHistBins = phasehist.BinCounts;
phaseHistEdges = phasehist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);


moment1phase = mean(phase);
moment2phase = var(phase);

fprintf('The first moment (mean) of the Magnitude Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Magnitude Distribution is: %.3f\n',moment2mag);

fprintf('The first moment (mean) of the Phase Distribution is: %.3f rad\n',moment1phase);
fprintf('The second moment (variance) of the Phase Distribution is: %.3f rad\n',moment2phase);
```






```
The first moment (mean) of the Magnitude Distribution is: 8.865
The second moment (variance) of the Magnitude Distribution is: 21.249
The first moment (mean) of the Phase Distribution is: 0.004 rad
The second moment (variance) of the Phase Distribution is: 3.306 rad
```

b)

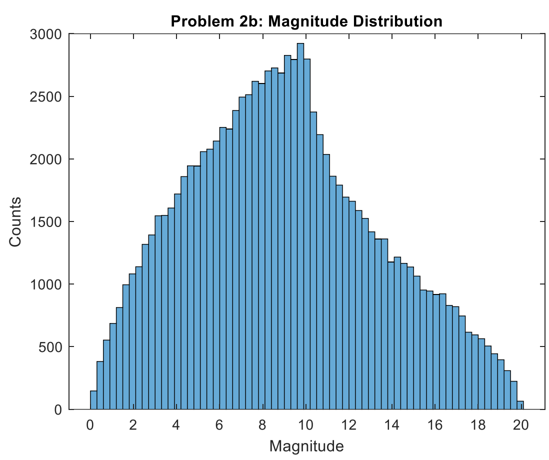
twopartb.m:

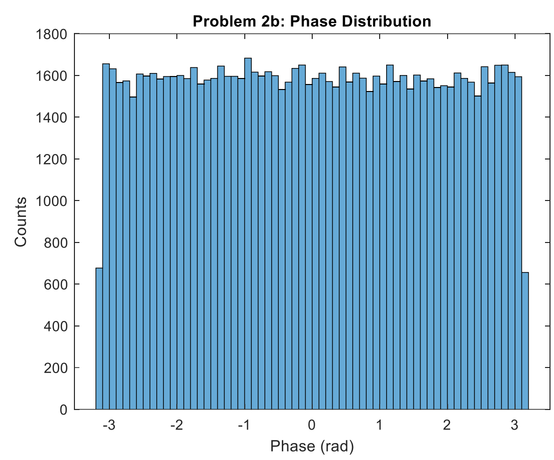
```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 4;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

mag = abs(phasor);
phase = angle(phasor);

figure(3);
maghist = histogram(mag);
title('Problem 2b: Magnitude Distribution');
xlabel('Magnitude');ylabel('Counts');

magHistBins = maghist.BinCounts;
```

Problem 2 (continued)

b) (continued)

```
magHistEdges = maghist.BinEdges;

figure(4);
phasehist = histogram(phase);
title('Problem 2b: Phase Distribution');
xlabel('Phase (rad)');ylabel('Counts');

phaseHistBins = phasehist.BinCounts;
phaseHistEdges = phasehist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);


moment1phase = mean(phase);
moment2phase = var(phase);

fprintf('The first moment (mean) of the Magnitude Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Magnitude Distribution is: %.3f\n',moment2mag);

fprintf('The first moment (mean) of the Phase Distribution is: %.3f rad\n',moment1phase);
fprintf('The second moment (variance) of the Phase Distribution is: %.3f rad\n',moment2phase);
```






```
The first moment (mean) of the Magnitude Distribution is: 8.992

The second moment (variance) of the Magnitude Distribution is: 19.087

The first moment (mean) of the Phase Distribution is: -0.005 rad

The second moment (variance) of the Phase Distribution is: 3.294 rad
```

There are approximately 5 random phasors needed to reasonably converse to the large-number result. Shown above are the results for 4 random phasors and the breakdown of the magnitude distribution.

c)

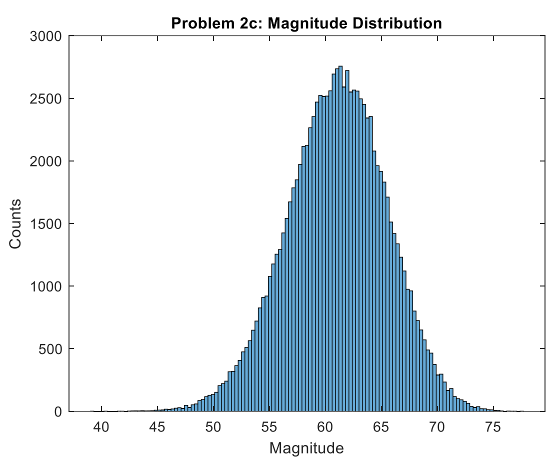
twopartc.m:

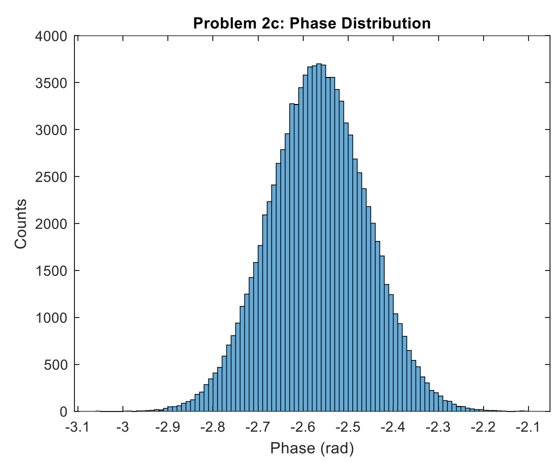
```
magDist = @constantMag;
phaseDist = @normalPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

mag = abs(phasor);
phase = angle(phasor);
```

Problem 2 (continued)

c) (continued)

```
figure(5);
maghist = histogram(mag);
title('Problem 2c: Magnitude Distribution');
xlabel('Magnitude');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

figure(6);
phasehist = histogram(phase);
title('Problem 2c: Phase Distribution');
xlabel('Phase (rad)');ylabel('Counts');

phaseHistBins = phasehist.BinCounts;
phaseHistEdges = phasehist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);


moment1phase = mean(phase);
moment2phase = var(phase);

fprintf('The first moment (mean) of the Magnitude Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Magnitude Distribution is: %.3f\n',moment2mag);

fprintf('The first moment (mean) of the Phase Distribution is: %.3f rad\n',moment1phase);
fprintf('The second moment (variance) of the Phase Distribution is: %.3f rad\n',moment2phase);
```






```
The first moment (mean) of the Magnitude Distribution is: 61.016

The second moment (variance) of the Magnitude Distribution is: 19.720

The first moment (mean) of the Phase Distribution is: -2.566 rad

The second moment (variance) of the Phase Distribution is: 0.012 rad
```

When the phase distribution is changed from uniform to normal, this change is directly reflected by the shape of the distribution seen on the right figure above being normal. The phase distribution is also no longer centered around 0 rad, but rather ~ -2.5 rad. The shape of the magnitude distribution also slightly changed from being slightly right skewed to more centered, as seen in the left figure above.

d)

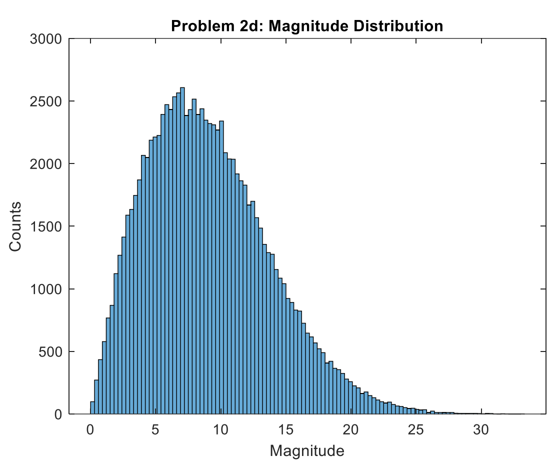
twopartd.m:

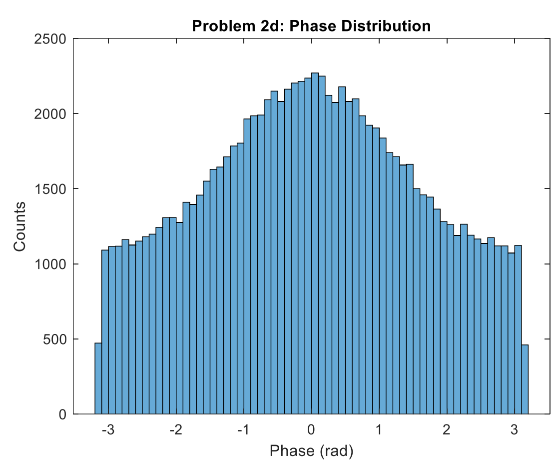
```
magDist = @constantMag;
phaseDist = @unformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
```

Problem 2 (continued)

d) (continued)

```
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

Ed = 2;
thetad = 0;

phasor = phasor + Ed*exp(1i*thetad);

mag = abs(phasor);
phase = angle(phasor);

figure(7);
maghist = histogram(mag);
title('Problem 2d: Magnitude Distribution');
xlabel('Magnitude');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

figure(8);
phasehist = histogram(phase);
title('Problem 2d: Phase Distribution');
xlabel('Phase (rad)');ylabel('Counts');

phaseHistBins = phasehist.BinCounts;
phaseHistEdges = phasehist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);


moment1phase = mean(phase);
moment2phase = var(phase);

fprintf('The first moment (mean) of the Magnitude Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Magnitude Distribution is: %.3f\n',moment2mag);

fprintf('The first moment (mean) of the Phase Distribution is: %.3f rad\n',moment1phase);
fprintf('The second moment (variance) of the Phase Distribution is: %.3f rad\n',moment2phase);
```






```
The first moment (mean) of the Magnitude Distribution is: 9.040

The second moment (variance) of the Magnitude Distribution is: 22.306

The first moment (mean) of the Phase Distribution is: -0.006 rad

The second moment (variance) of the Phase Distribution is: 2.609 rad
```

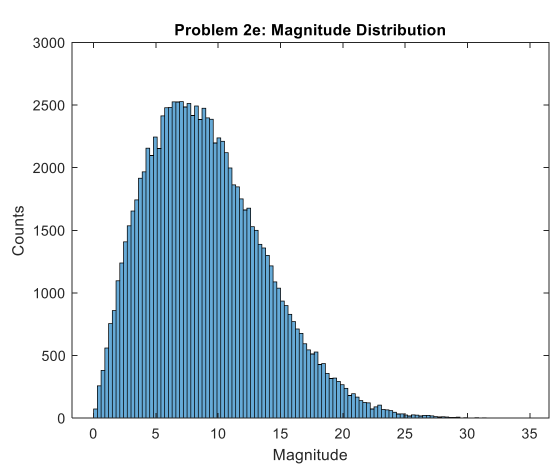
Problem 2 (continued)

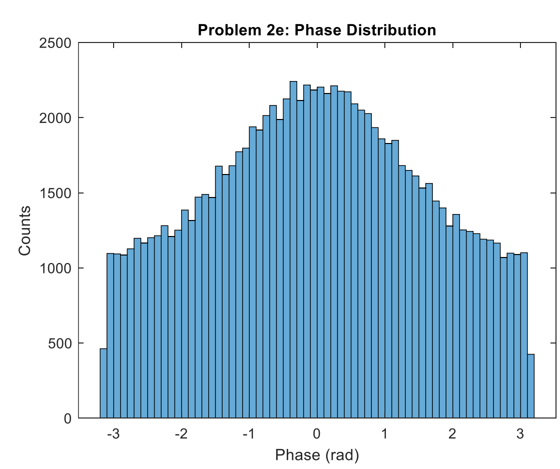
e)

twoparte.m:

```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end
%%
Ed = 200;
thetad = 0;

phasor = phasor + Ed*exp(1i*thetad);

mag = abs(phasor);
phase = angle(phasor);

figure(7);
maghist = histogram(mag);
title('Problem 2e: Magnitude Distribution');
xlabel('Magnitude');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

figure(8);
phasehist = histogram(phase);
title('Problem 2e: Phase Distribution');
xlabel('Phase (rad)');ylabel('Counts');

phaseHistBins = phasehist.BinCounts;
phaseHistEdges = phasehist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);


moment1phase = mean(phase);
moment2phase = var(phase);

fprintf('The first moment (mean) of the Magnitude Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Magnitude Distribution is: %.3f\n',moment2mag);

fprintf('The first moment (mean) of the Phase Distribution is: %.3f rad\n',moment1phase);
fprintf('The second moment (variance) of the Phase Distribution is: %.3f rad\n',moment2phase);
```

For Ed = 2:

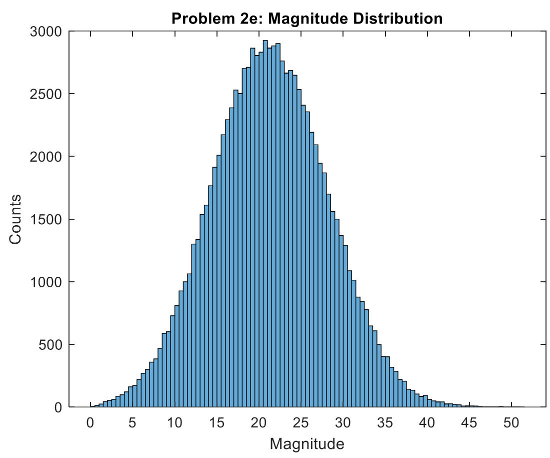


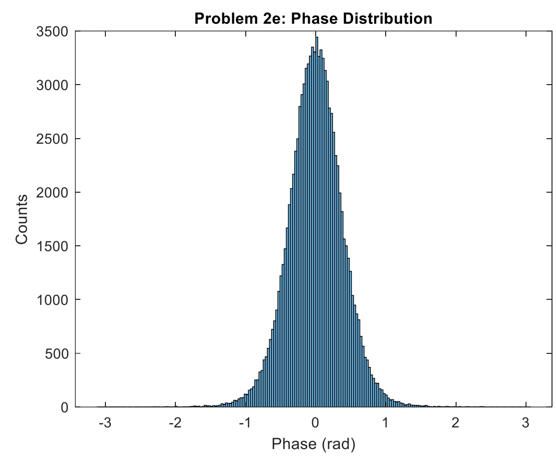


Problem 2 (continued)

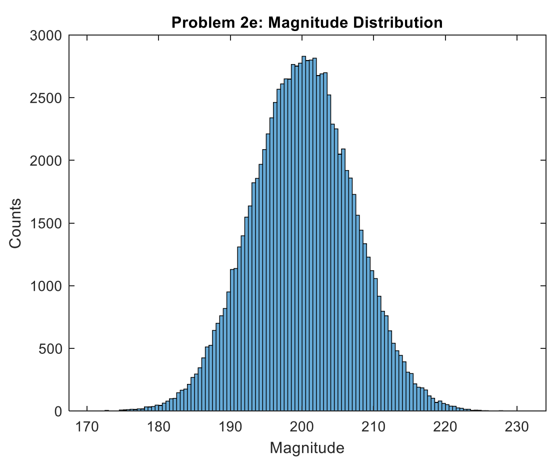
e) (continued)

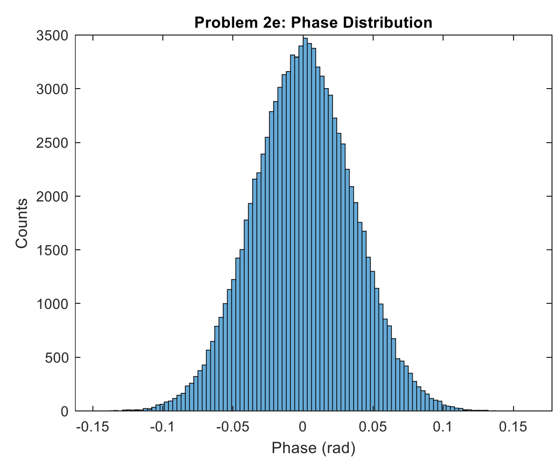
For Ed = 20:





For Ed = 200:





As Ed approaches infinity, the magnitude distribution becomes more normally distributed around the value of Ed. In other words, as Ed increases, the deterministic phasor dictates the magnitude distribution. Also, the phase distribution also becomes more normal around 0 rad as Ed increases.

Problem 3

a)

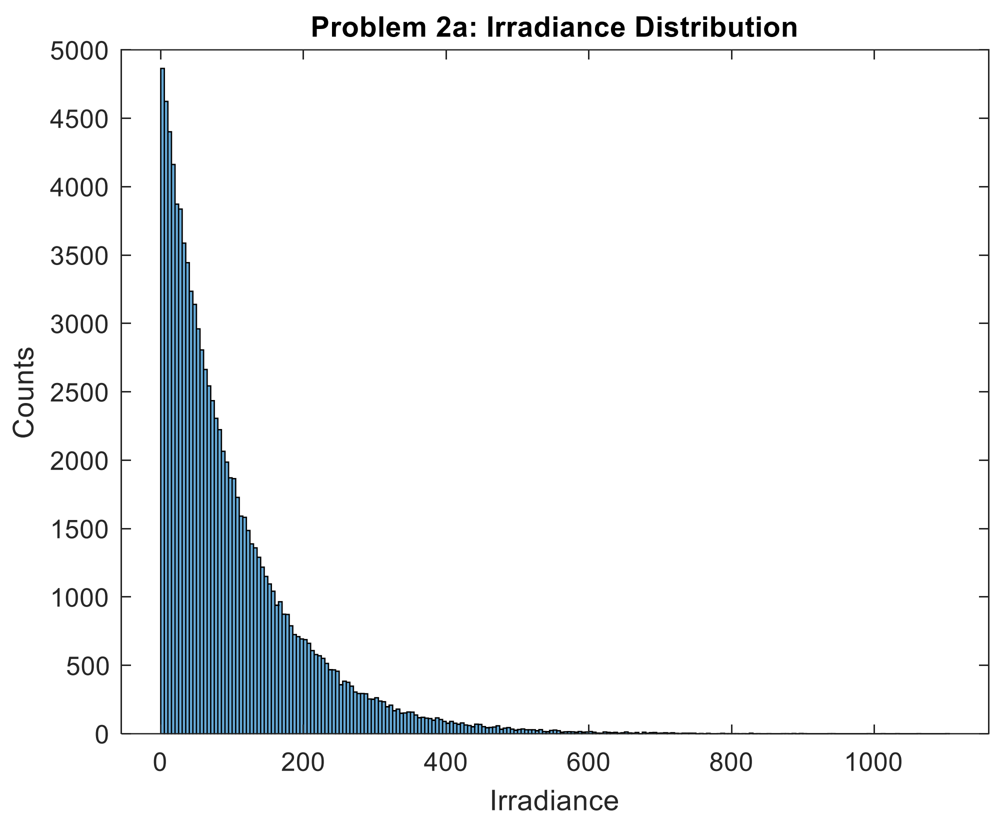
threeparta.m:

```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end
```

Problem 3 (continued)

a) (continued)

```
mag = (abs(phasor)).^2;

figure(1);
maghist = histogram(mag);
title('Problem 2a: Irradiance Distribution');
xlabel('Irradiance');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);

fprintf('The first moment (mean) of the Irradiance Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Irradiance Distribution is: %.3f\n',moment2mag);
```




```
The first moment (mean) of the Irradiance Distribution is: 99.970

The second moment (variance) of the Irradiance Distribution is: 9843.156
```

In the case of irradiance, only magnitude squared is taken into account.

b)

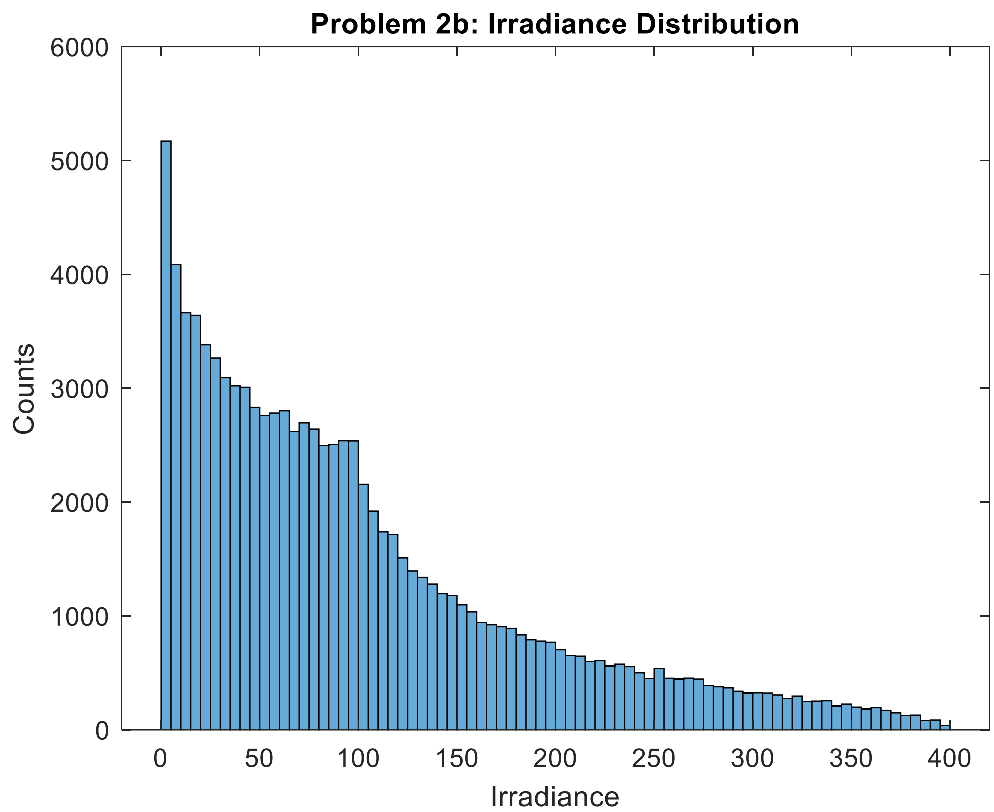
threepartb.m:

```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 4;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

mag = (abs(phasor)).^2;
```

Problem 3 (continued)

b) (continued)

```
figure(1);
maghist = histogram(mag);
title('Problem 2b: Irradiance Distribution');
xlabel('Irradiance');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);

fprintf('The first moment (mean) of the Irradiance Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Irradiance Magnitude Distribution is:
%.3f\n',moment2mag);
```




```
The first moment (mean) of the Irradiance Distribution is: 100.126

The second moment (variance) of the Irradiance Magnitude Distribution is: 7514.734
```

Similar to problem 2, there needs to be at least 5 random phasors to reasonably converse to the large-number result. Shown above are the results for 4 random phasors and the breakdown of the irradiance distribution.

c)

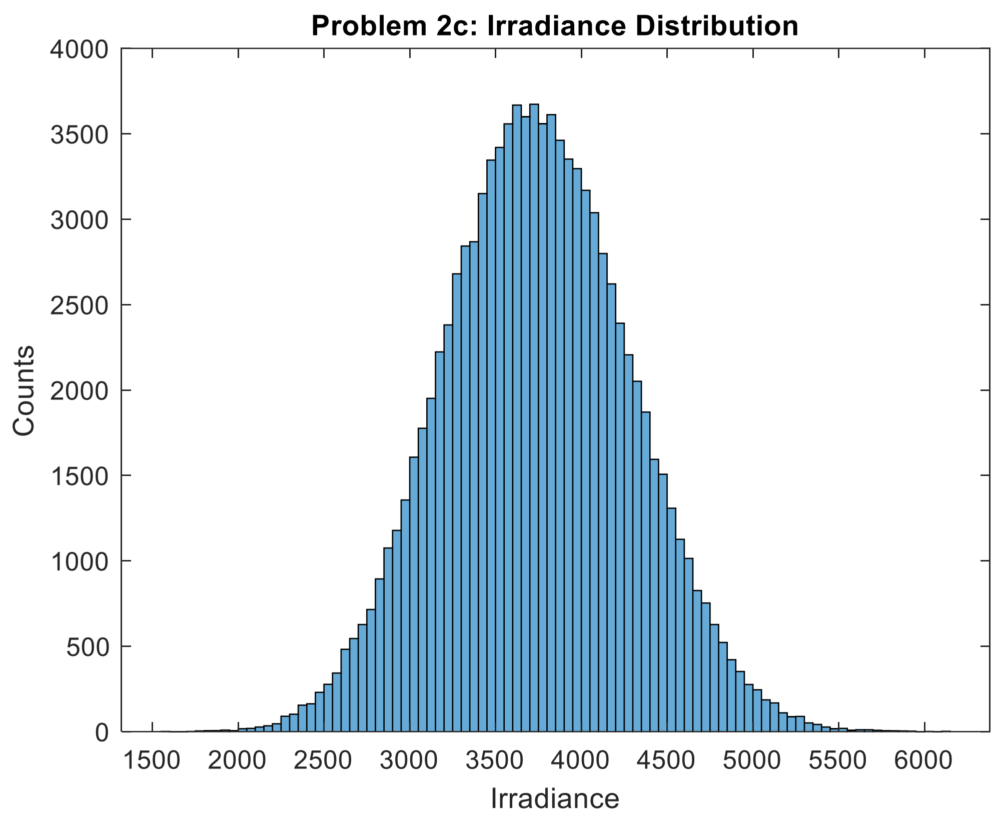
threepartc.m:

```
magDist = @constantMag;
phaseDist = @normalPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

mag = (abs(phasor)).^2;
```

Problem 3 (continued)

c) (continued)

```
figure(1);
maghist = histogram(mag);
title('Problem 2c: Irradiance Distribution');
xlabel('Irradiance');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);

fprintf('The first moment (mean) of the Irradiance Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Irradiance Magnitude Distribution is:
%.3f\n',moment2mag);
```




```
The first moment (mean) of the Irradiance Distribution is: 3741.813

The second moment (variance) of the Irradiance Magnitude Distribution is: 293566.112
```

Similar to problem 2, changing the distribution of the phase to normal results in a normal distribution of irradiance.

d)

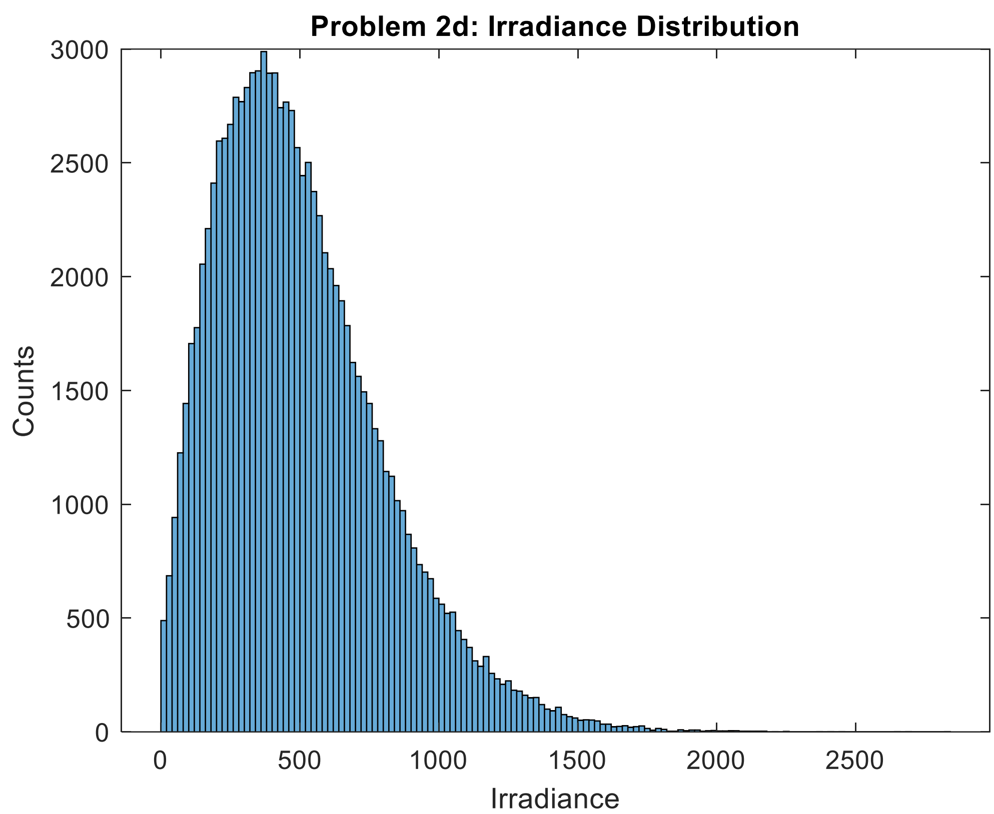
threepartd.m:

```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

Ed = 20;
thetad = 0;
```

Problem 3 (continued)

d) (continued)

```
phasor = phasor + Ed*exp(1i*thetad);

mag = (abs(phasor)).^2;

figure(1);
maghist = histogram(mag);
title('Problem 2d: Irradiance Distribution');
xlabel('Irradiance');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);

fprintf('The first moment (mean) of the Irradiance Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Irradiance Magnitude Distribution is:
%.3f\n',moment2mag);
```




```
The first moment (mean) of the Irradiance Distribution is: 499.397

The second moment (variance) of the Irradiance Magnitude Distribution is: 90028.984
```

e)

threeparte.m:

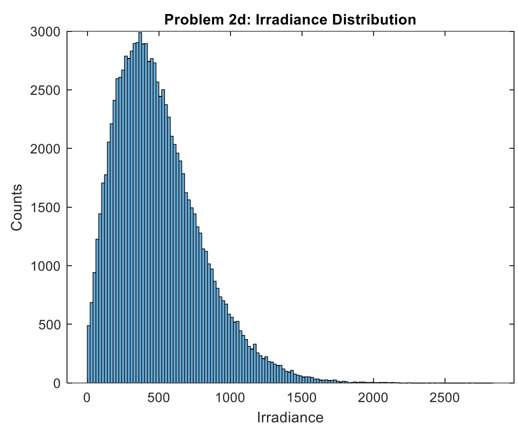
```
magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 10^5;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M

    phasor(k) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);

end

Ed = 2000;
```

Problem 3 (continued)

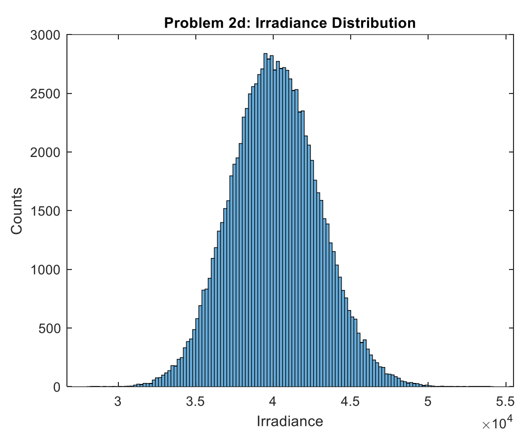
e) (continued)

```
thetad = 0;

phasor = phasor + Ed*exp(1i*thetad);

mag = (abs(phasor)).^2;

figure(1);
maghist = histogram(mag);
title('Problem 2d: Irradiance Distribution');
xlabel('Irradiance');ylabel('Counts');

magHistBins = maghist.BinCounts;
magHistEdges = maghist.BinEdges;

moment1mag = mean(mag);
moment2mag = var(mag);

fprintf('The first moment (mean) of the Irradiance Distribution is: %.3f\n',moment1mag);
fprintf('The second moment (variance) of the Irradiance Magnitude Distribution is:
%.3f\n',moment2mag);
```

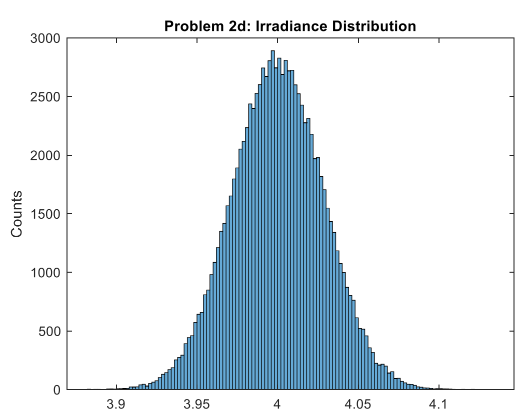
For Ed = 20:



For Ed = 200:



For Ed = 2000:



Problem 3 (continued)

e) (continued)

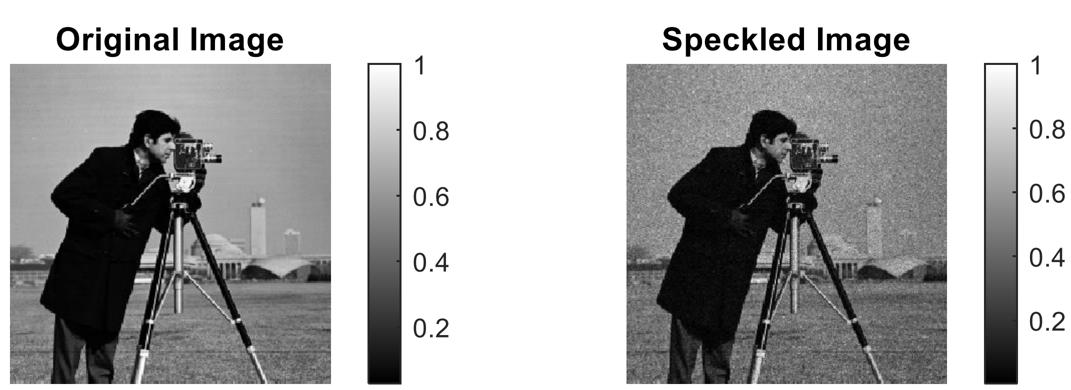
Similar to problem 2, as the value for Ed increases, the irradiance distribution becomes more normal around the value of the magnitude squared of Ed. This suggests that as Ed increases, the deterministic phasor dictates the irradiance distribution.

Problem 4

a)

fourparta.m:

```
ogpic = imread('cameraman.tif');
ogpic = double(ogpic);

magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 256;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
phaseMean = 10;
phaseVar = 1;

for k = 1:M
    for j = 1:M
        phasor(k,j) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);
    end
end

aplha = 10;
newpic = aplha.*sqrt(ogpic)+phasor;
newpic = (abs(newpic)).^2;

figure(1);
subplot(1,2,1);
imshow(ogpic./max(max(ogpic)),[]);colorbar;
title('Original Image');
subplot(1,2,2);
imshow(newpic./max(max(newpic)),[]);colorbar;
title('Speckled Image');
```



b)

fourpartb.m:

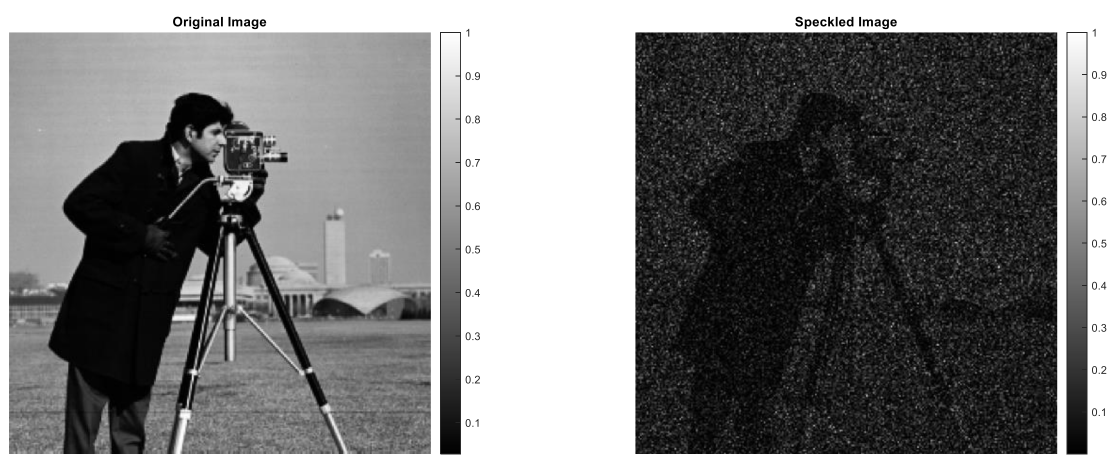
```
ogpic = imread('cameraman.tif');
ogpic = double(ogpic);

magDist = @constantMag;
phaseDist = @uniformPhase;

N = 10^2;
M = 256;
phasor = zeros(M,1);

magMean = 10;
magVar = 1;
```

Problem 4 (continued)

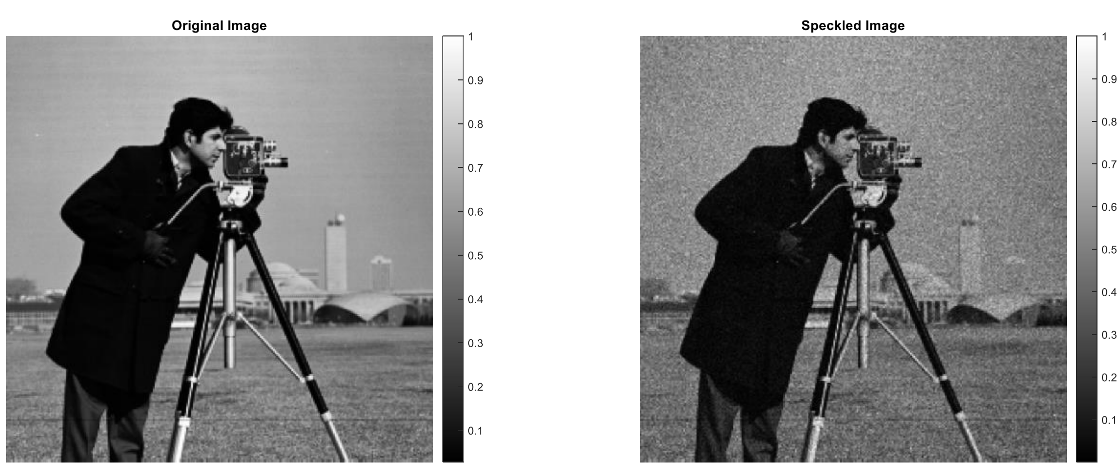
b) (continued)

```
phaseMean = 10;
phaseVar = 1;

for k = 1:M
    for j = 1:M
        phasor(k,j) = randomPhasorSum(N,magDist,magMean,magVar,phaseDist,phaseMean,phaseVar);
    end
end

aplha = 10;
newpic = aplha.*sqrt(ogpic)+phasor;
newpic = (abs(newpic)).^2;

figure(1);
subplot(1,2,1);
imshow(ogpic./max(max(ogpic)),[]);colorbar;
title('Original Image');
subplot(1,2,2);
imshow(newpic./max(max(newpic)),[]);colorbar;
title('Speckled Image');
```

For alpha = 1:



For alpha = 10:



Problem 4 (continued)

b) (continued)

For alpha = 100:

As the value of alpha decreases, the effect of the speckle on image quality increases. Inversely, as alpha increases, the original image and speckled image look more and more similar.

Problem 5

This homework took me 6 hours of productive time.