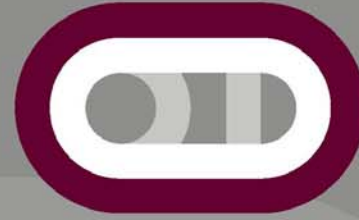


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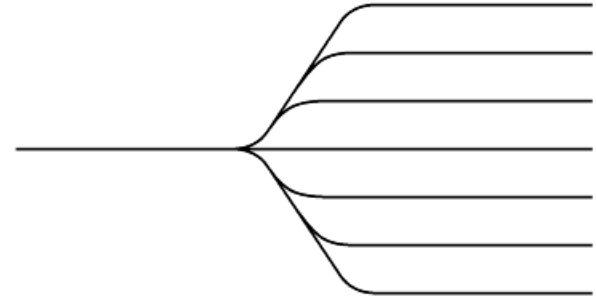
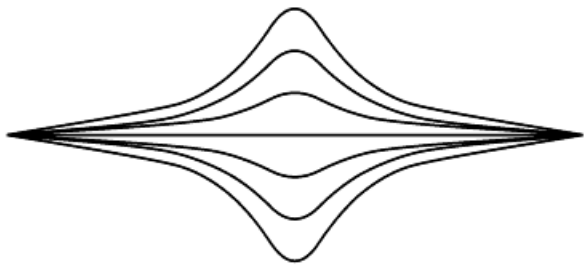
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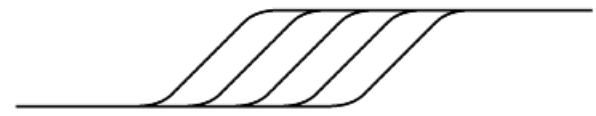
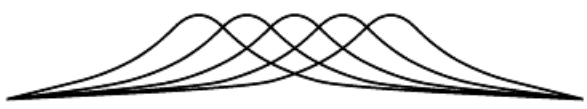
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Gain

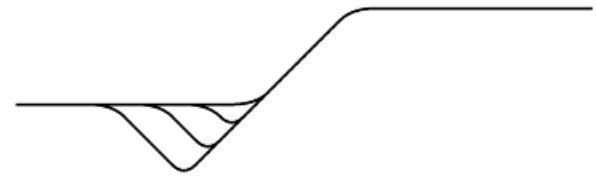


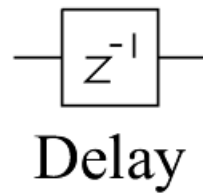
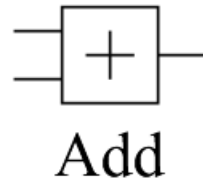
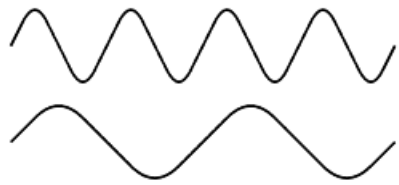
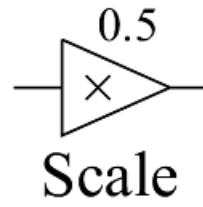
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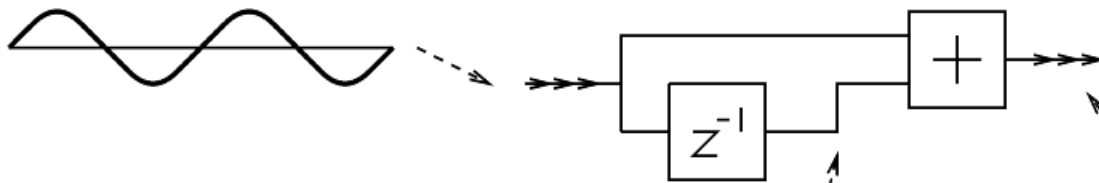


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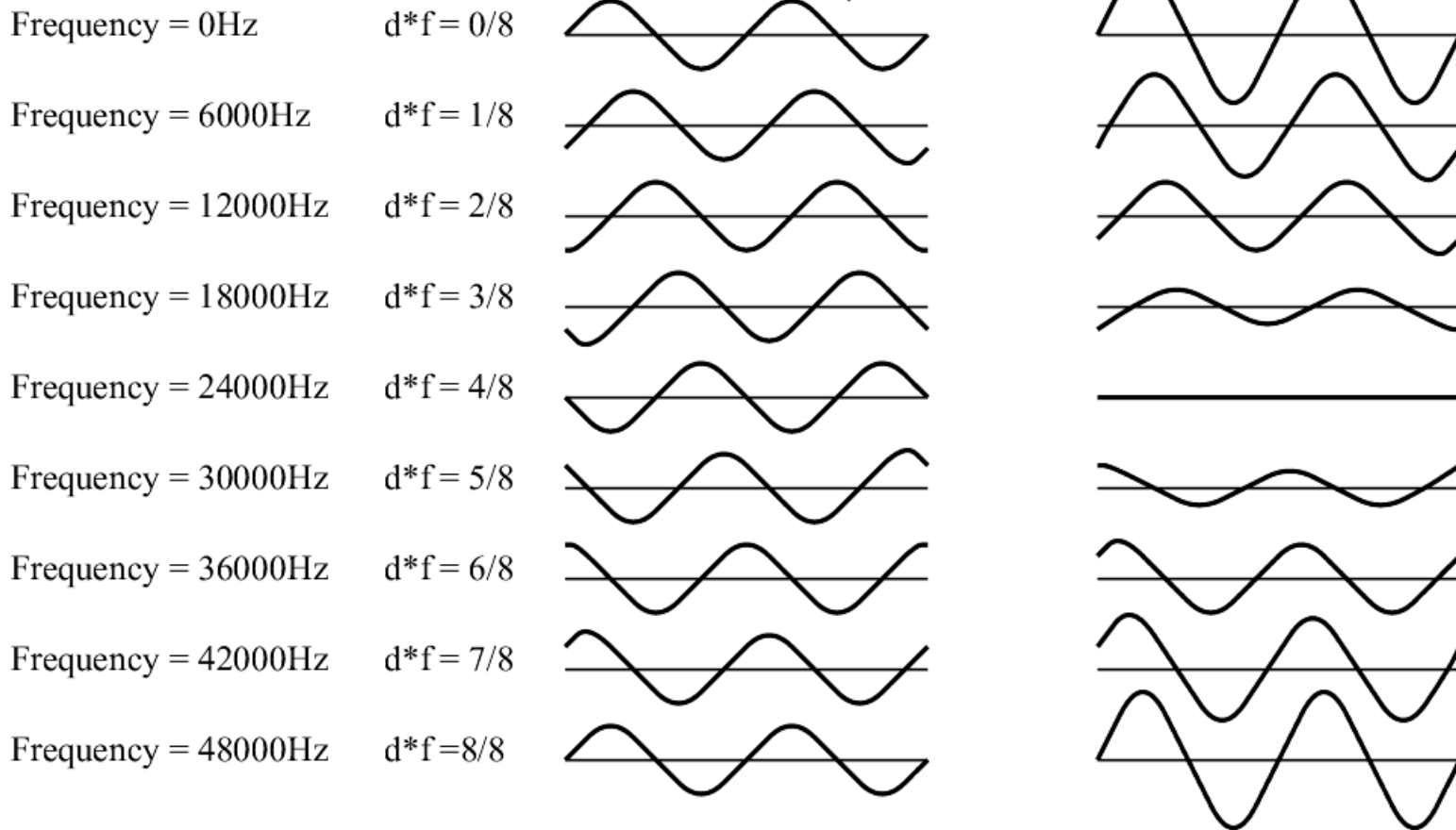
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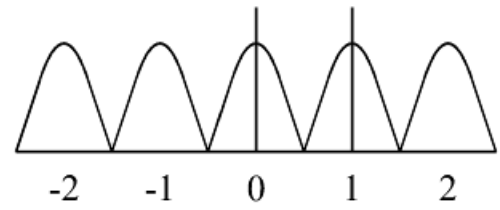
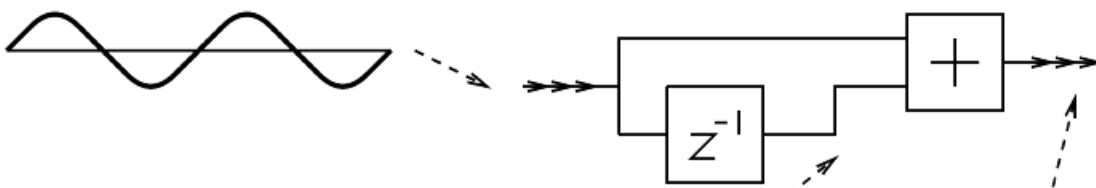




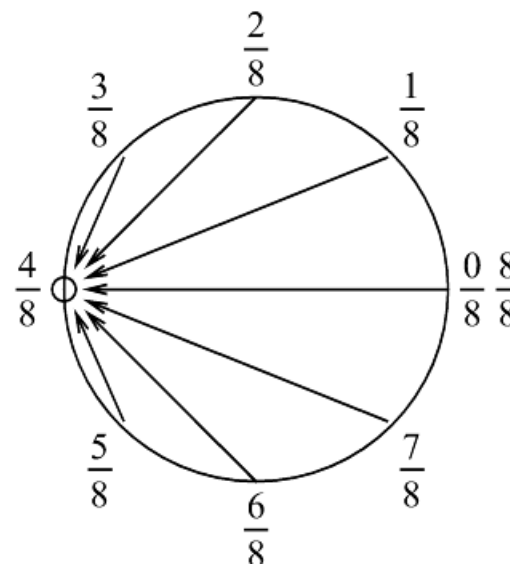
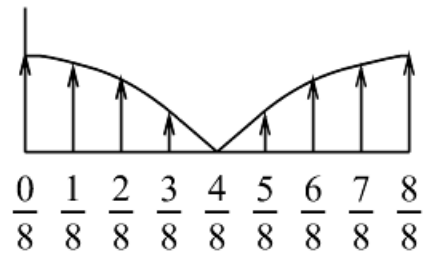
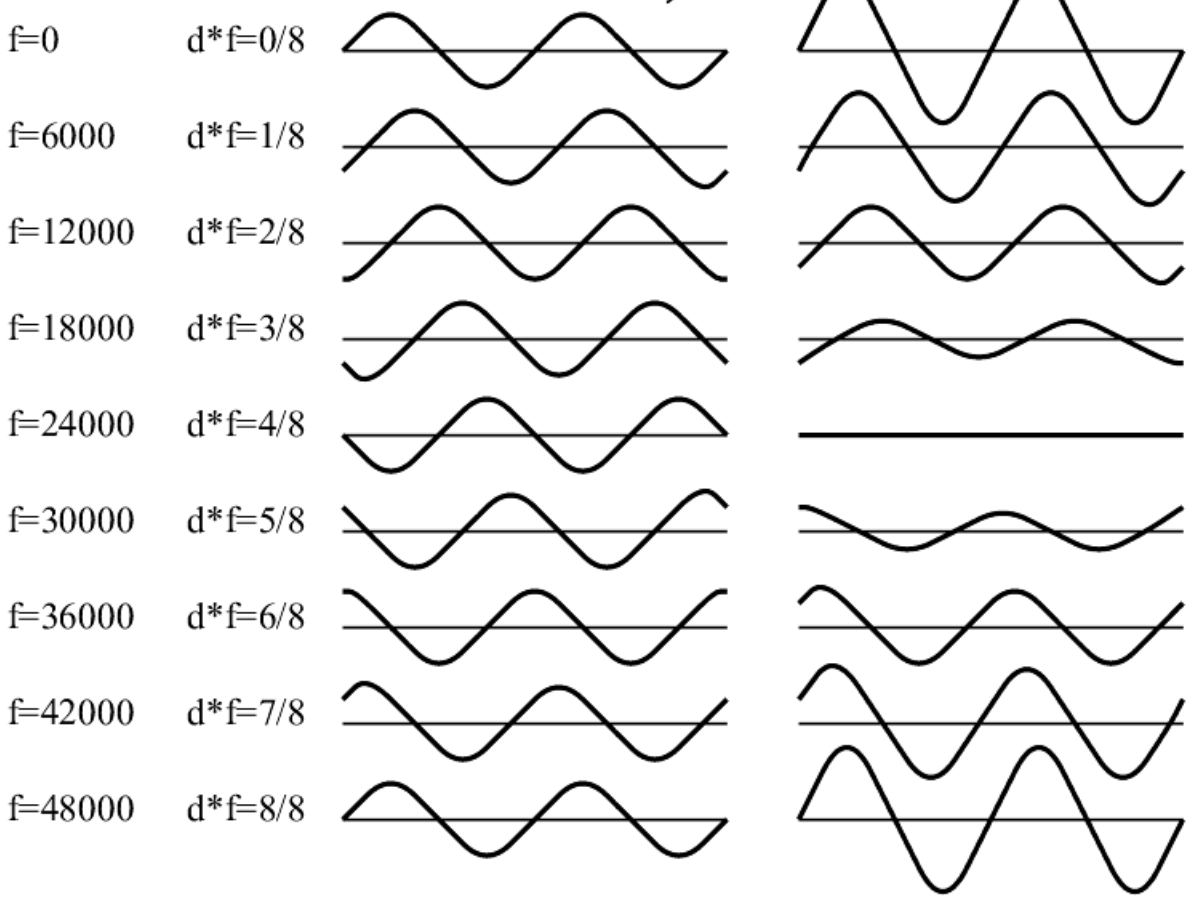


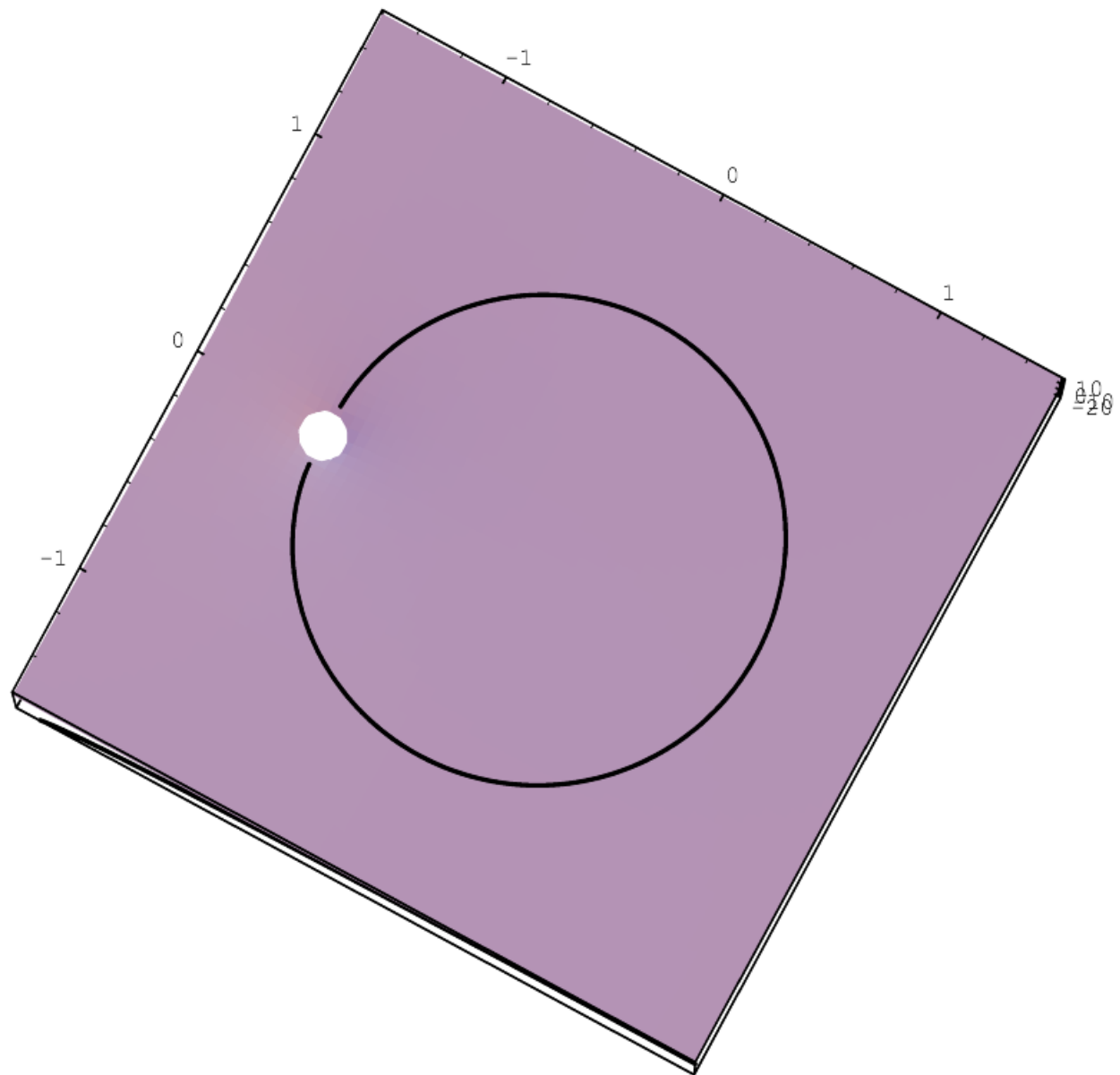
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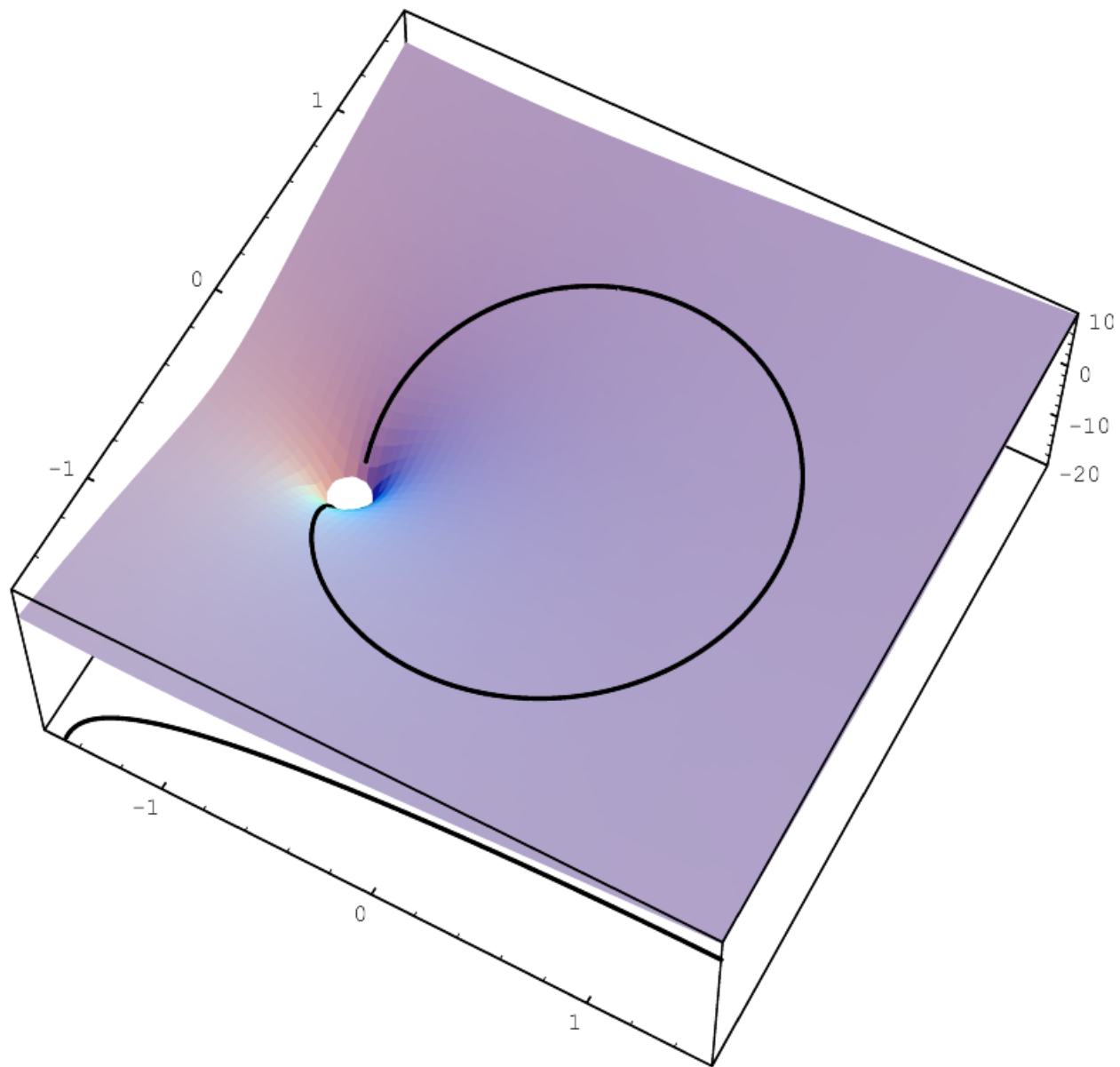


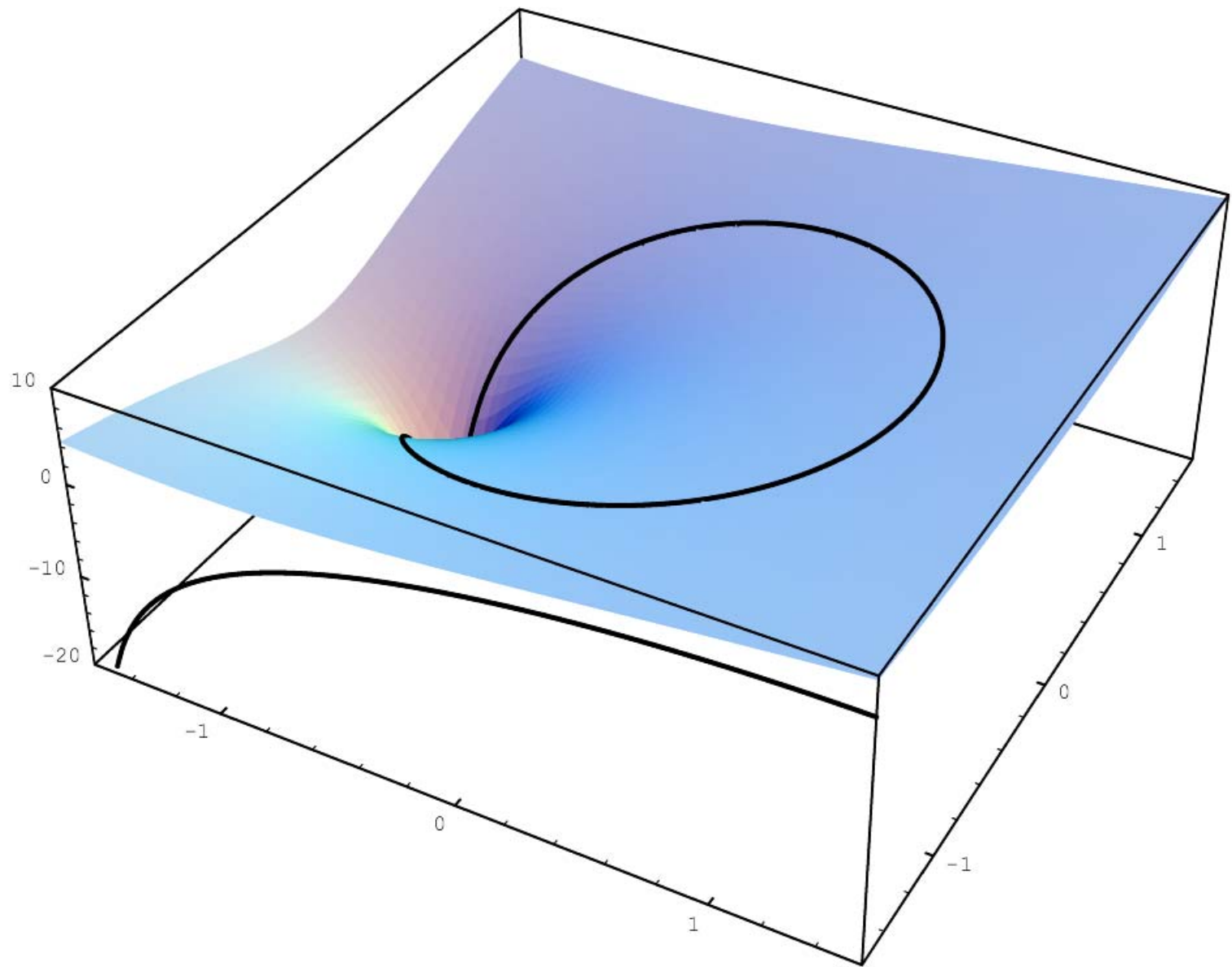


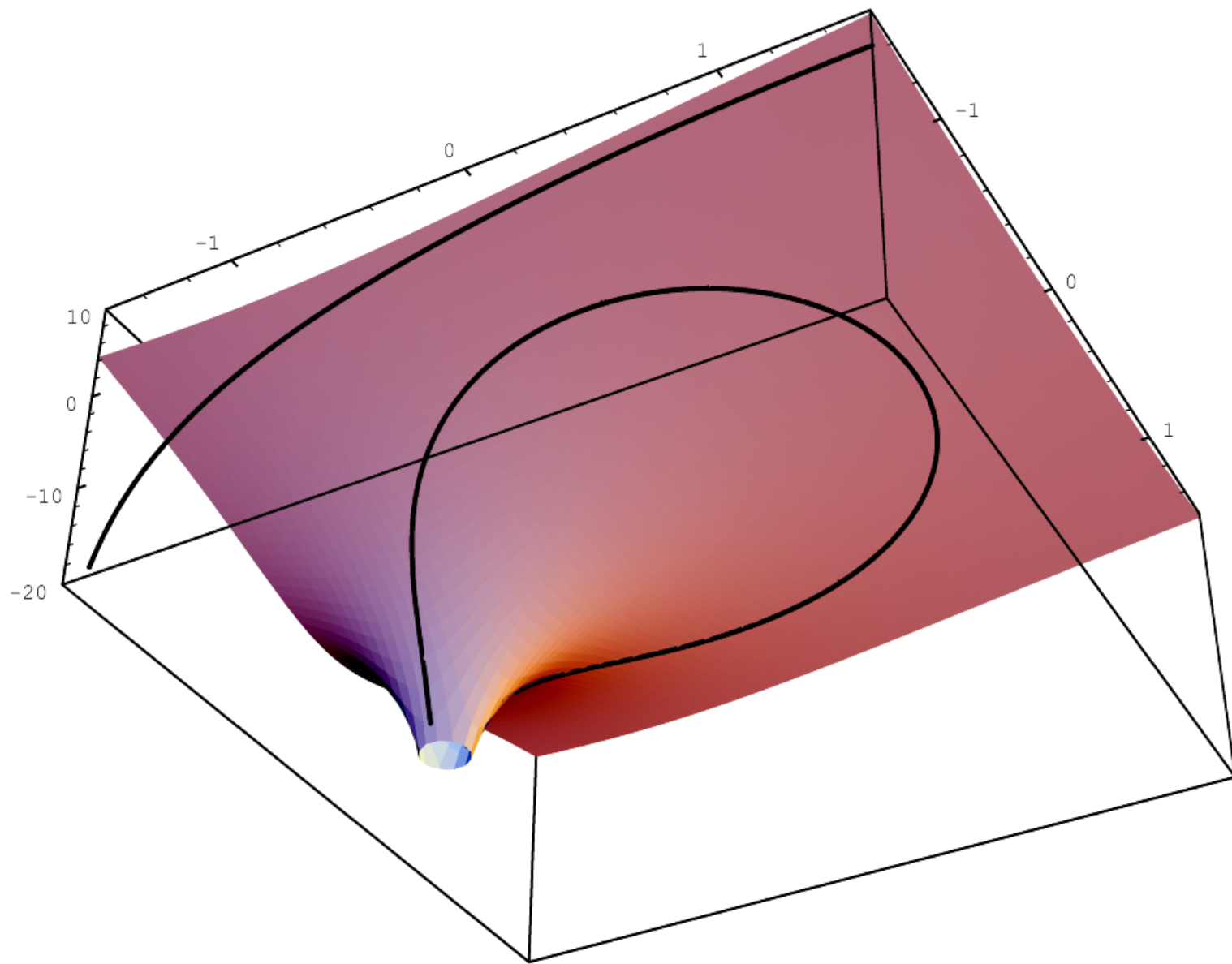
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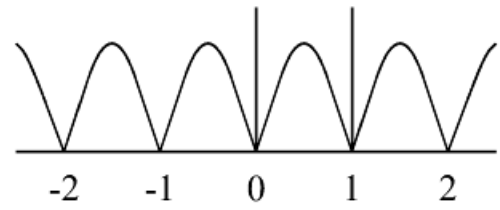
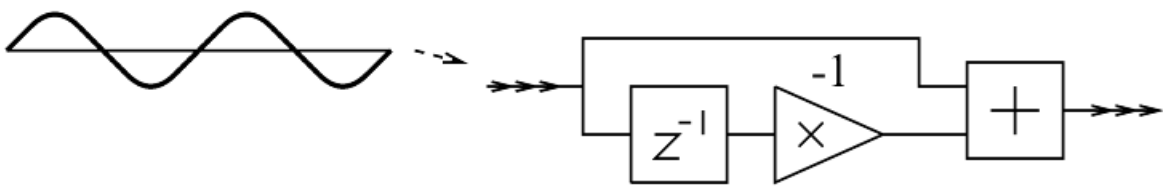




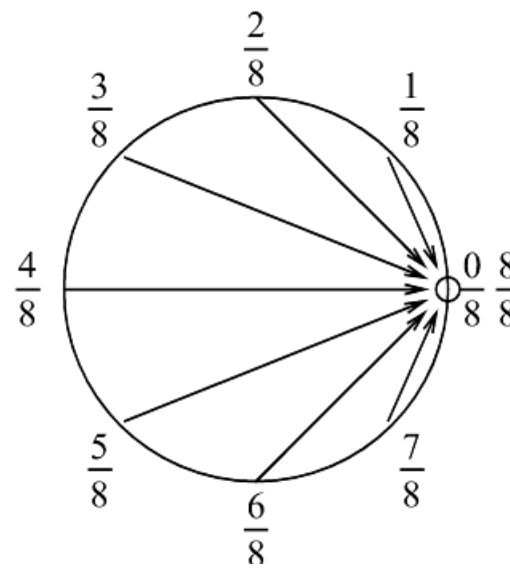
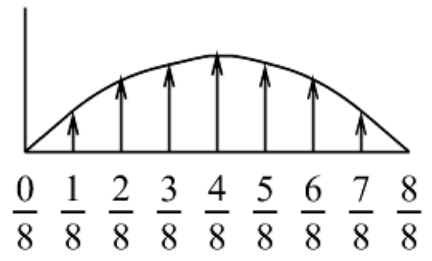
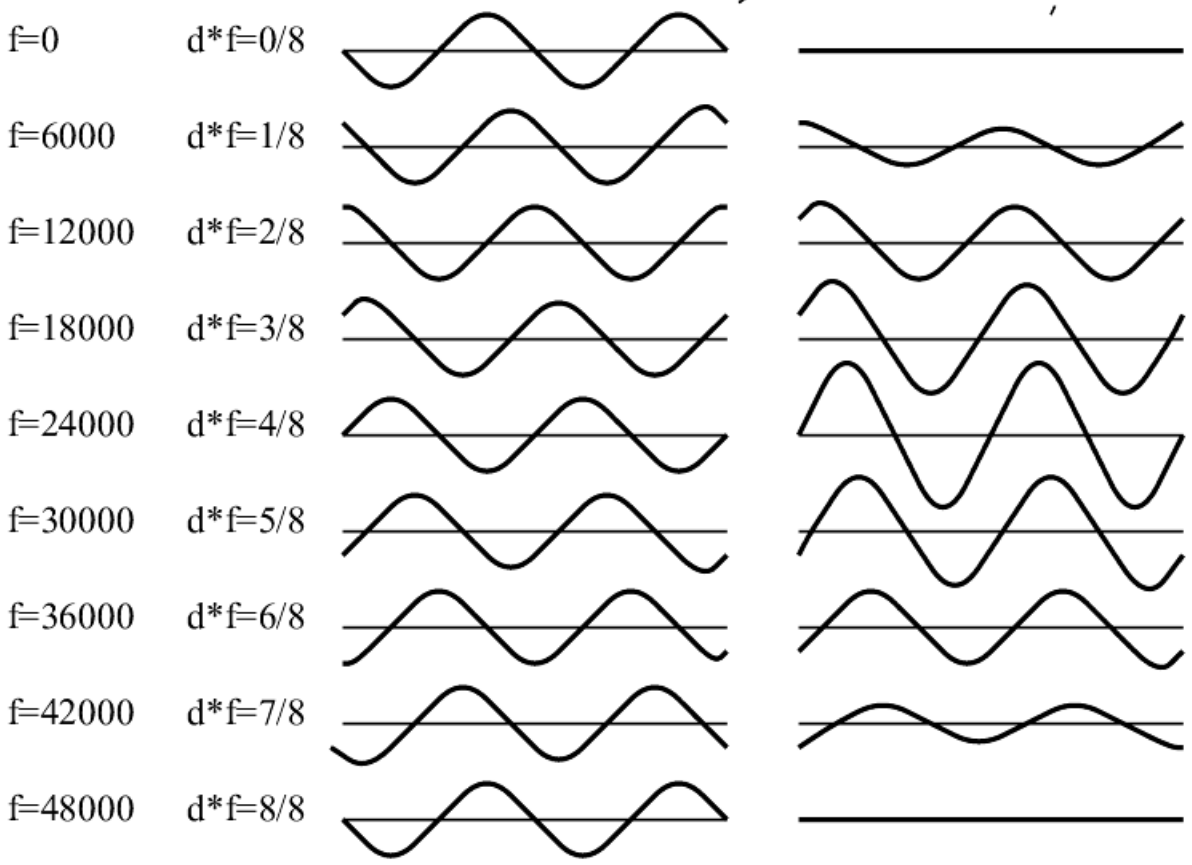


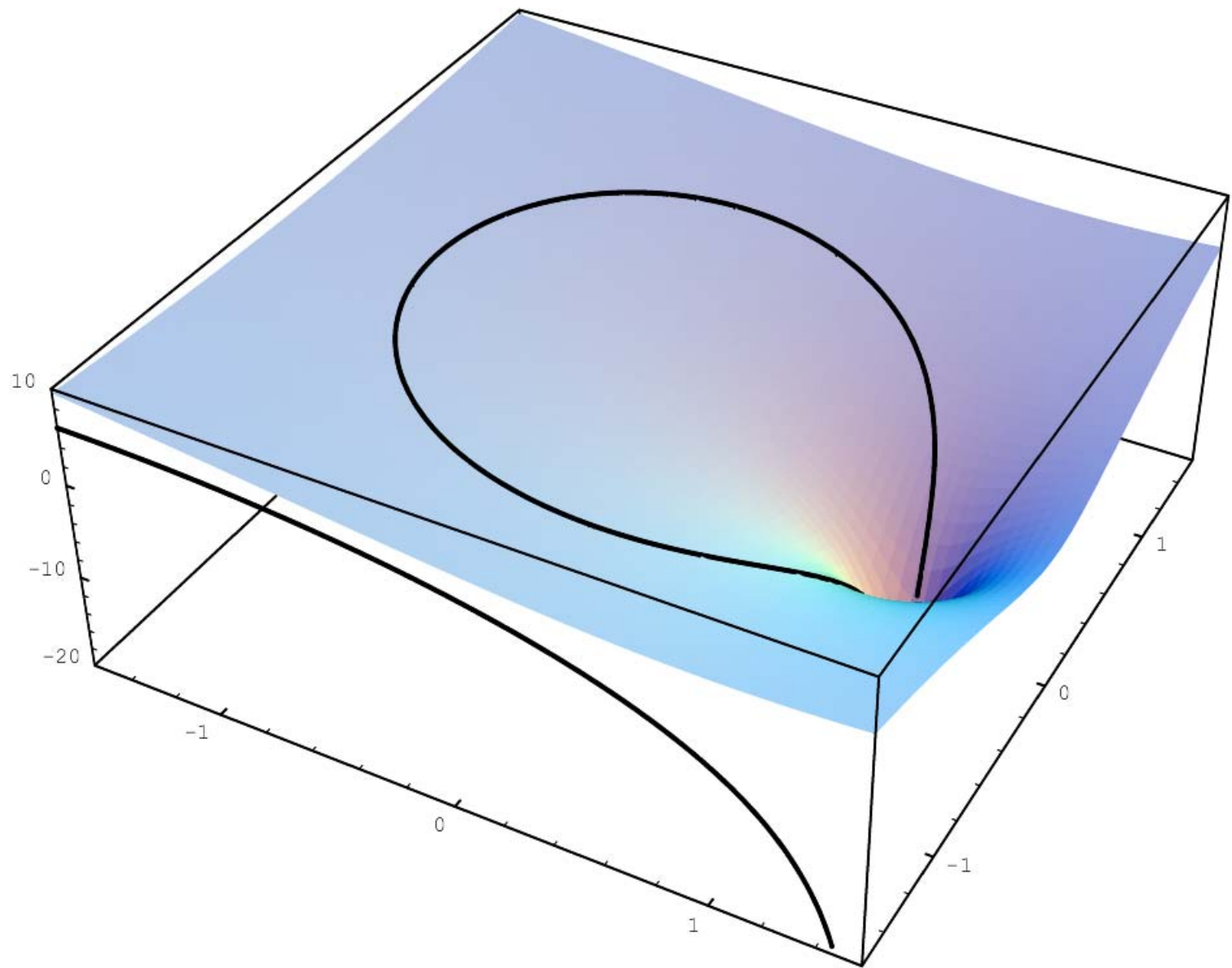


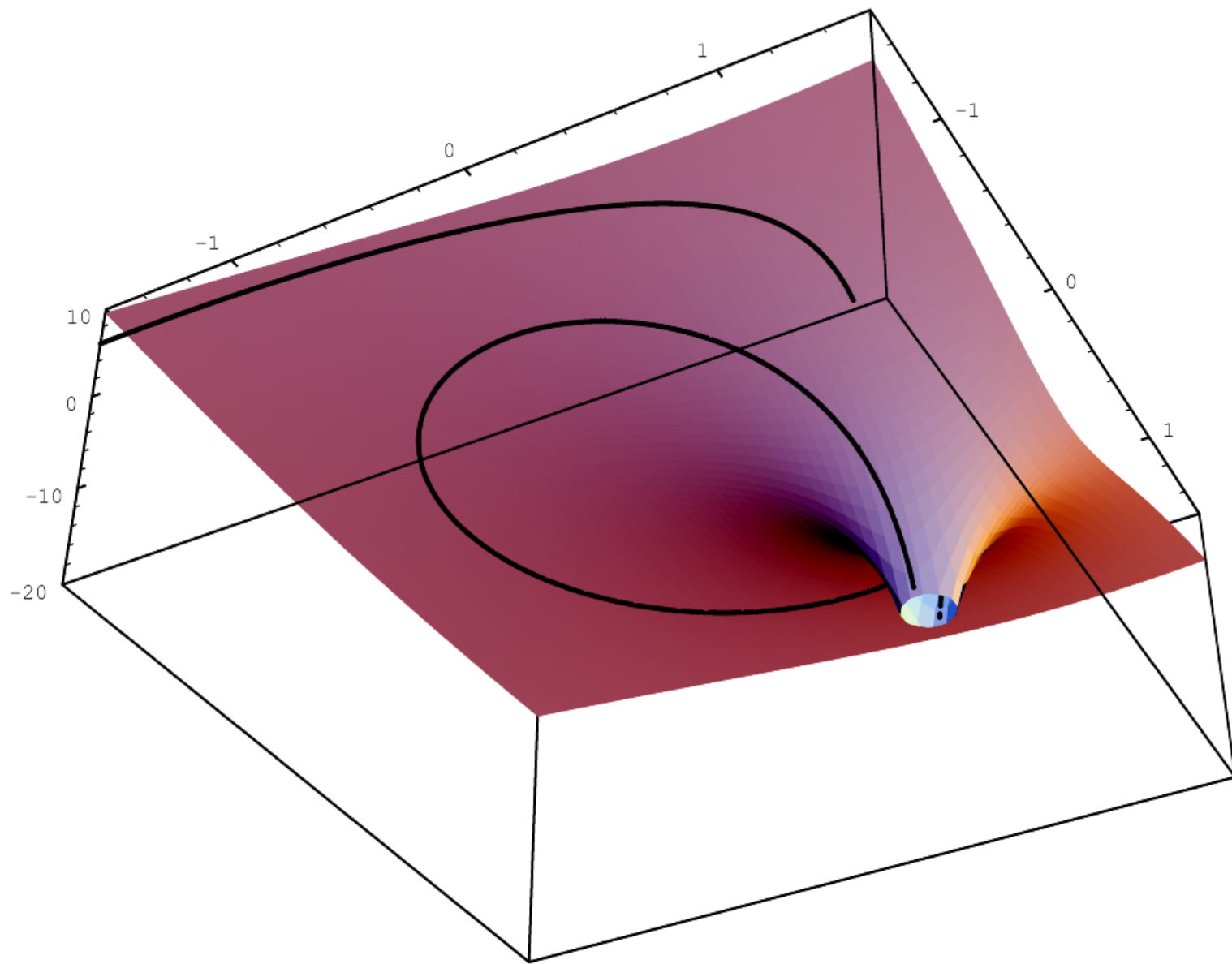


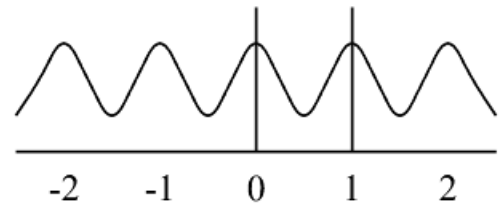
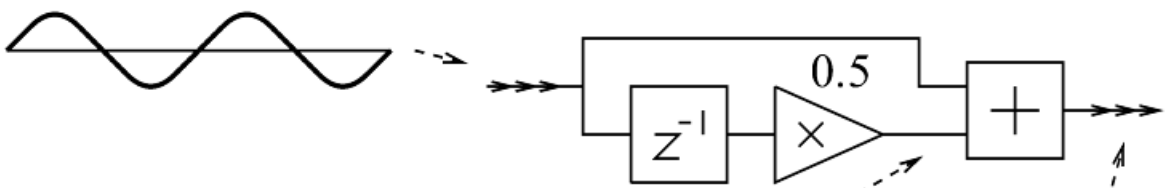


At $d=1/48000$

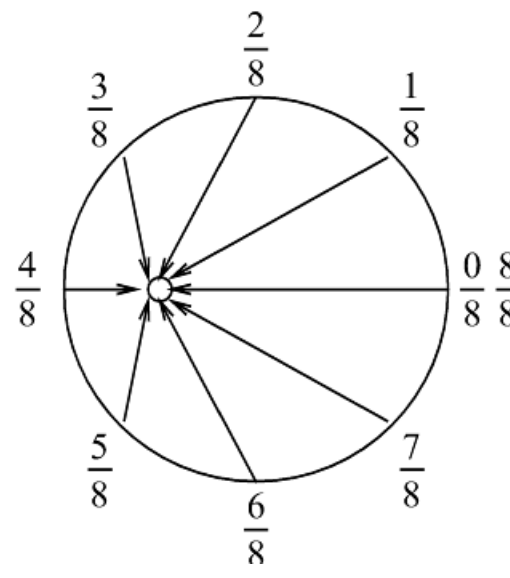
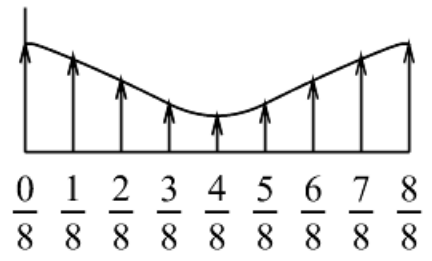
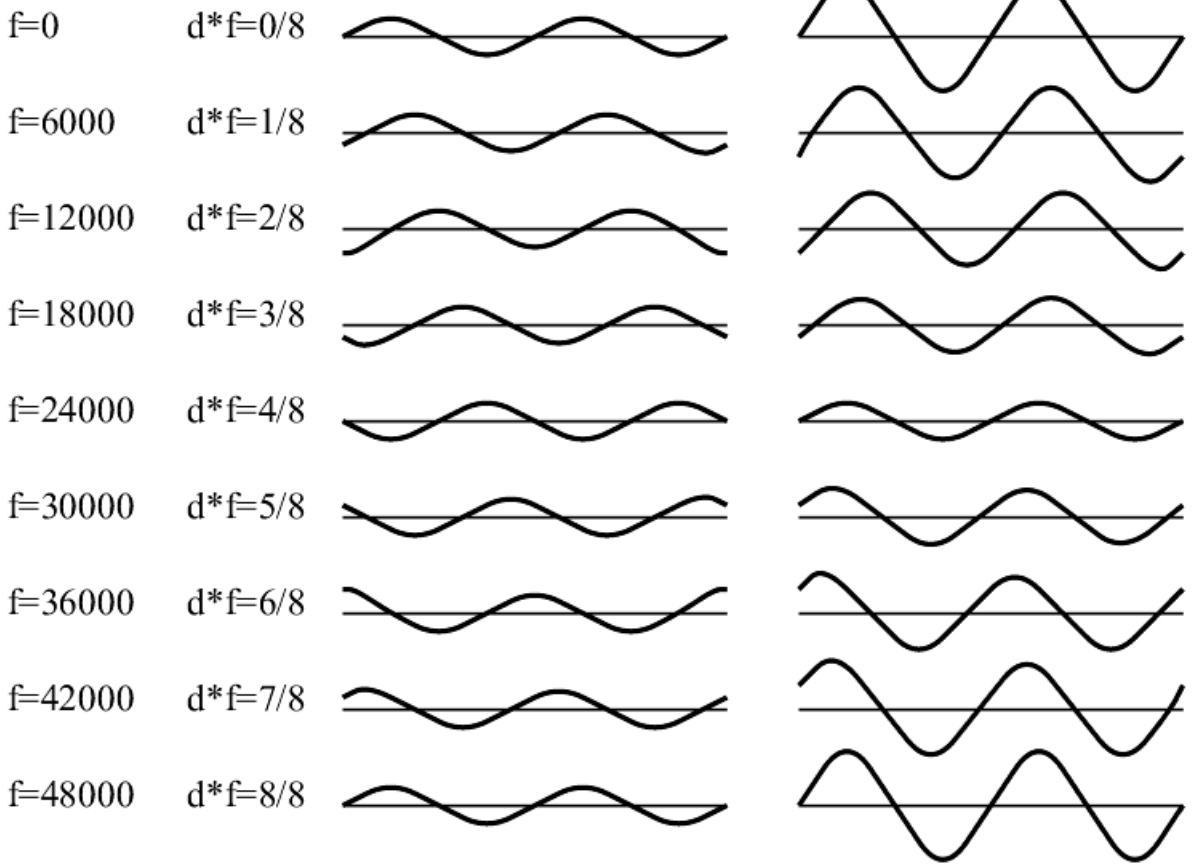


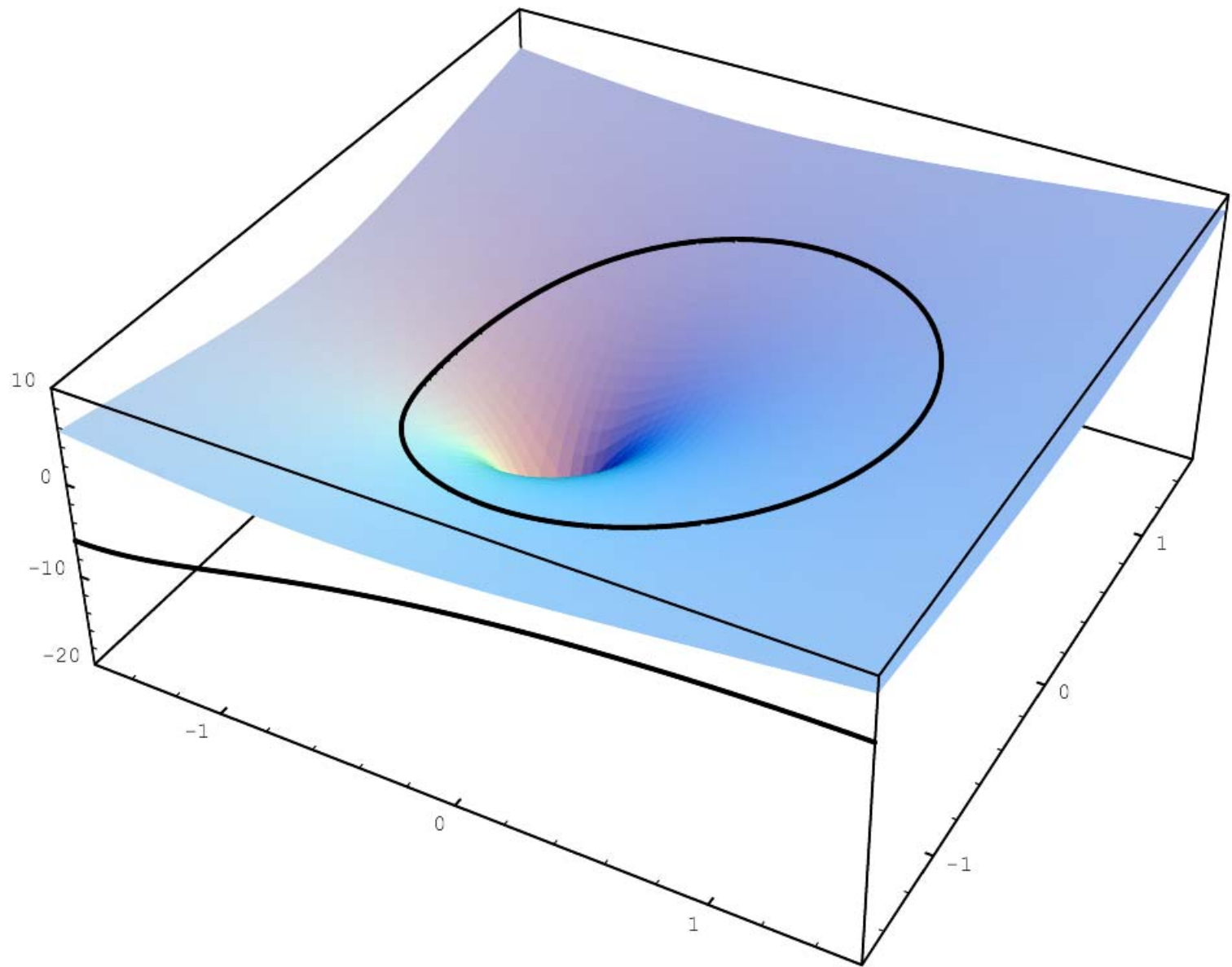


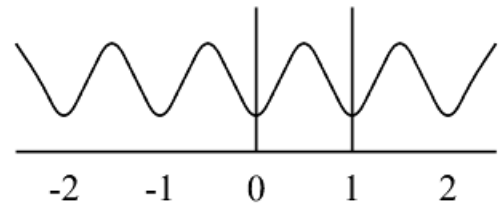
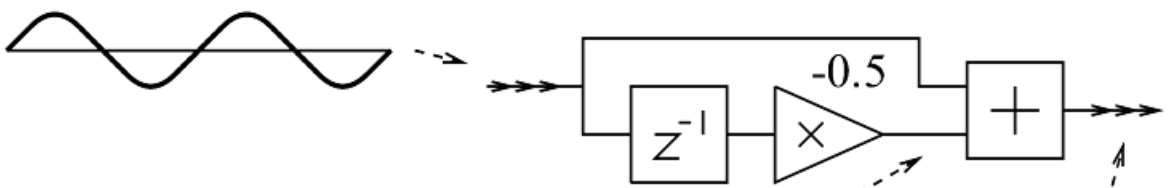




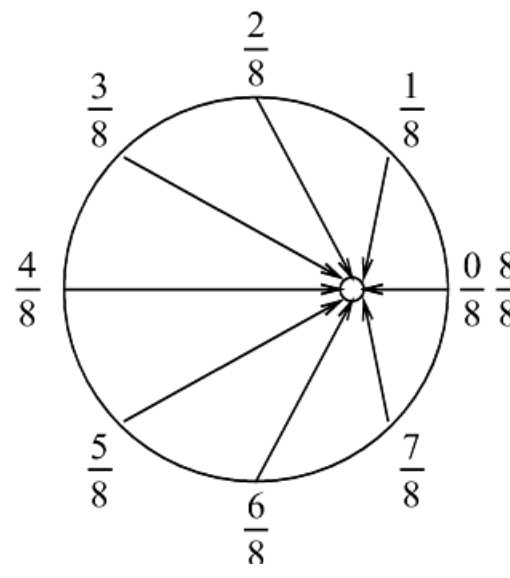
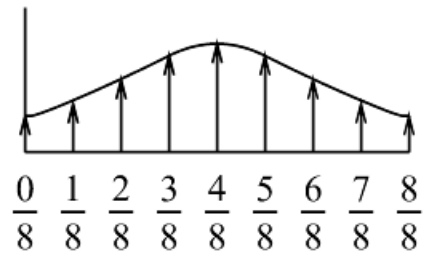
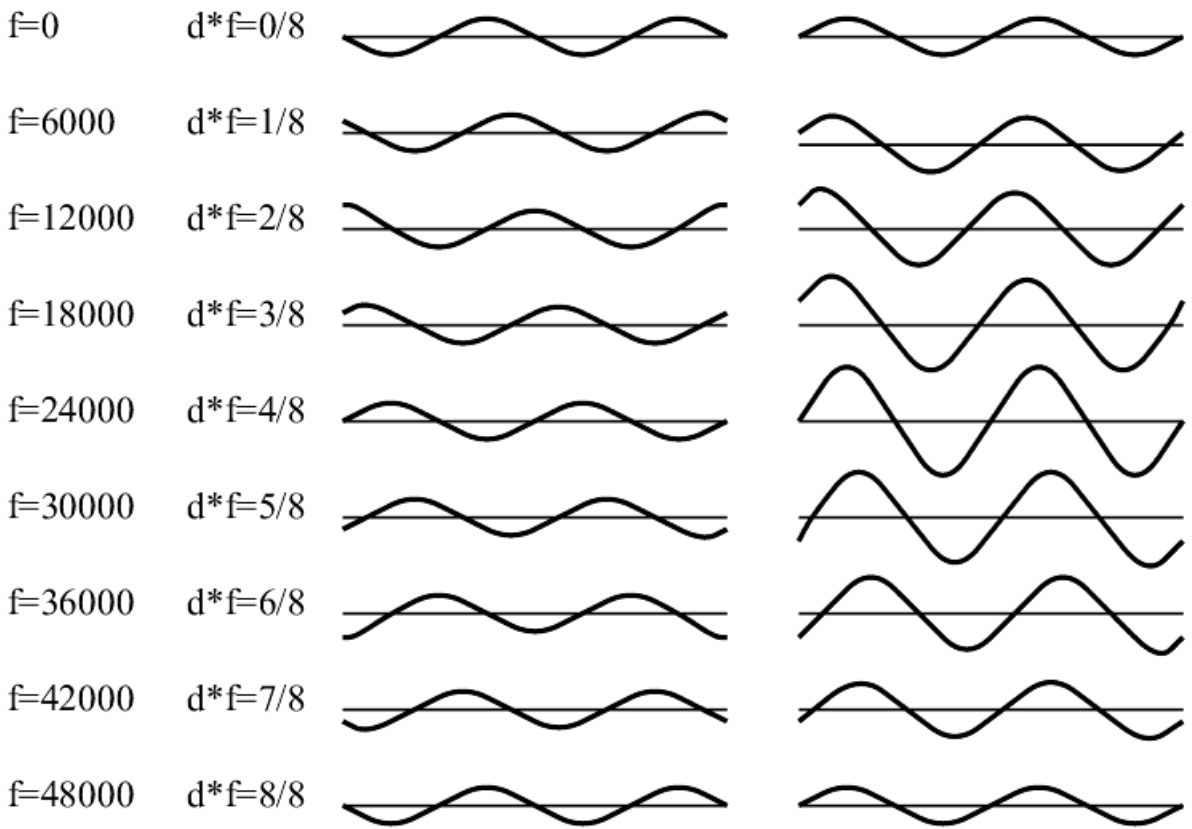
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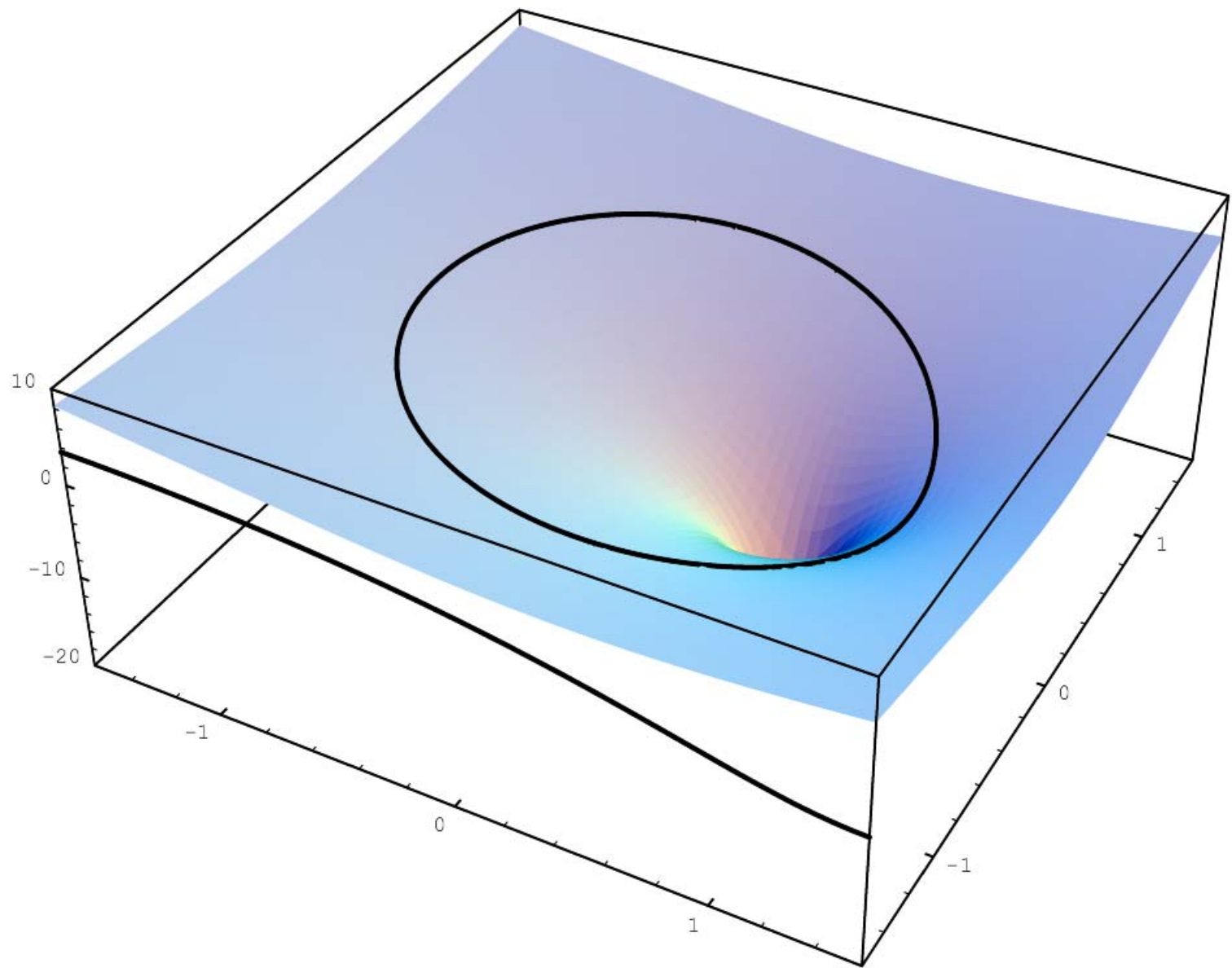


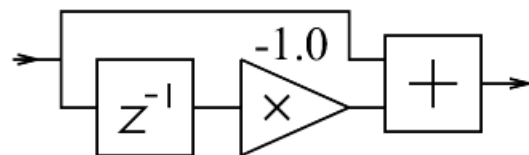
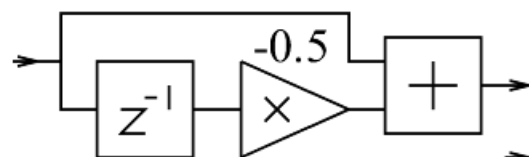
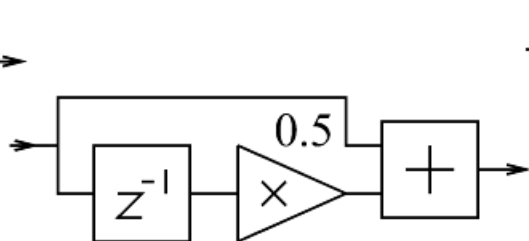
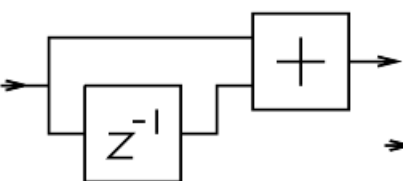
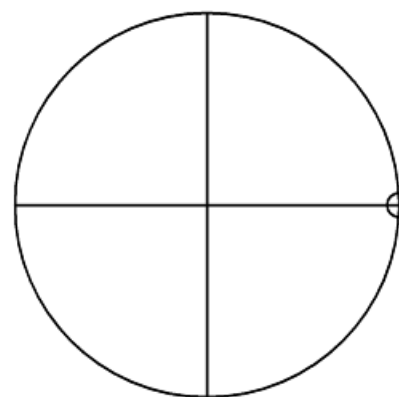
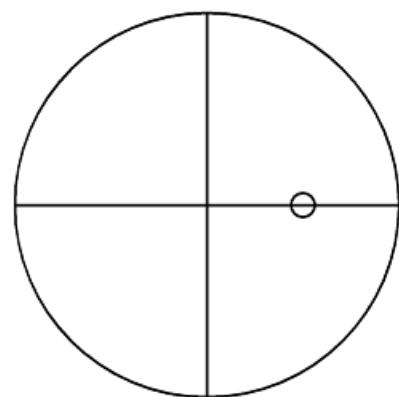
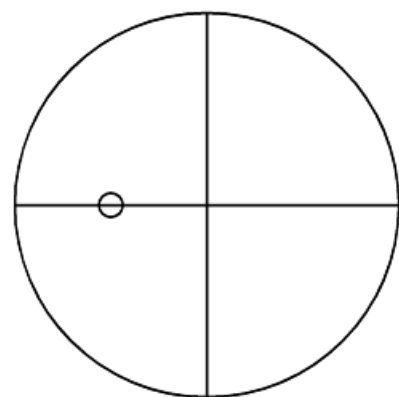
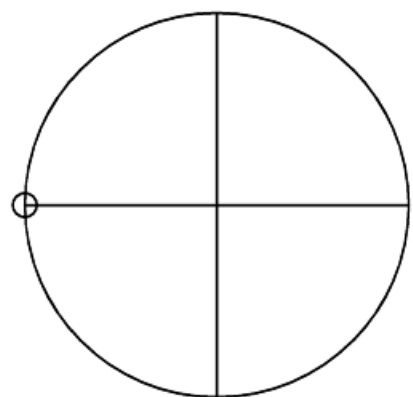
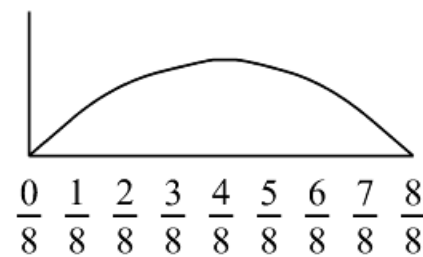
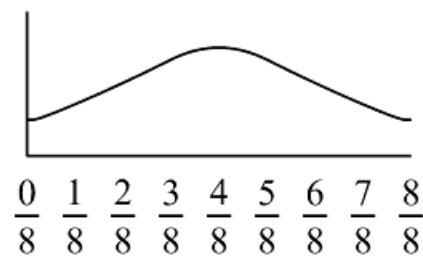
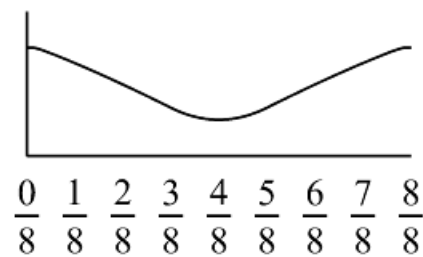
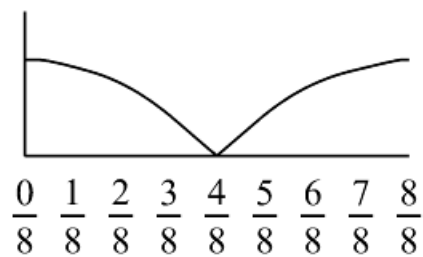
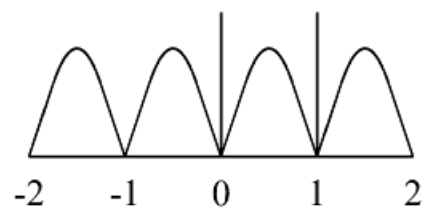
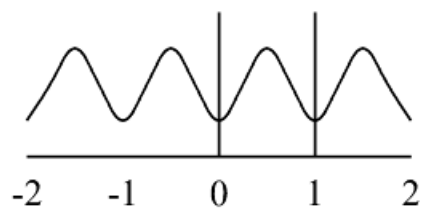
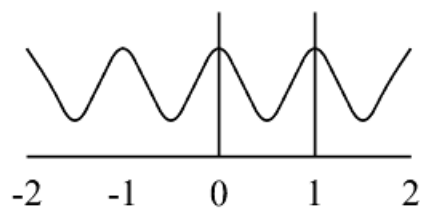
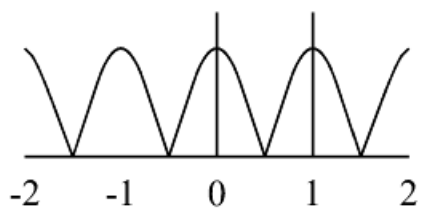


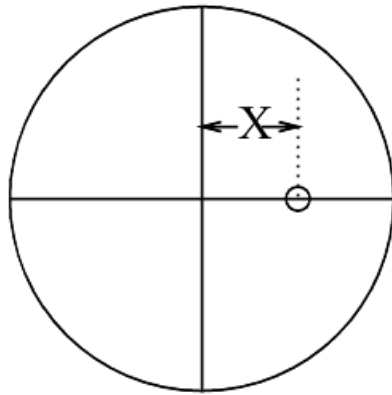


At $d=1/48000$

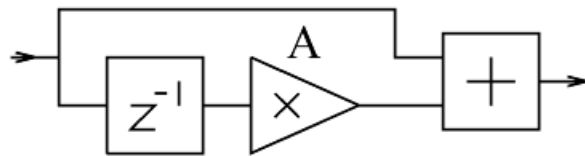




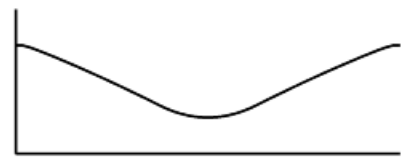




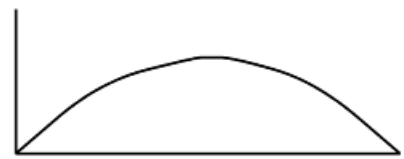
$$X = -A$$



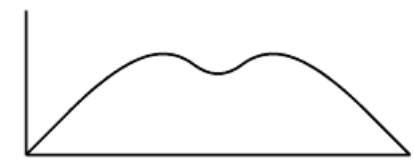
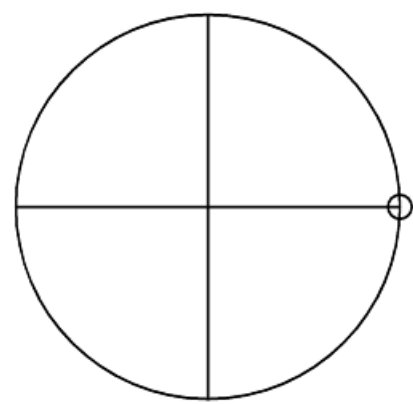
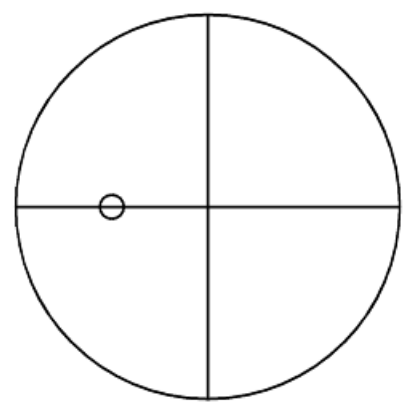
$$A = -X$$



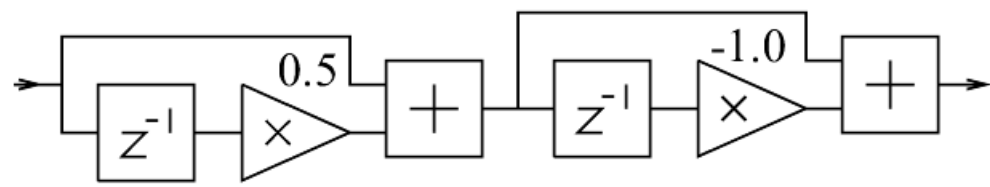
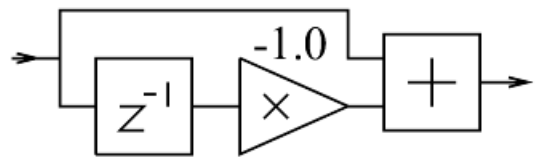
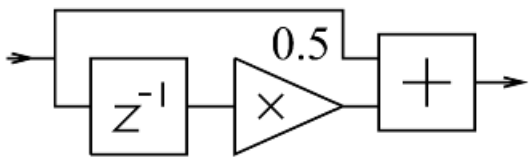
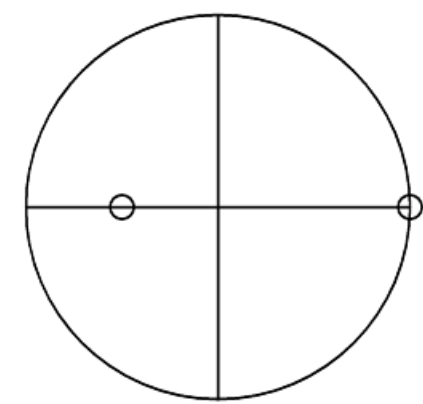
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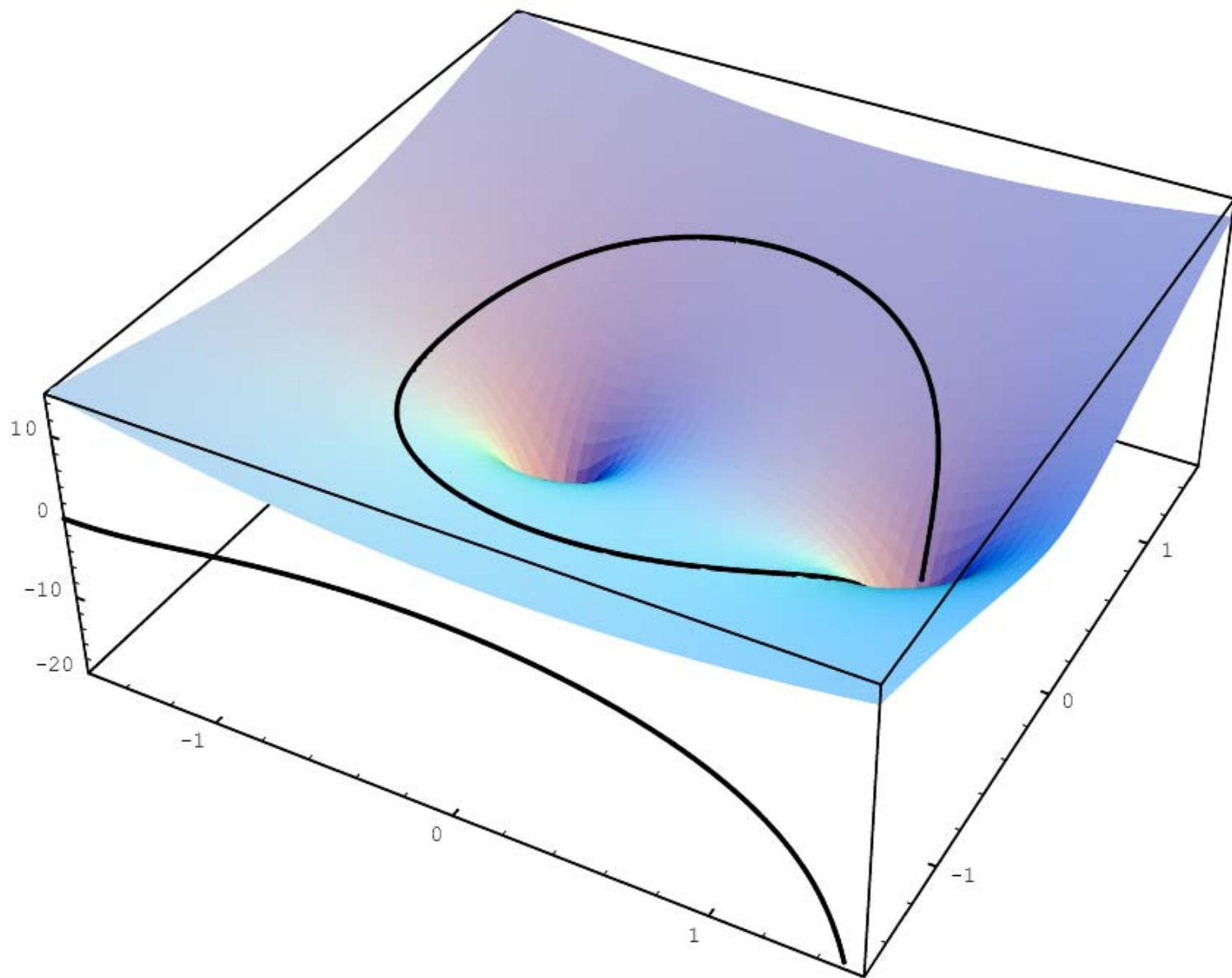


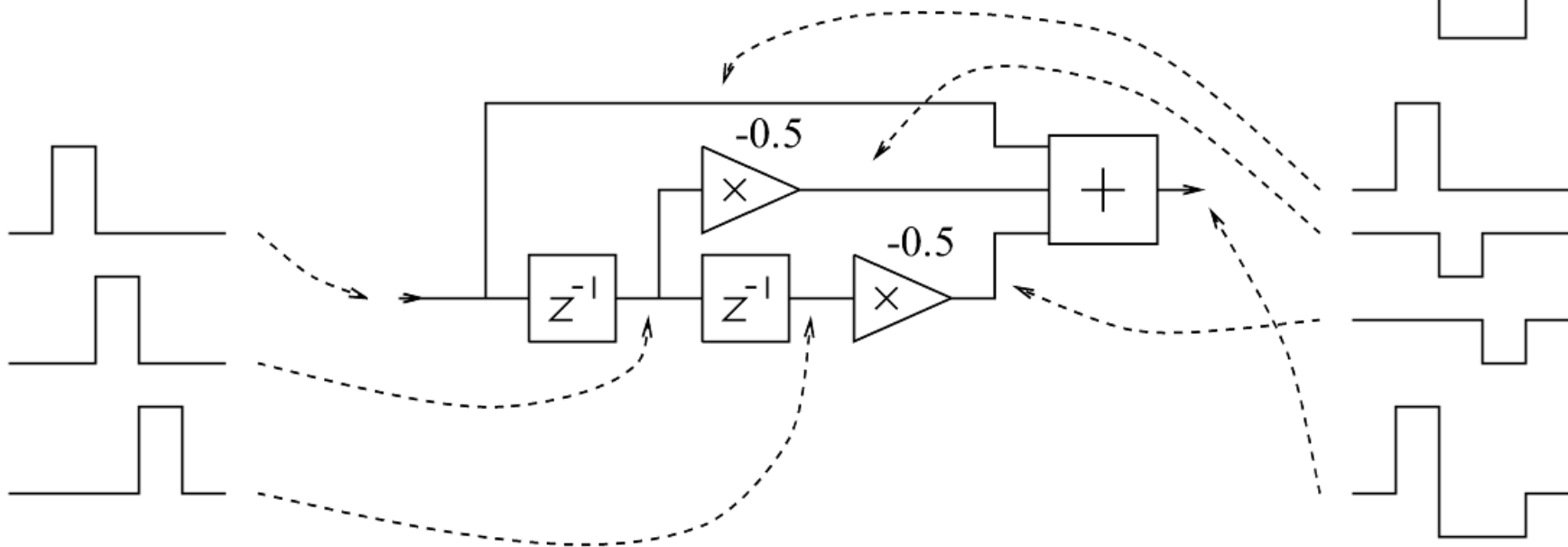
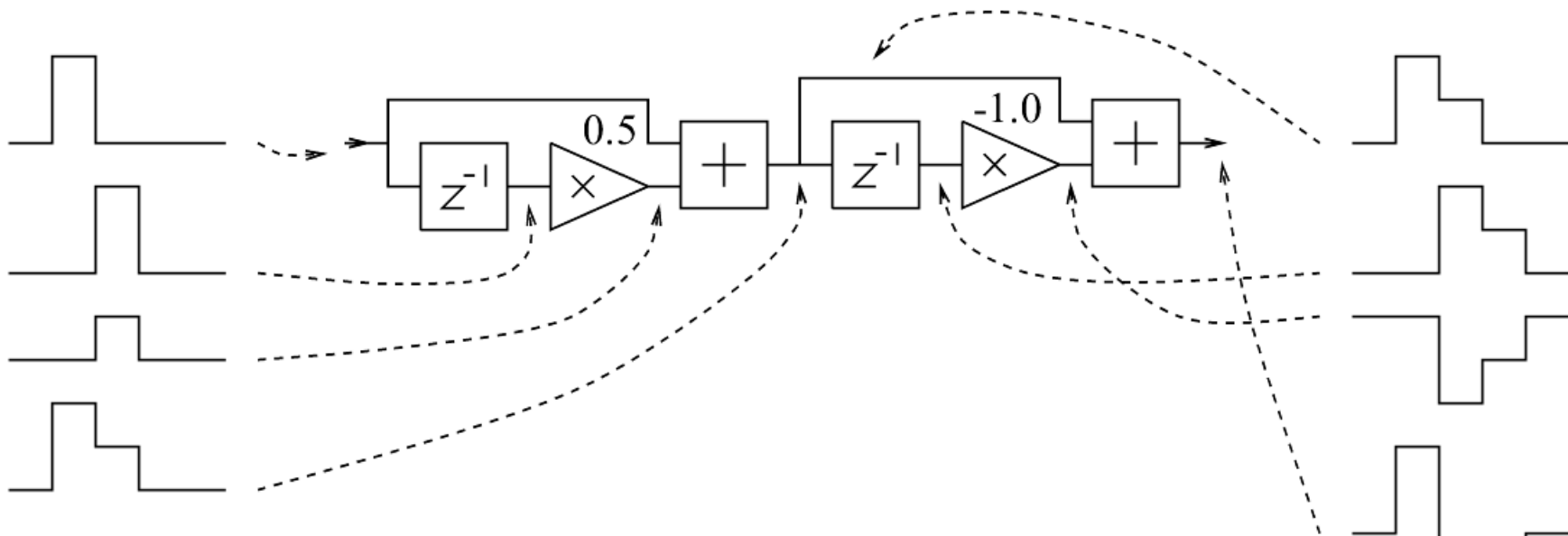
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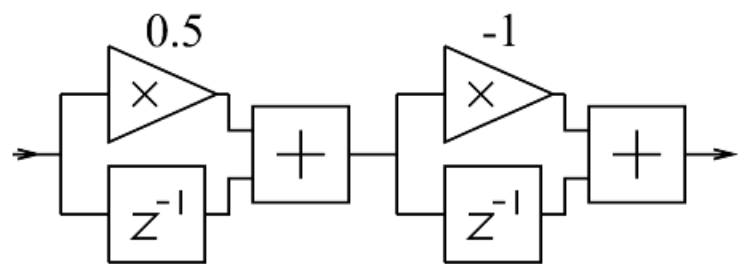
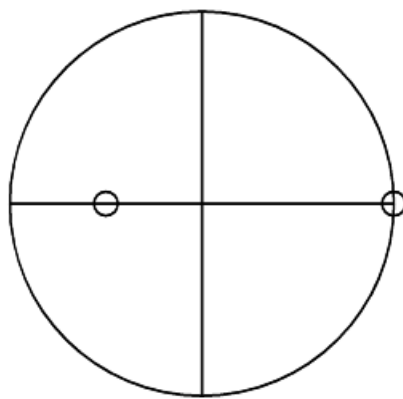


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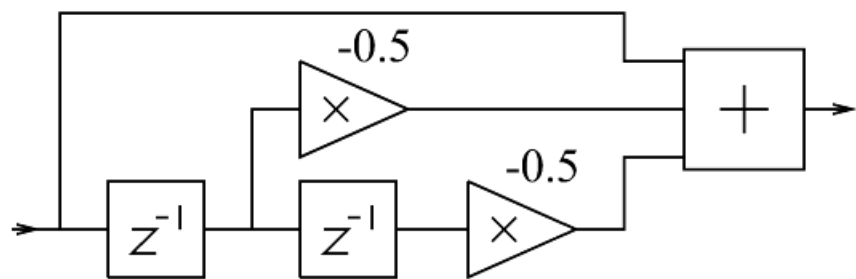


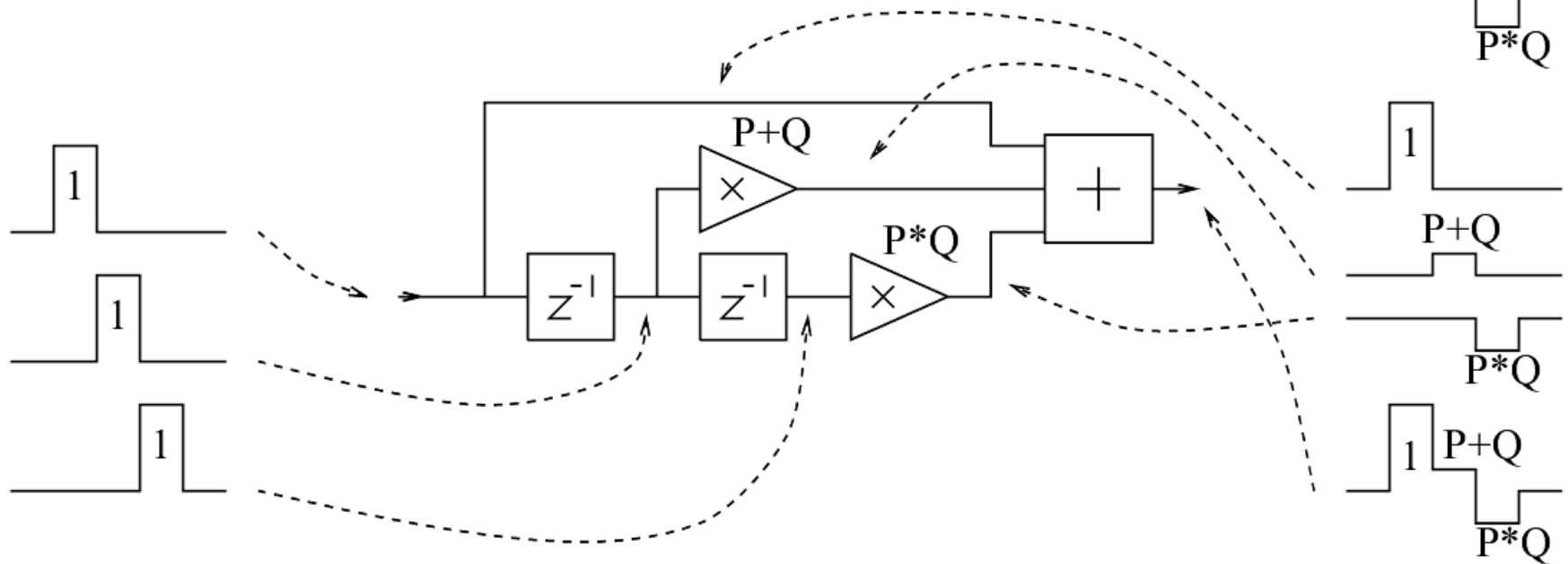
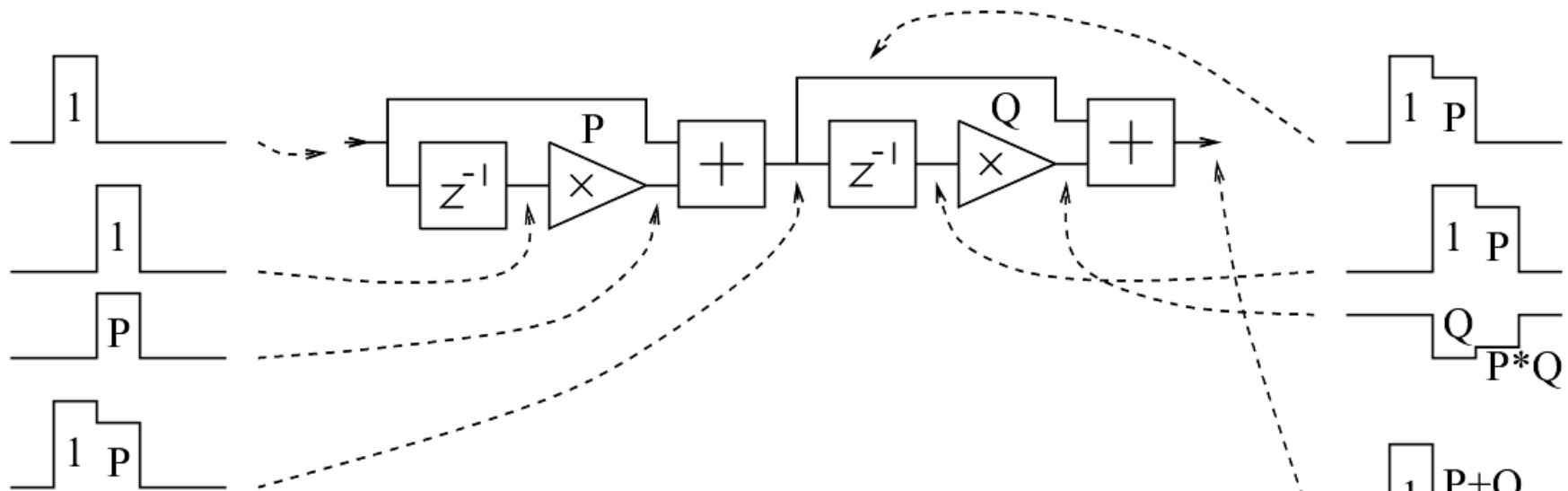


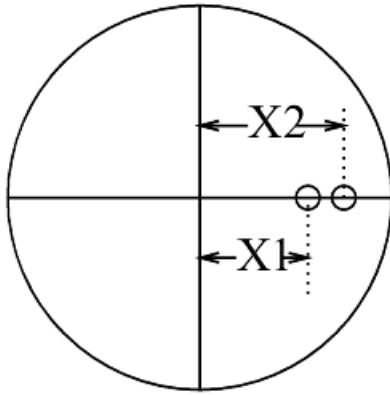




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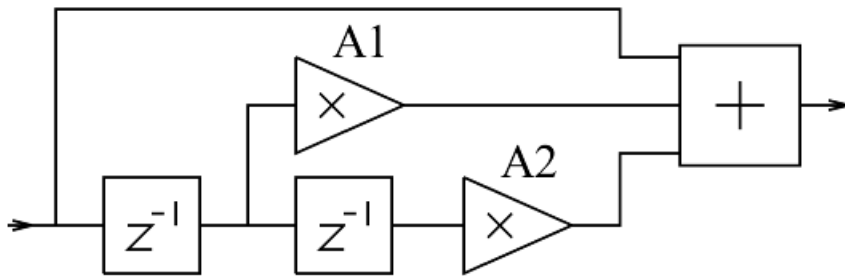






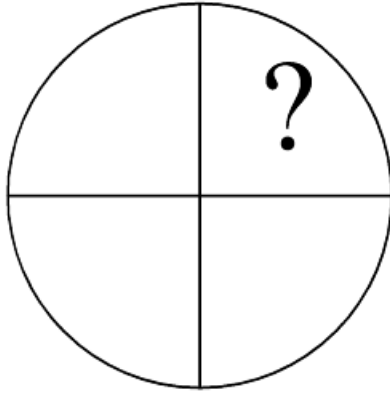
$$X1 = (A1 - \text{Sqrt}(A1 * A1 - 4 * A2)) / 2$$

$$X2 = (A1 + \text{Sqrt}(A1^2 - 4 * A2)) / 2$$



$$A1 = - (X1 + X2)$$

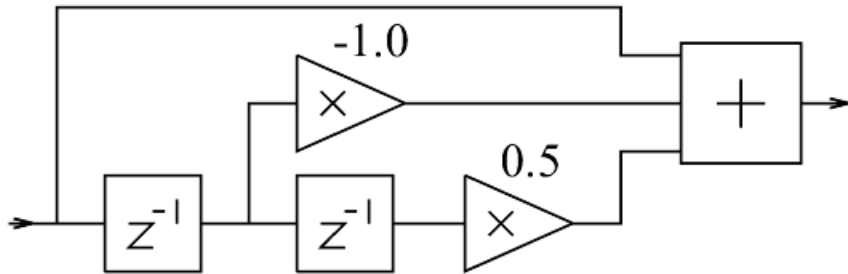
$$A2 = X1 * X2$$



$$X1 = (A1 - \text{Sqrt}(A1 * A1 - 4 * A2)) / 2$$

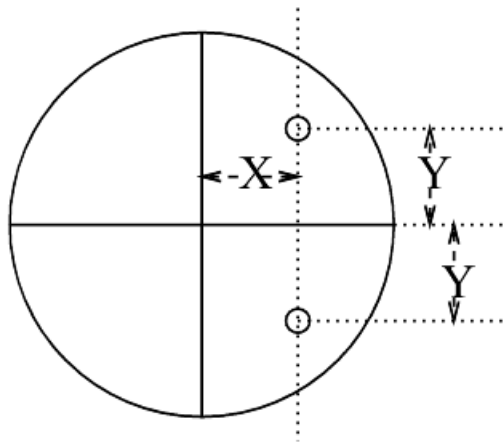
$$X2 = (A1 + \text{Sqrt}(A1 * A1 - 4 * A2)) / 2$$

$\text{Sqrt}(-1.0)$



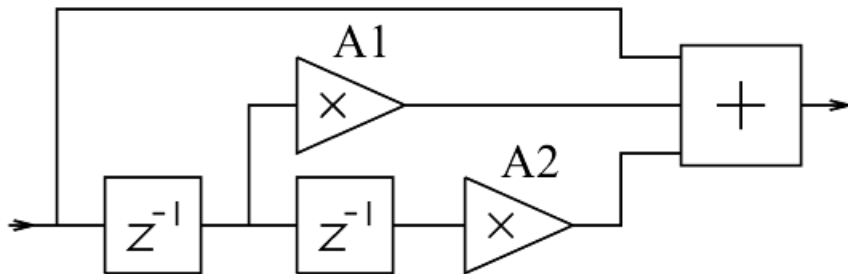
$$A1 = -1.0$$

$$A2 = 0.5$$



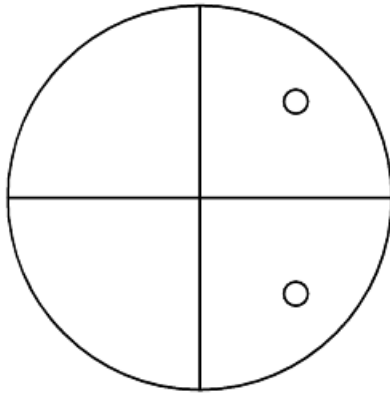
$$X = -A1 / 2$$

$$Y = \text{Sqrt}(-A1 * A1 + 4 * A2) / 2$$



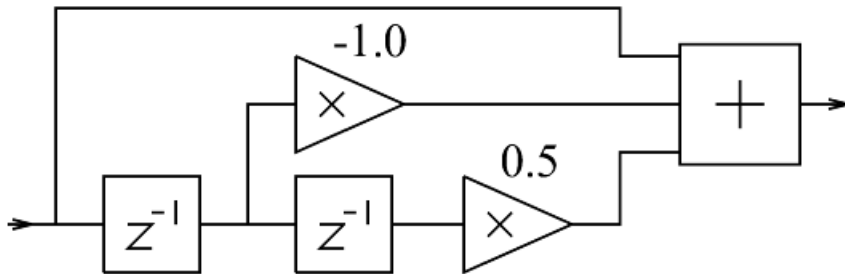
$$A1 = -2 * X$$

$$A2 = X * X + Y * Y$$



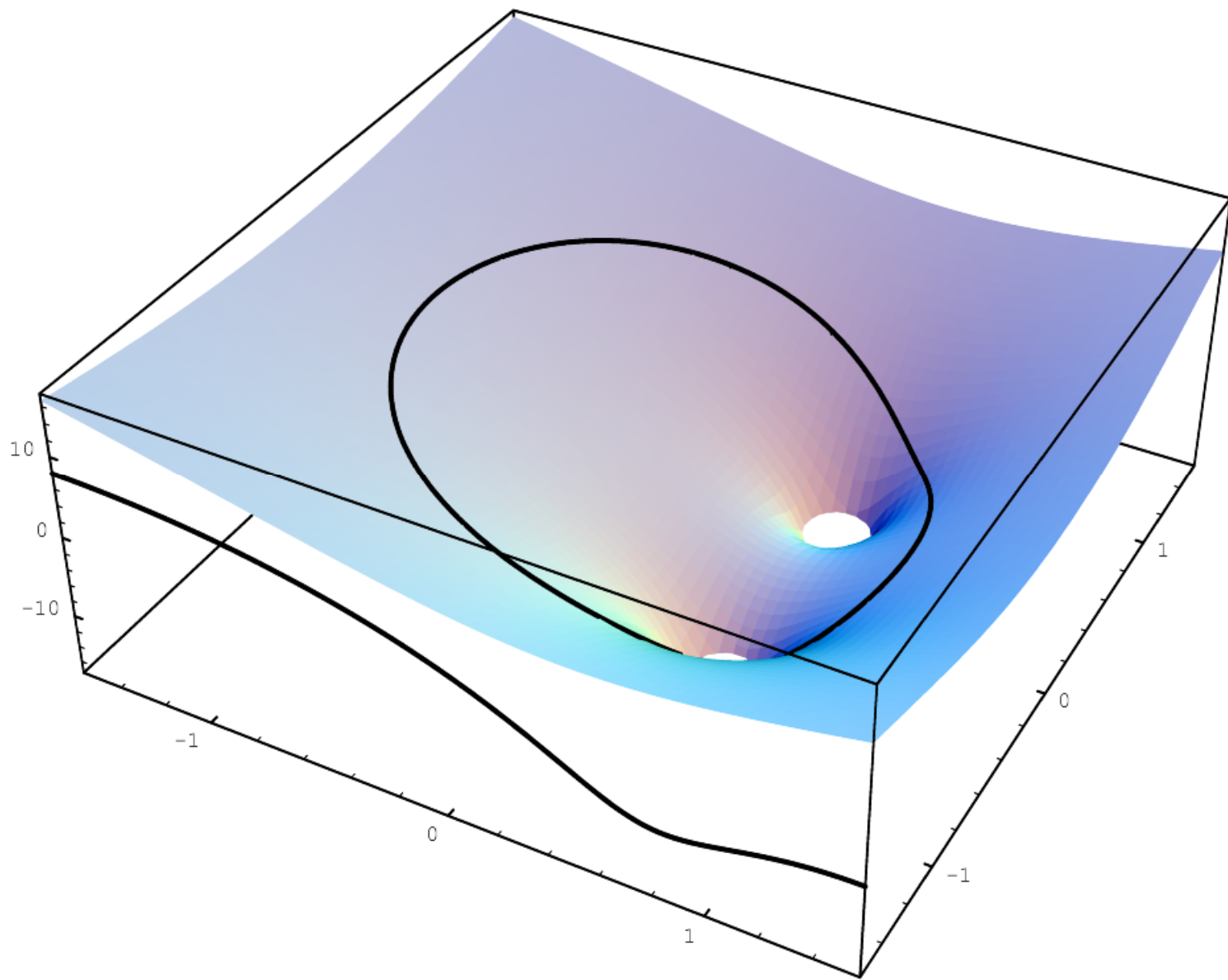
$$X = -A1 / 2 = 0.5$$

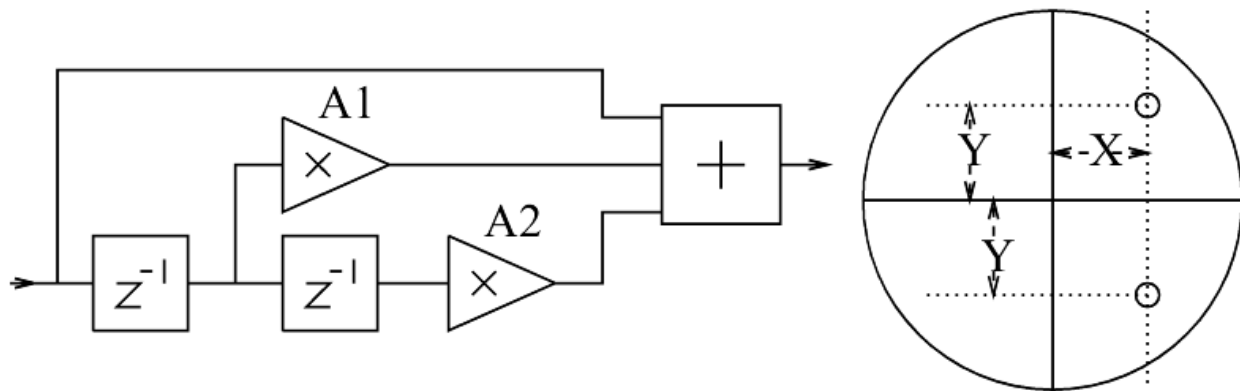
$$Y = \text{Sqrt}(-A1 * A1 + 4 * A2) / 2 = 0.5$$



$$A1 = -1.0$$

$$A2 = 0.5$$



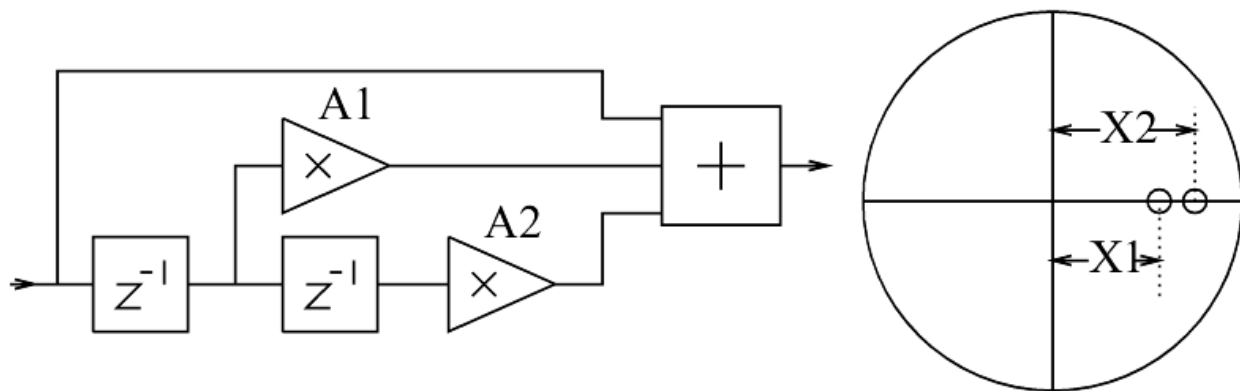


$$A1 = -2 * X$$

$$A2 = X * X + Y * Y$$

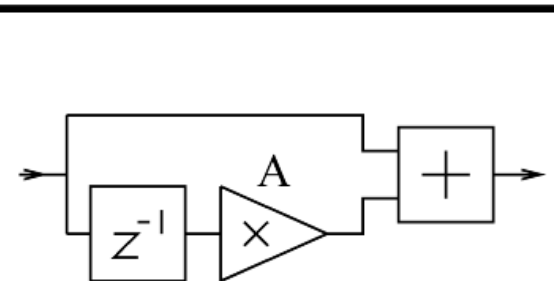
$$X = -A1 / 2$$

$$Y = \text{Sqrt}(-A1 * A1 + 4 * A2) / 2$$

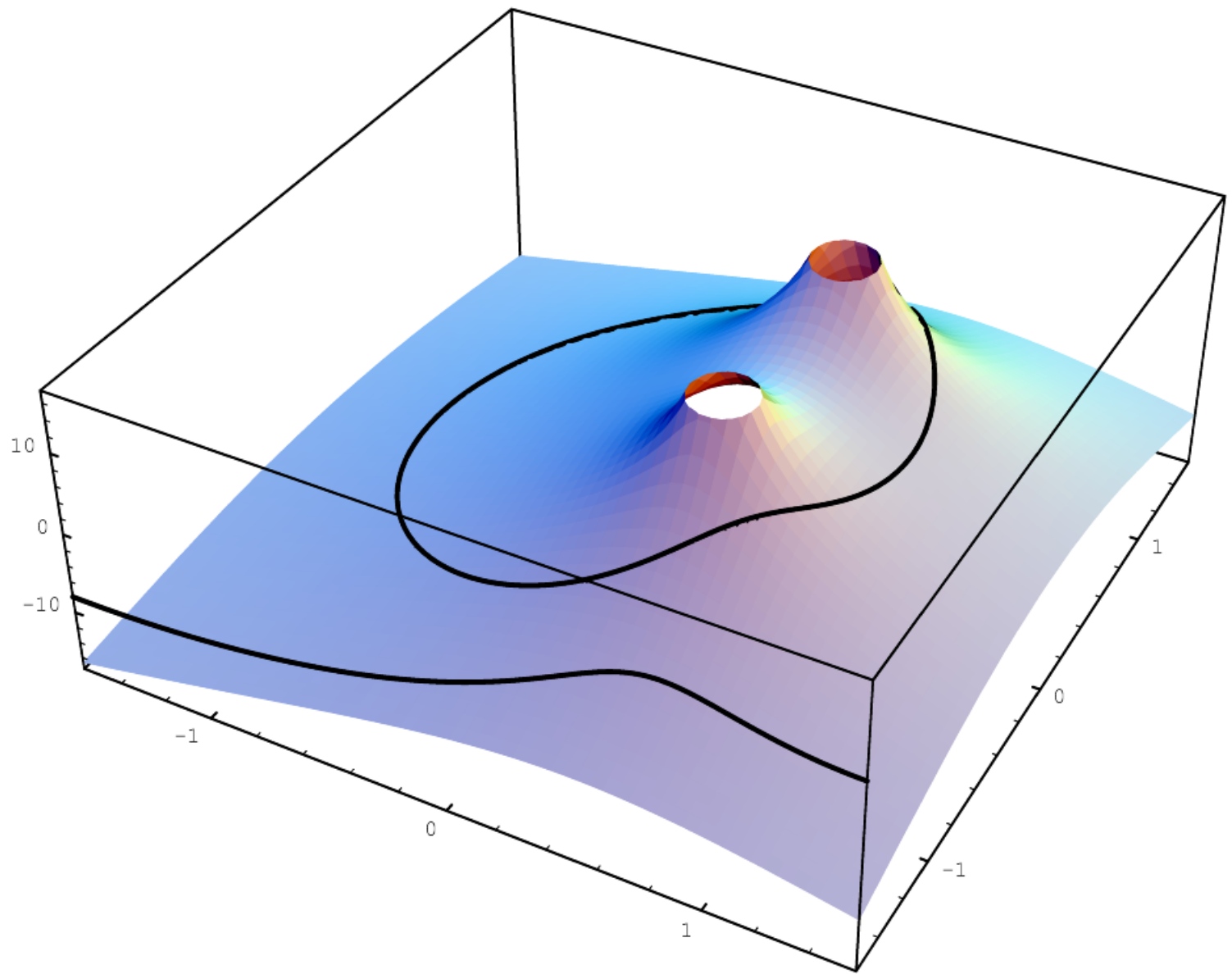


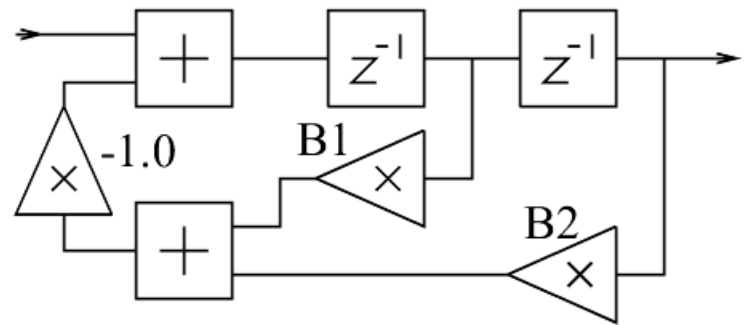
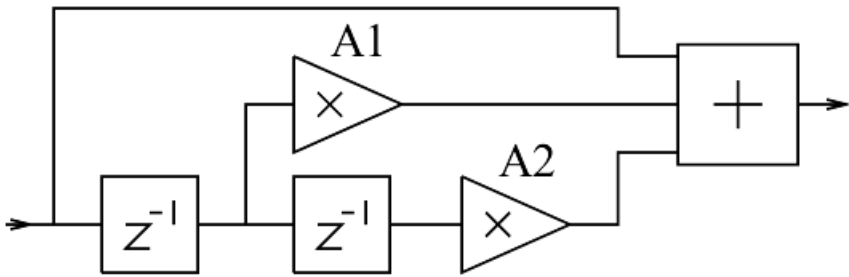
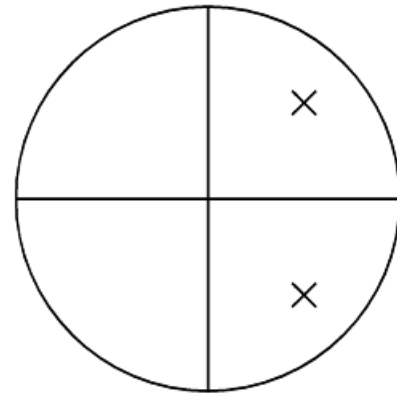
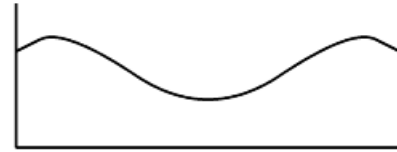
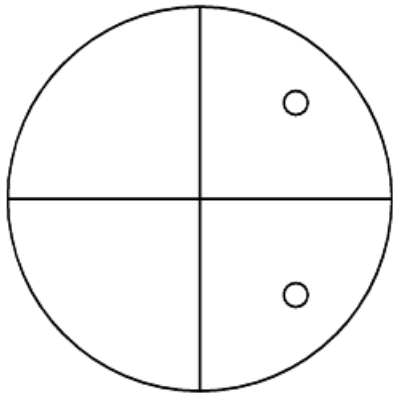
$$A1 = -(X1 + X2) \quad X1 = (A1 - \text{Sqrt}(A1 * A1 - 4 * A2)) / 2$$

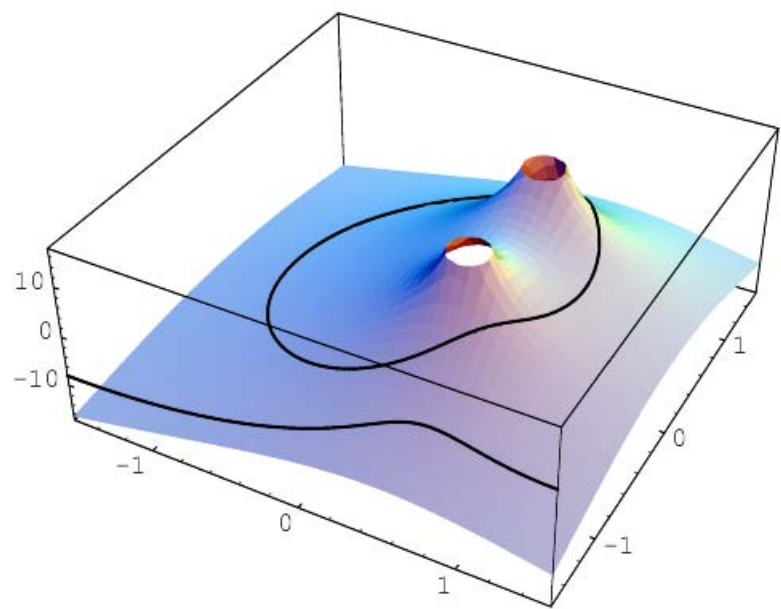
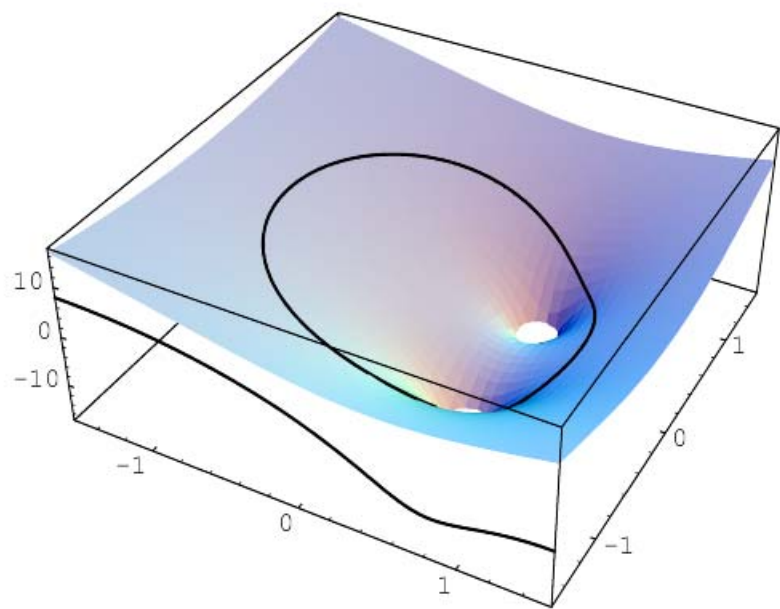
$$A2 = X1 * X2 \quad X2 = (A1 + \text{Sqrt}(A1 * A1 - 4 * A2)) / 2$$

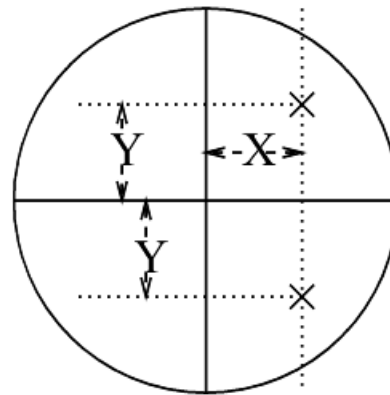
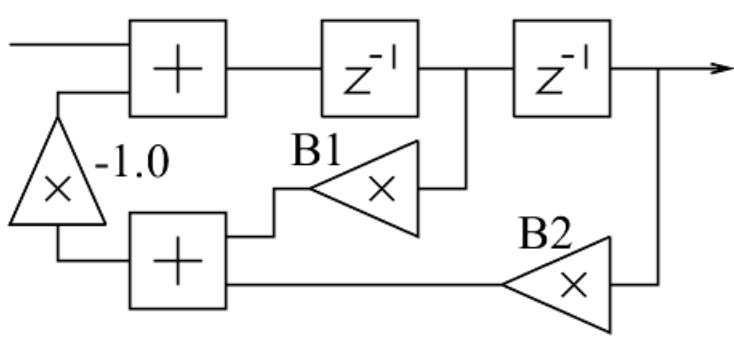


$$A = -X \quad X = -A$$



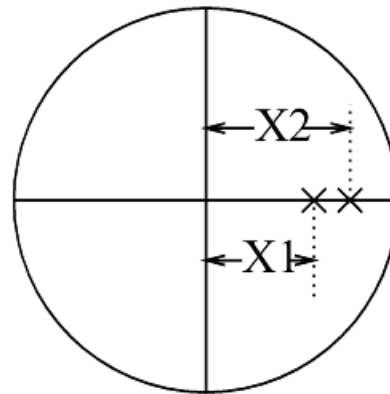
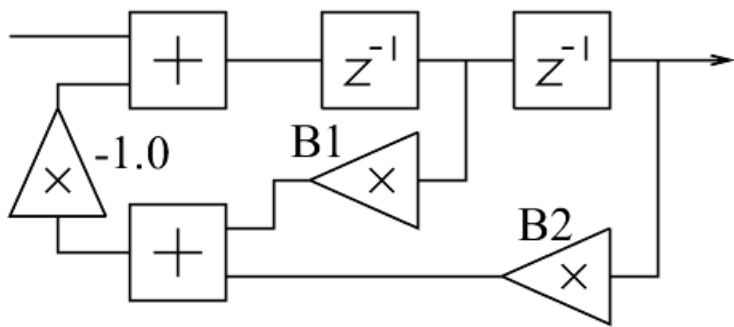






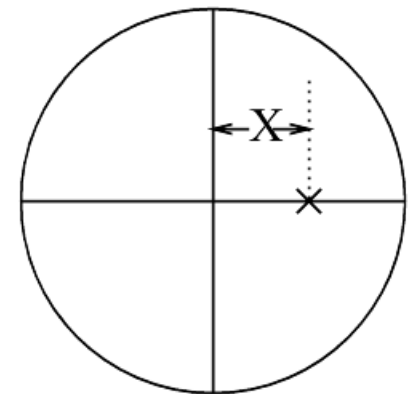
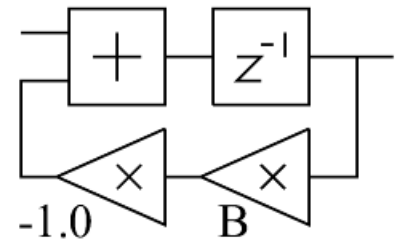
$$B1 = -2 * X \quad X = -B1 / 2$$

$$B2 = X * X + Y * Y \quad Y = \text{Sqrt}(-B1 * B1 + 4 * B2) / 2$$

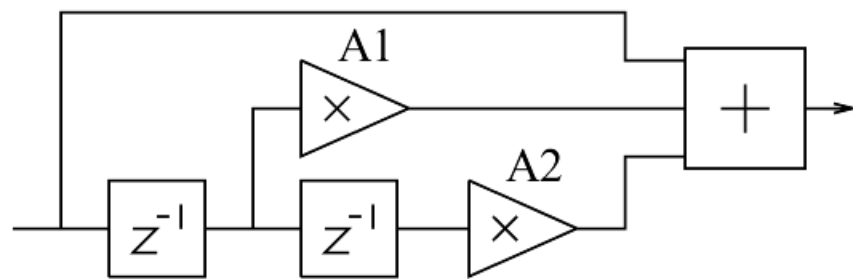
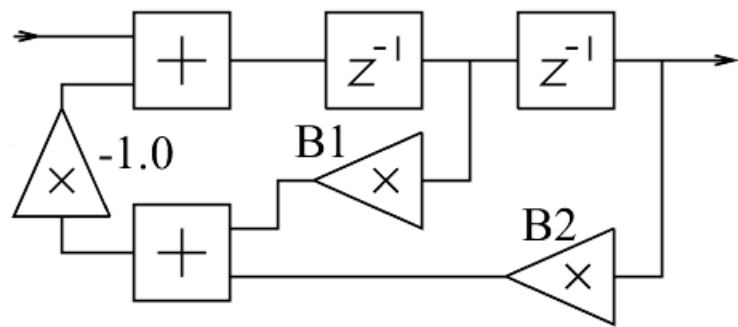
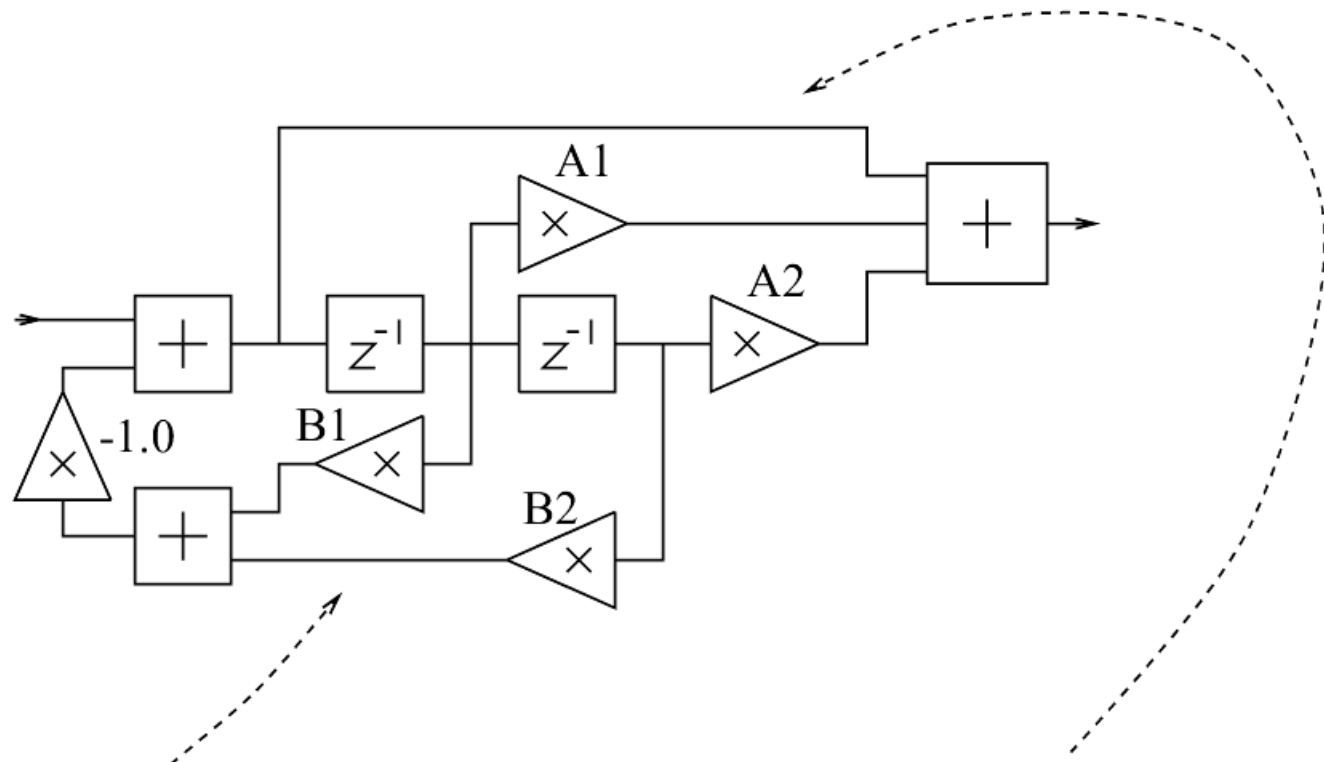


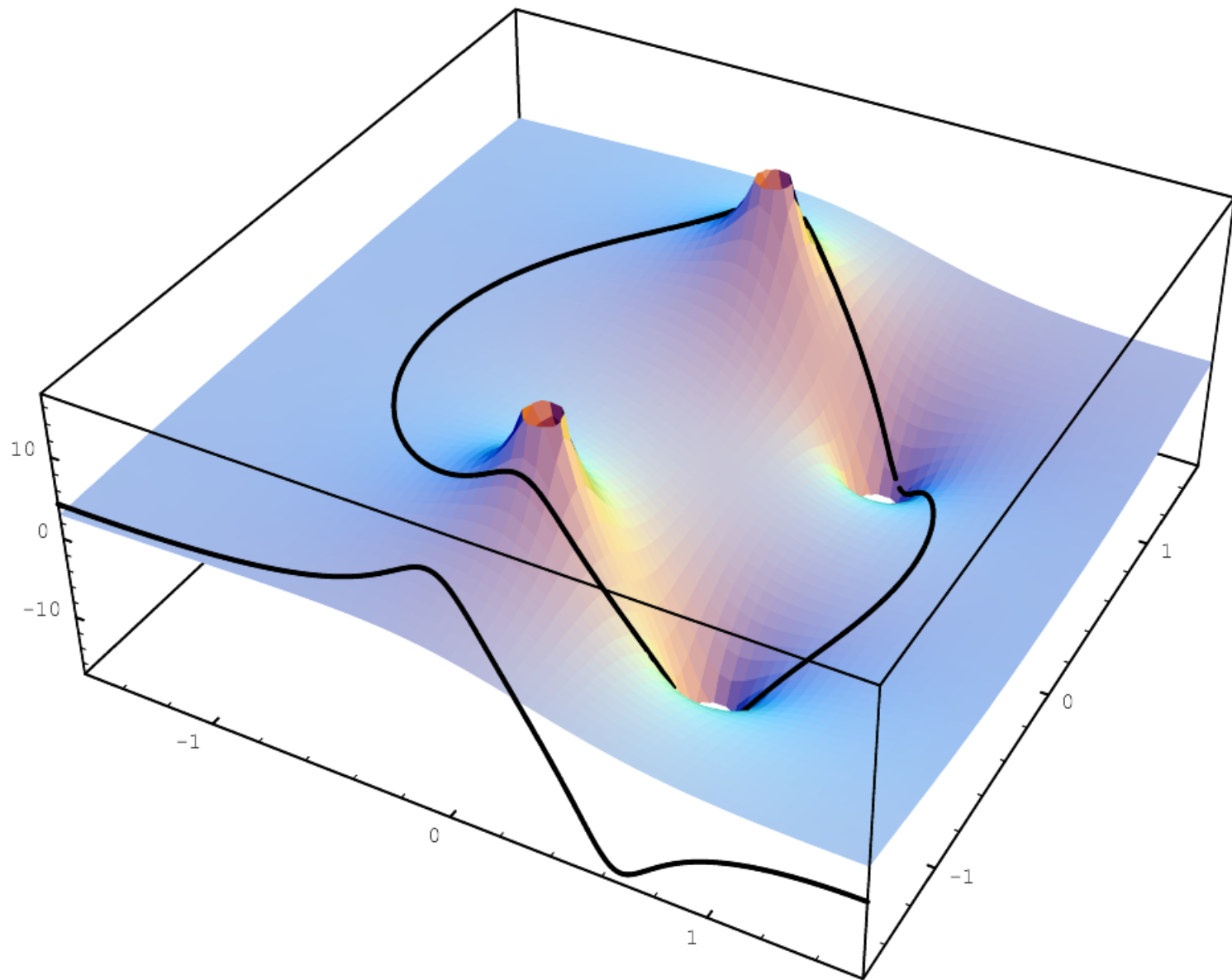
$$B1 = -(X1 + X2) \quad X1 = (B1 - \text{Sqrt}(B1 * B1 - 4 * B2)) / 2$$

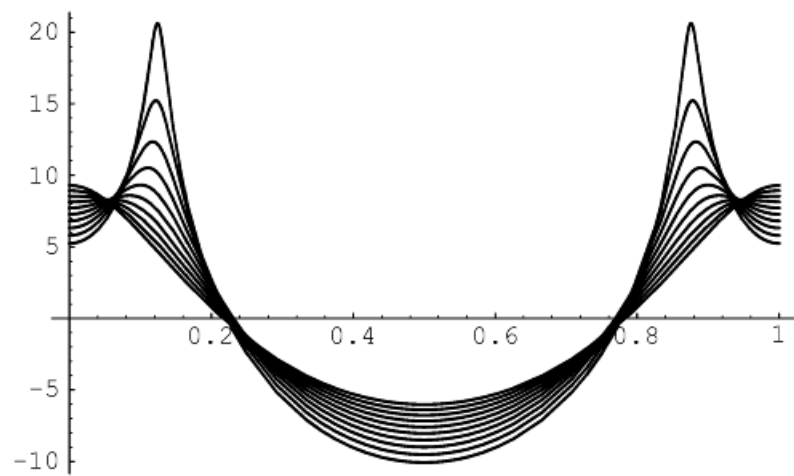
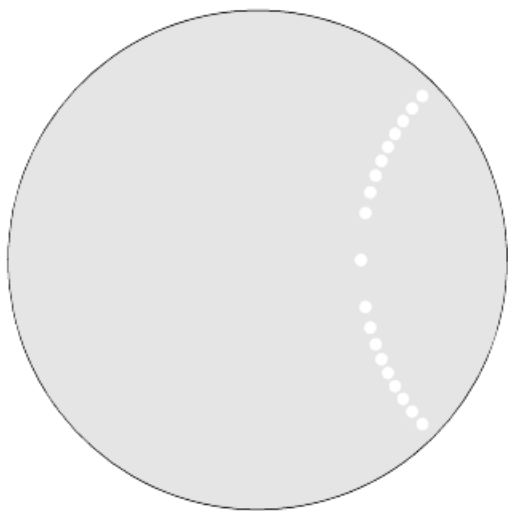
$$B2 = X1 * X2 \quad X2 = (B1 + \text{Sqrt}(B1 * B1 - 4 * B2)) / 2$$

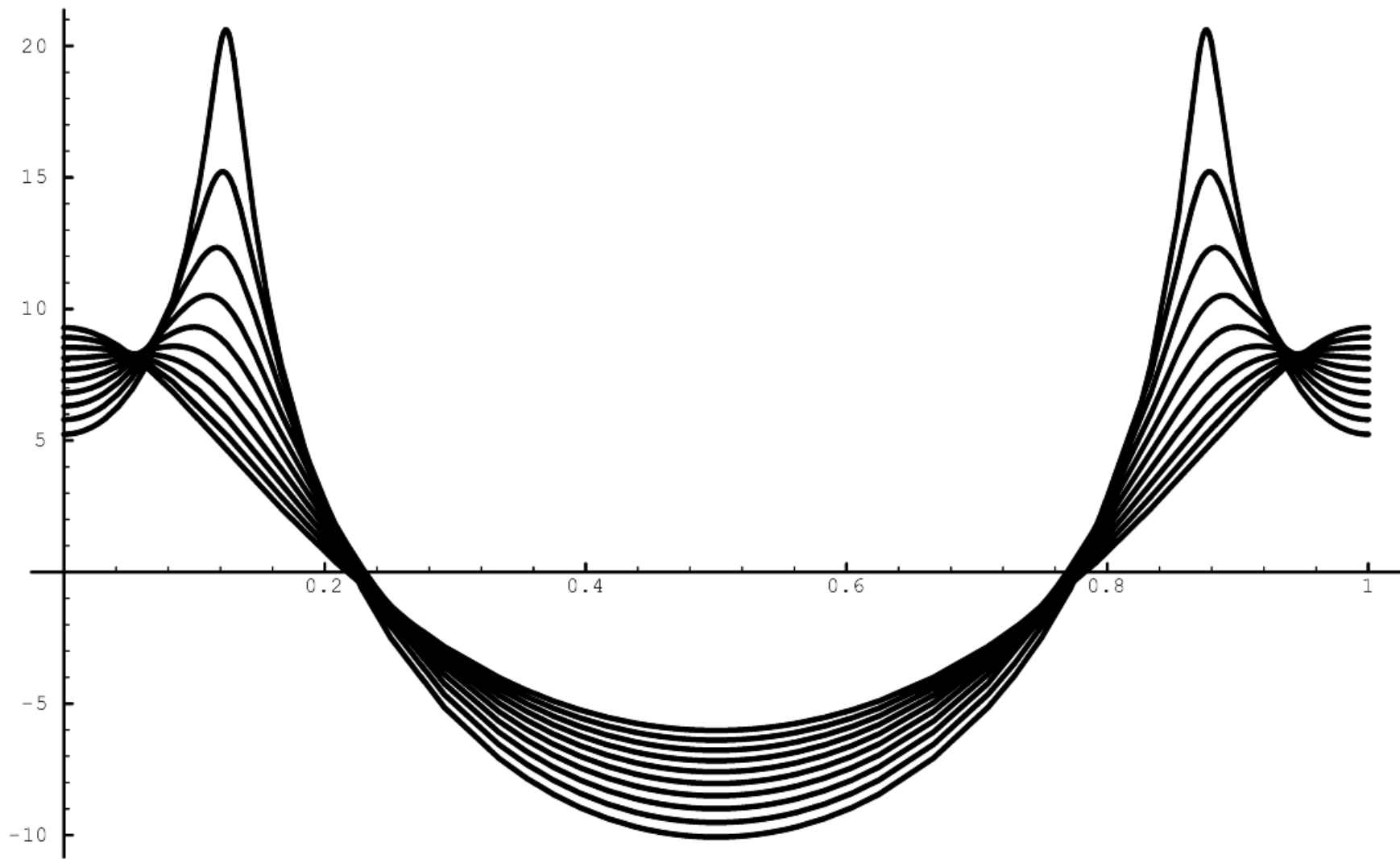


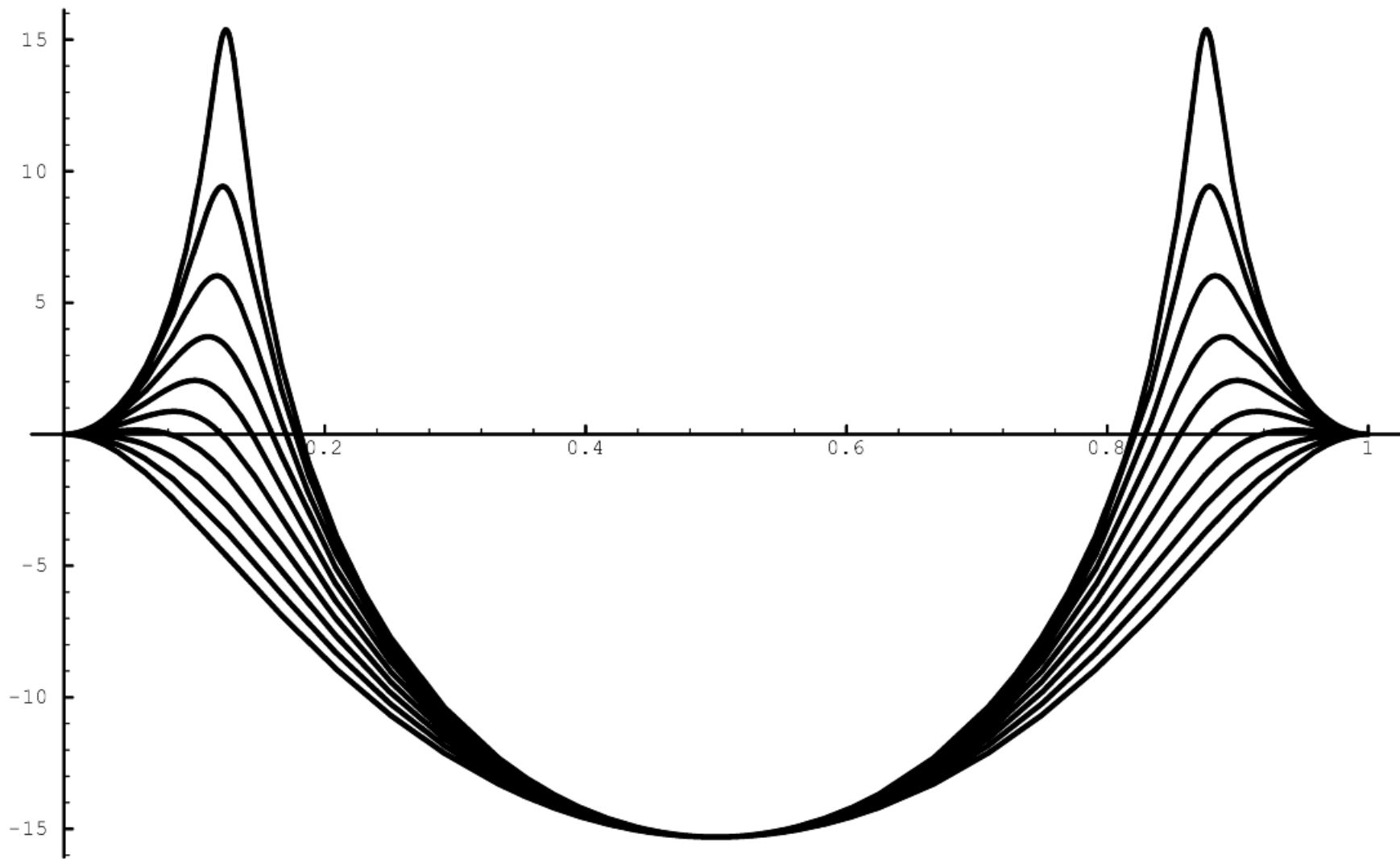
$$B = -X \quad X = -B$$

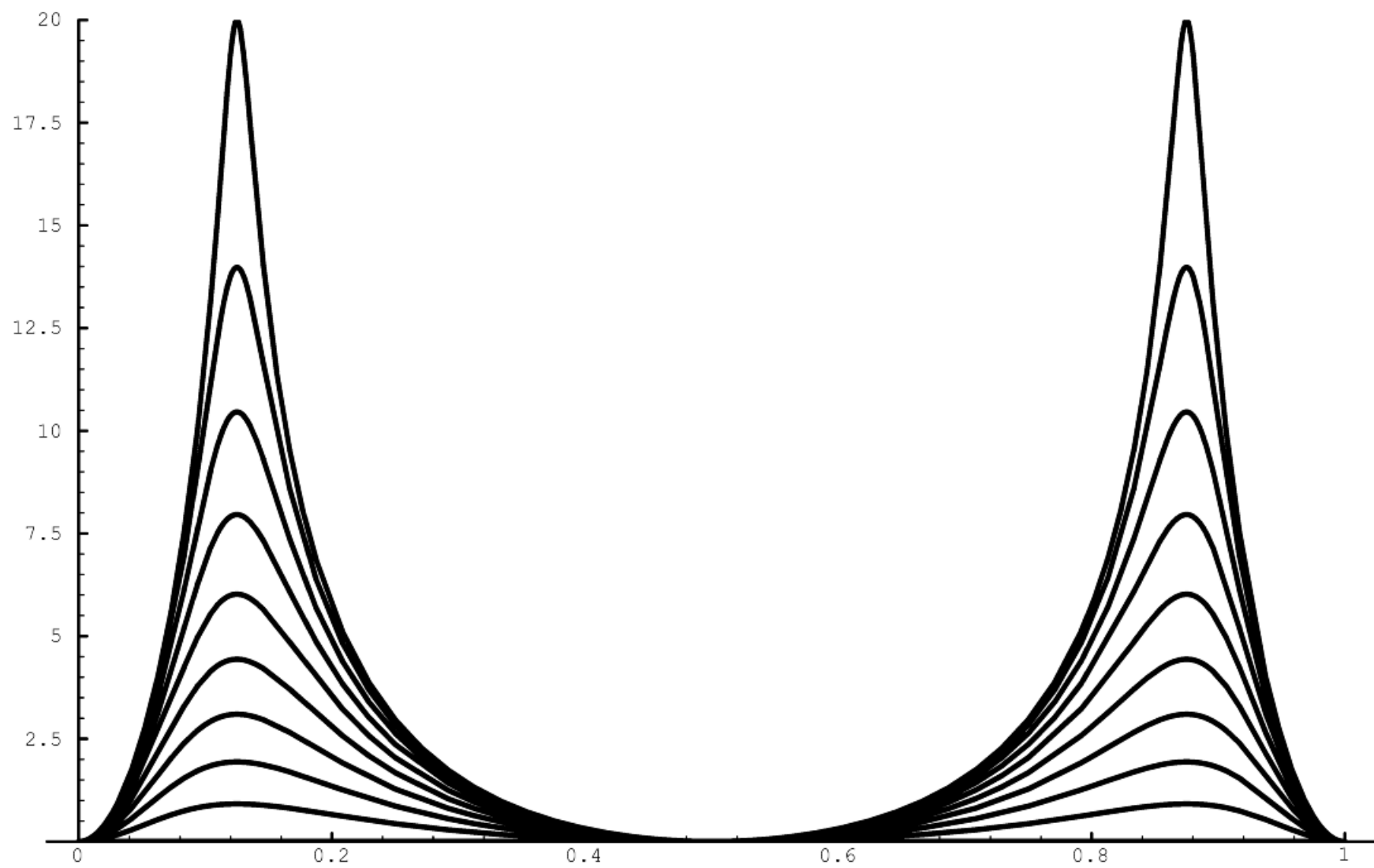


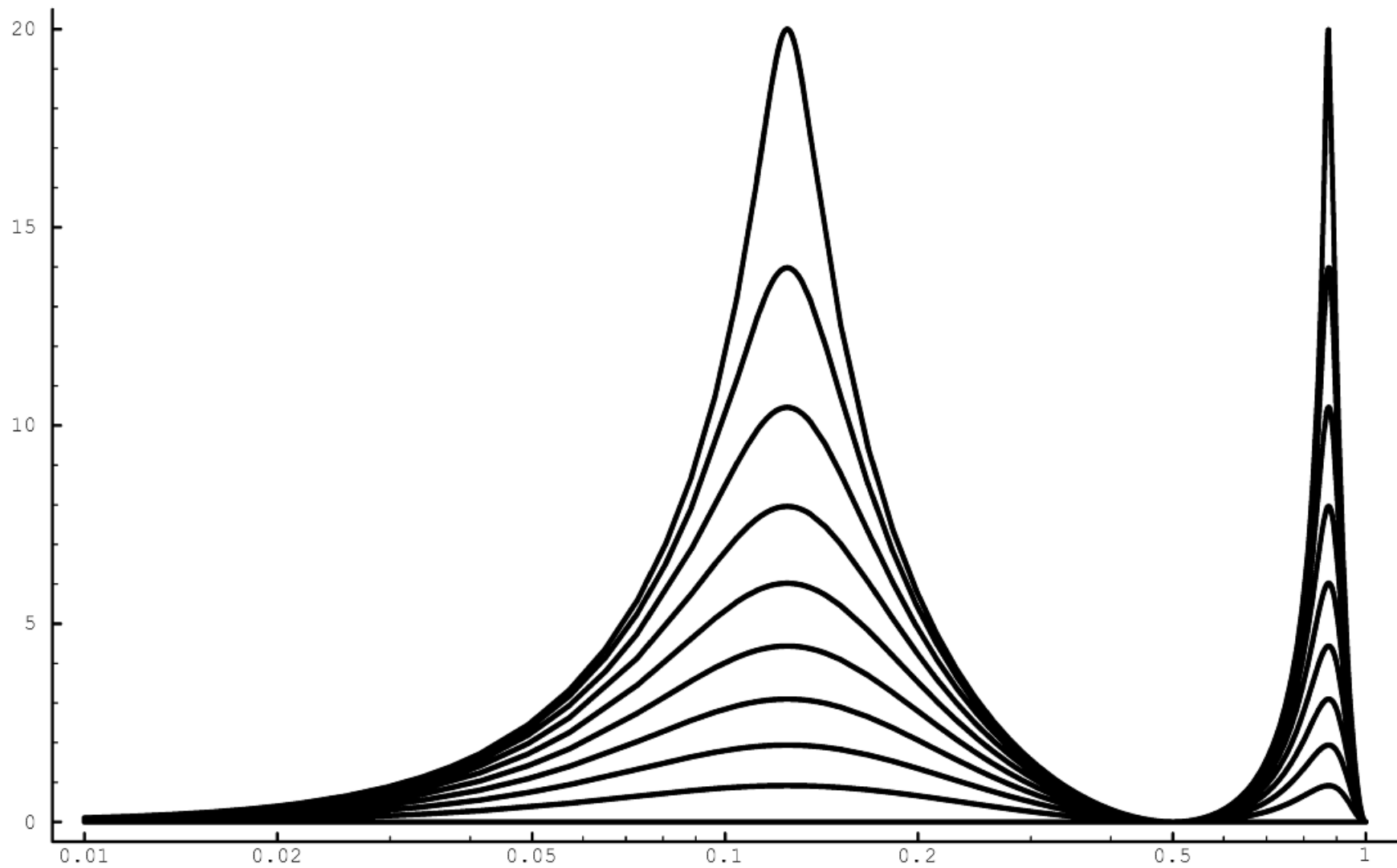


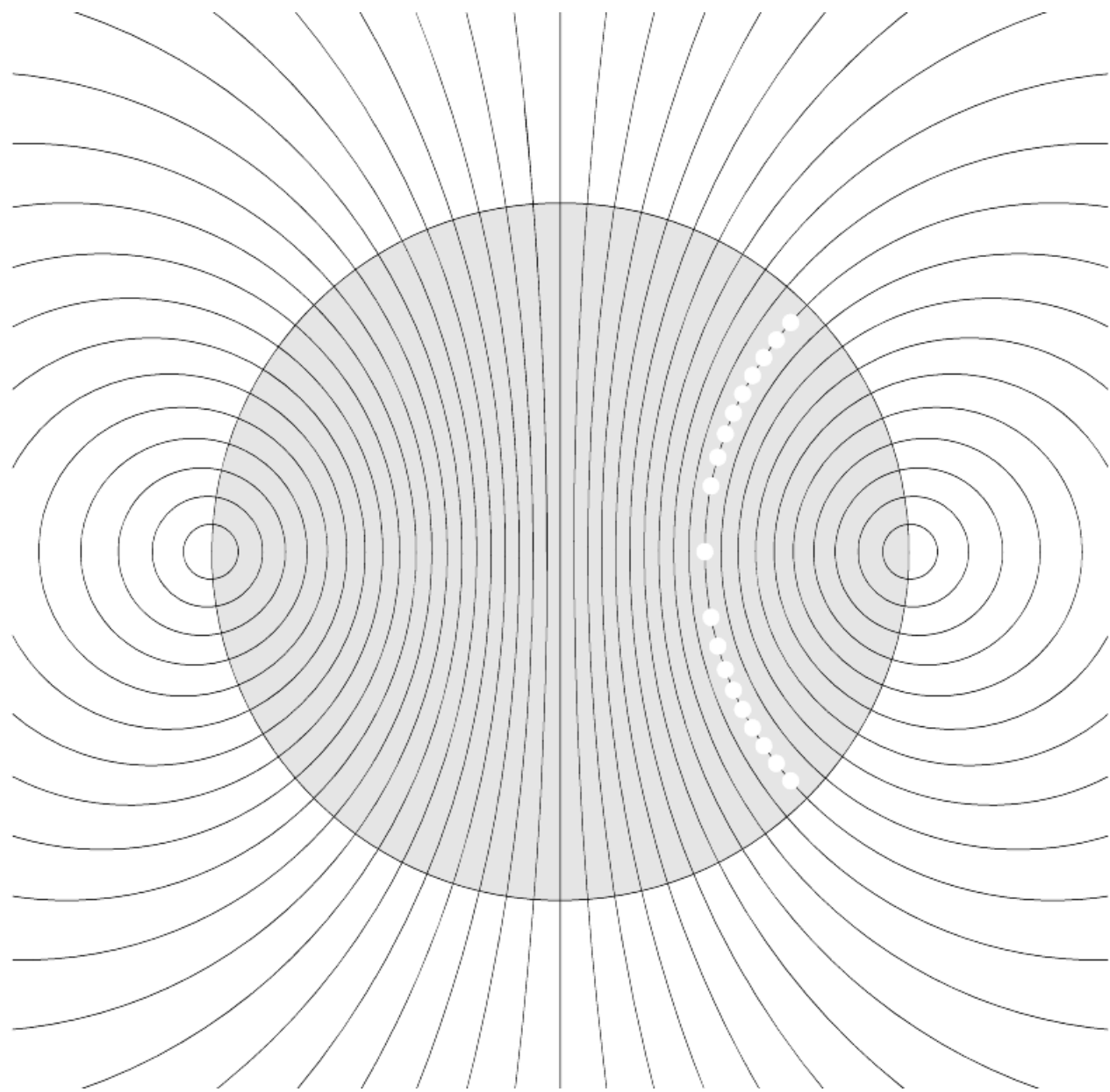


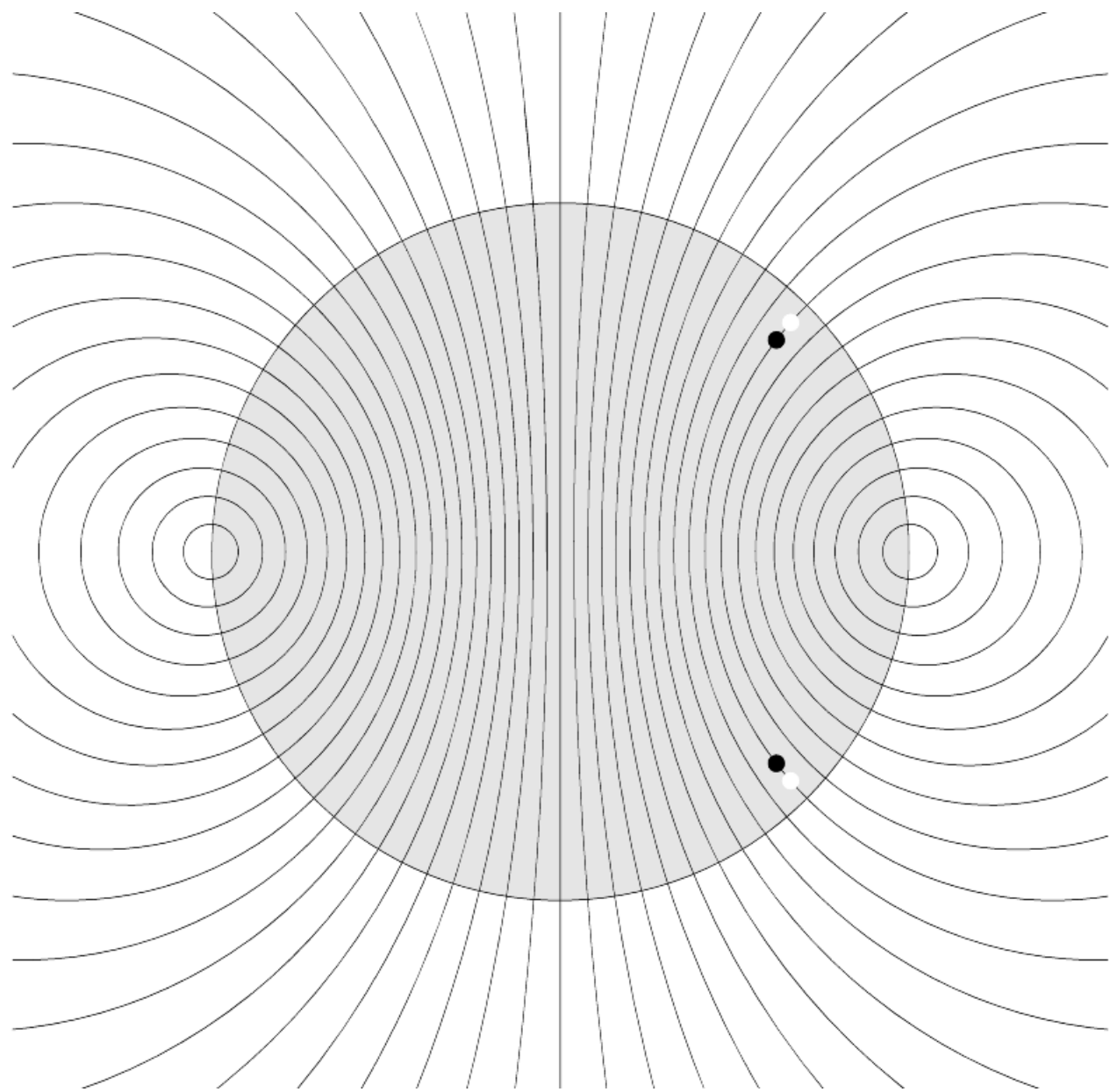


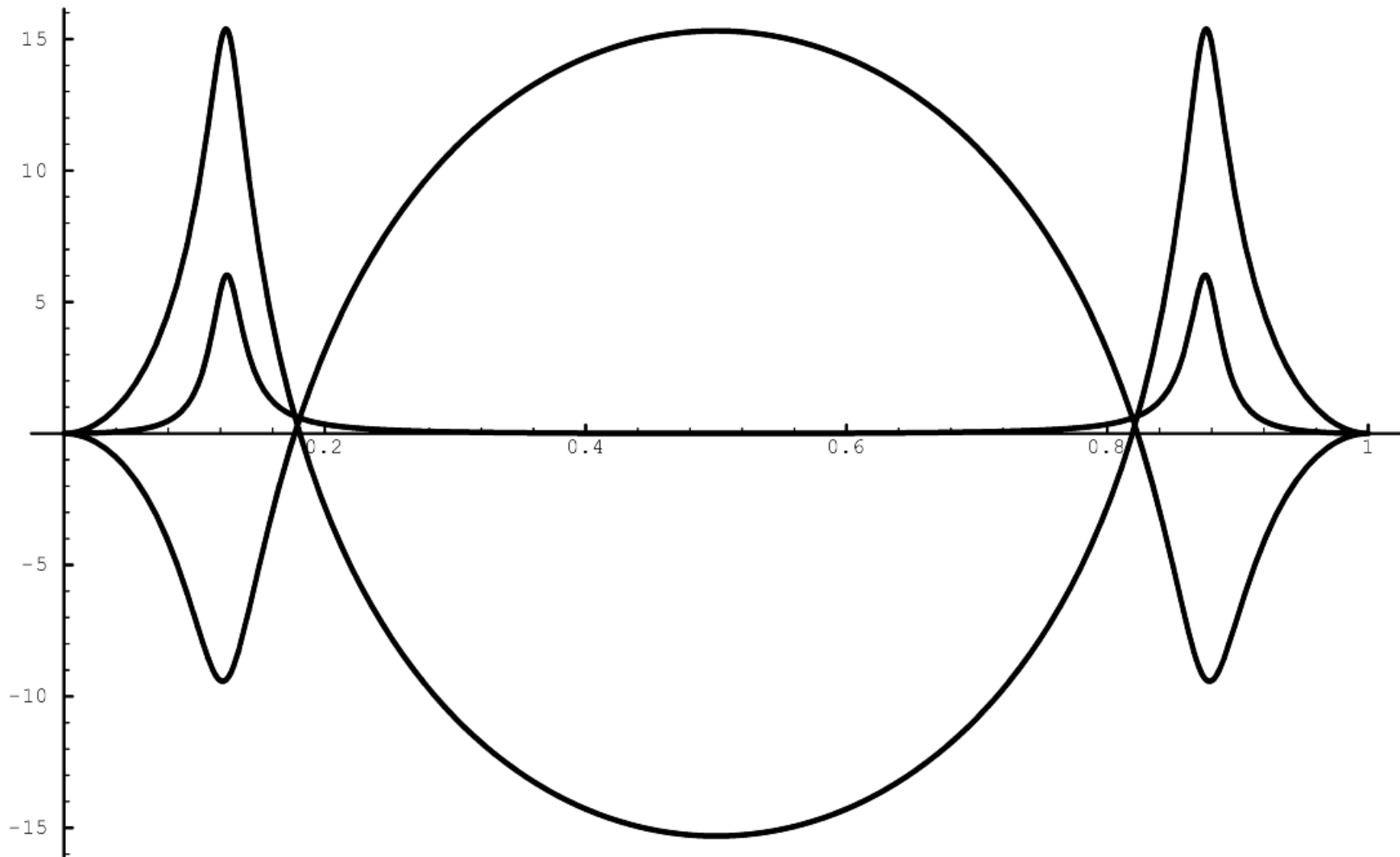


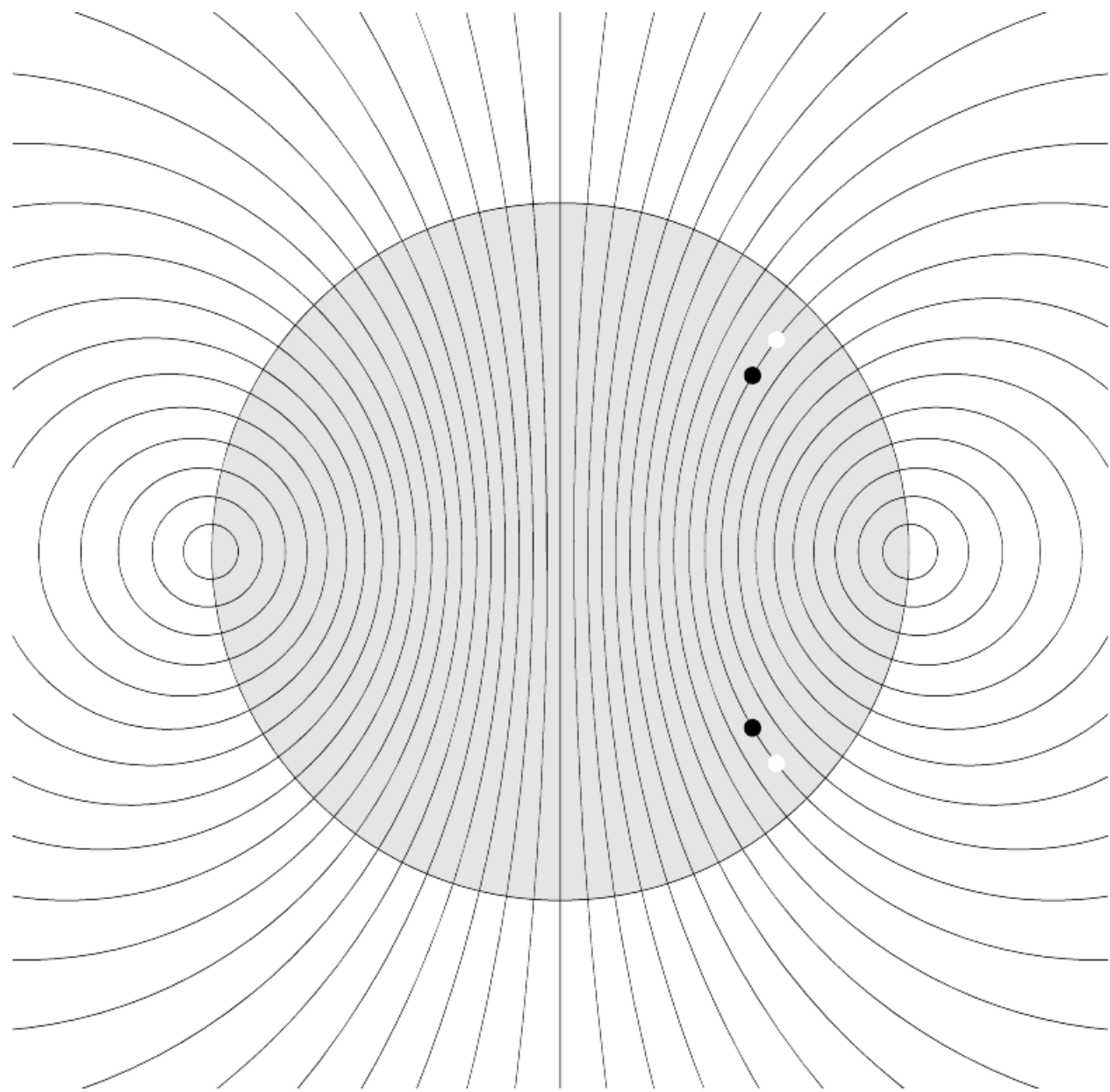


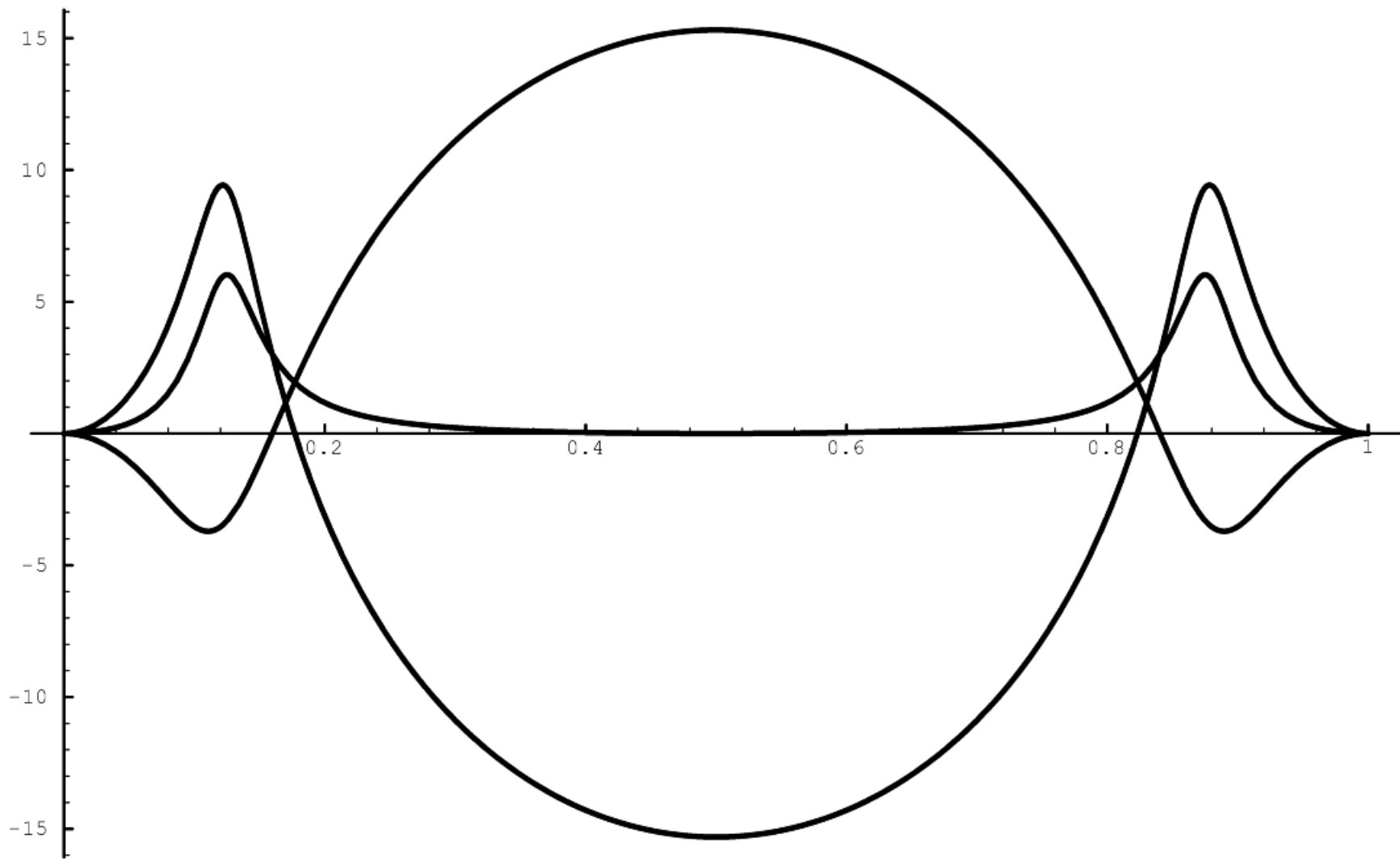


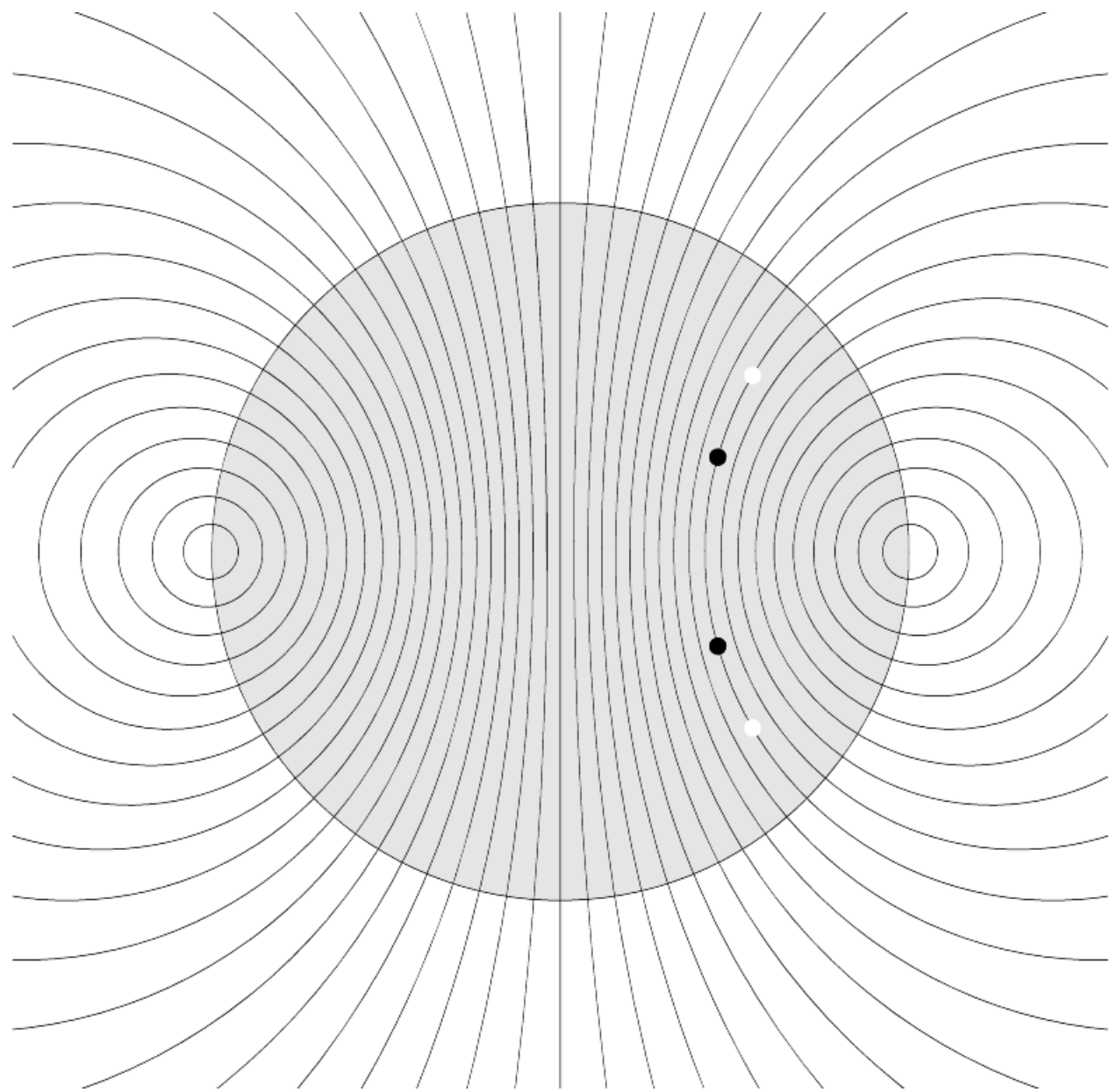


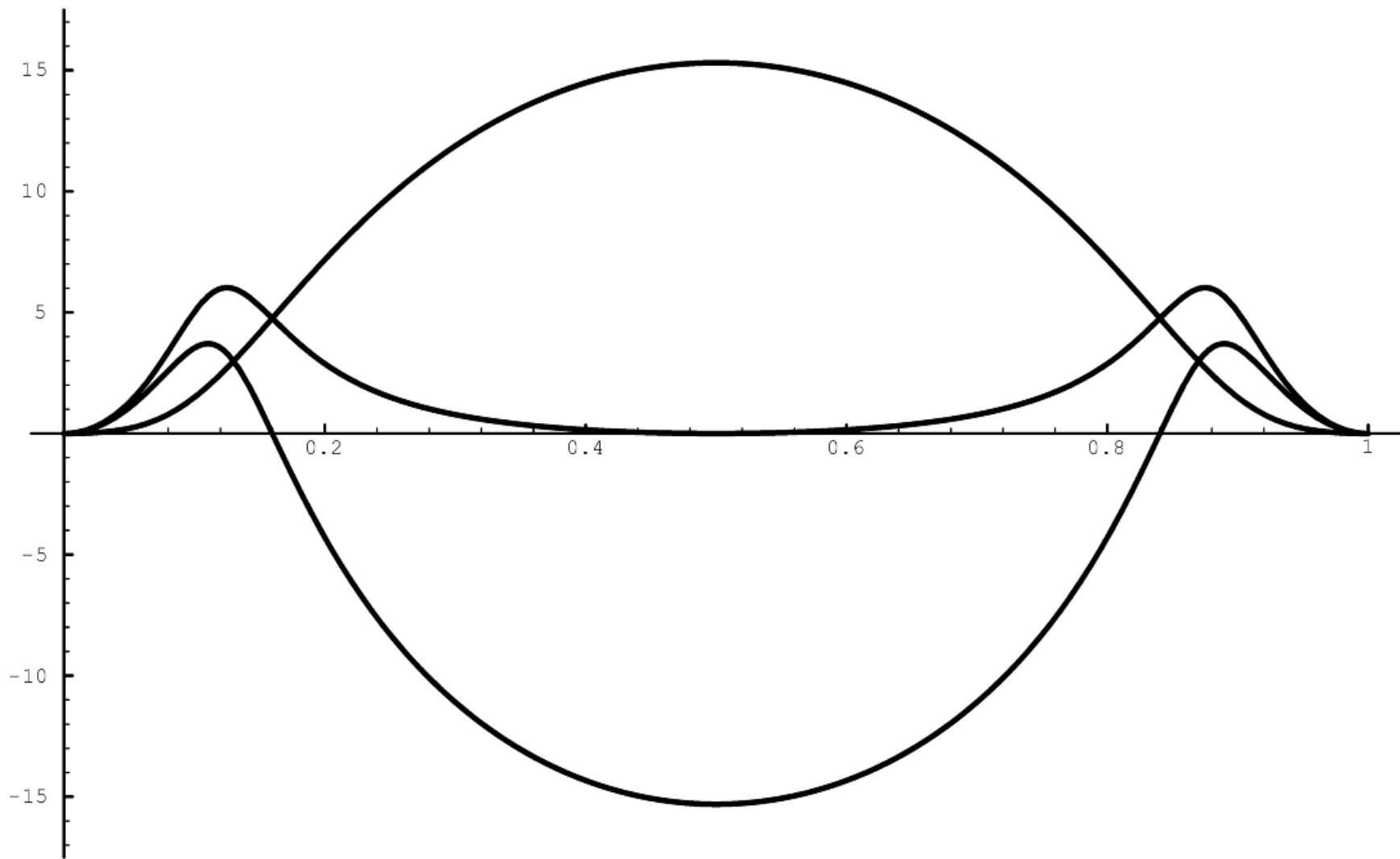


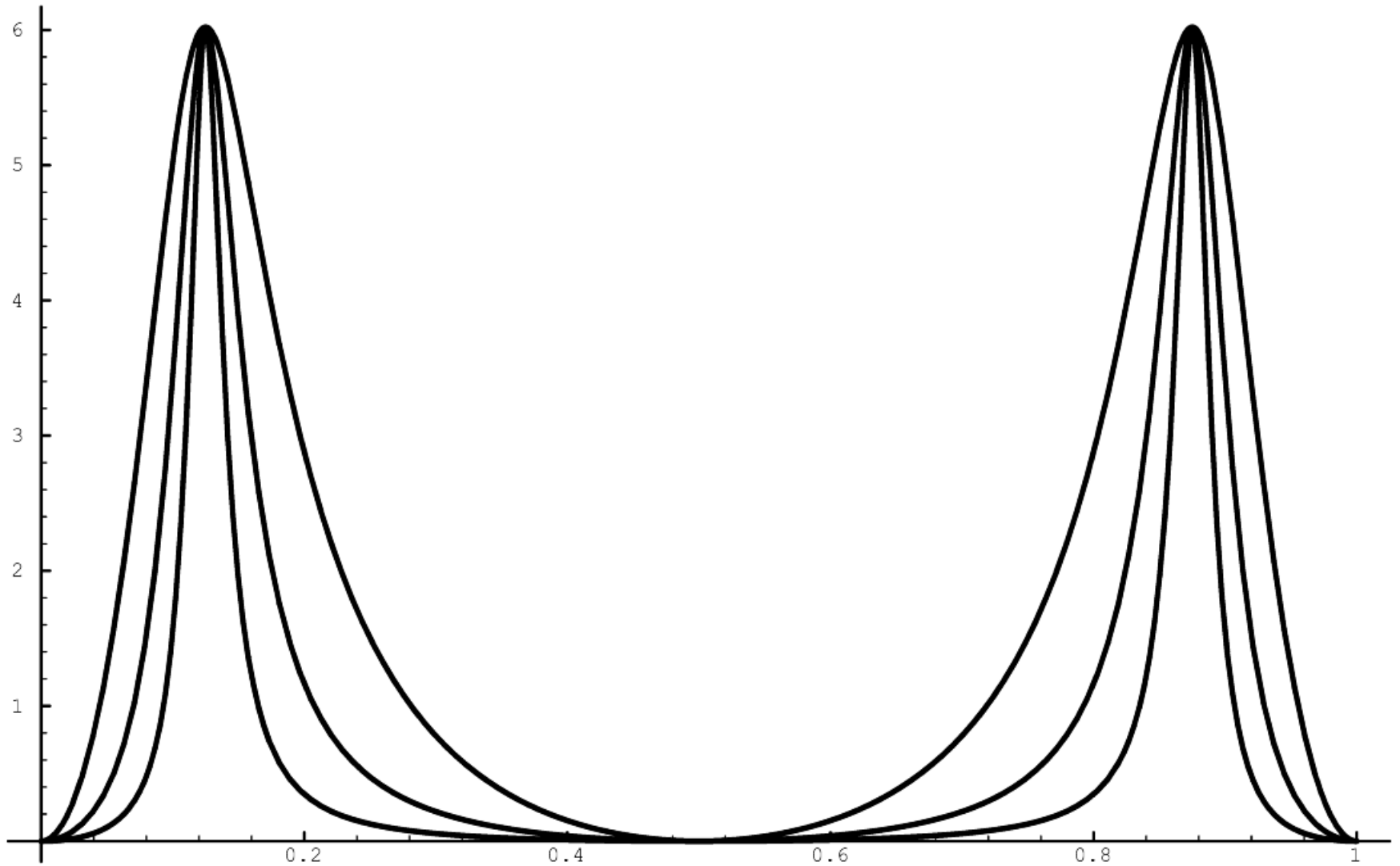


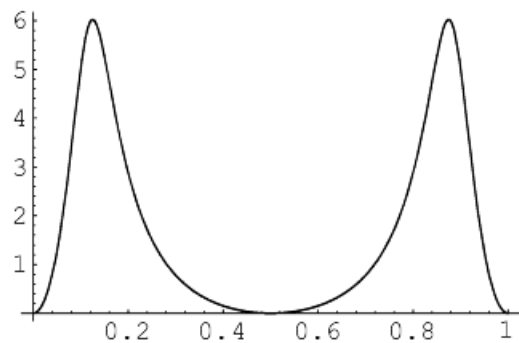
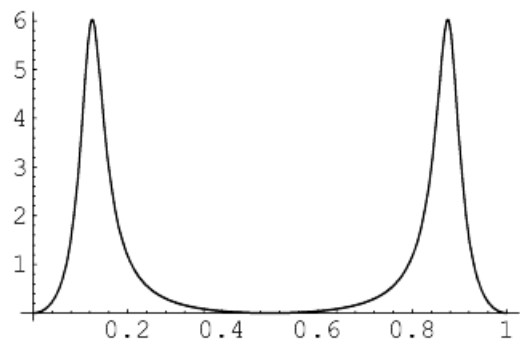
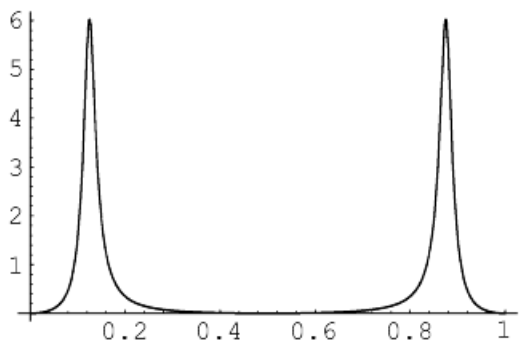
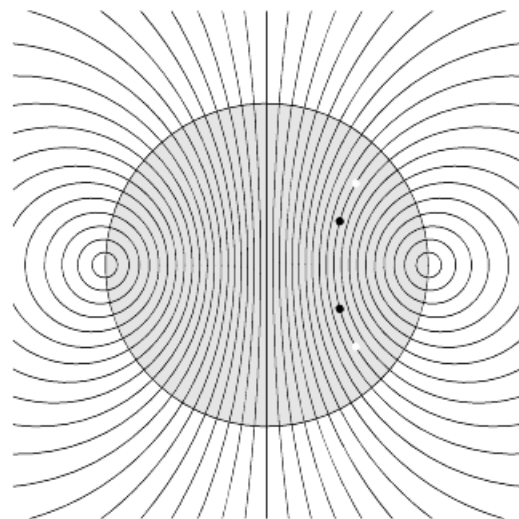
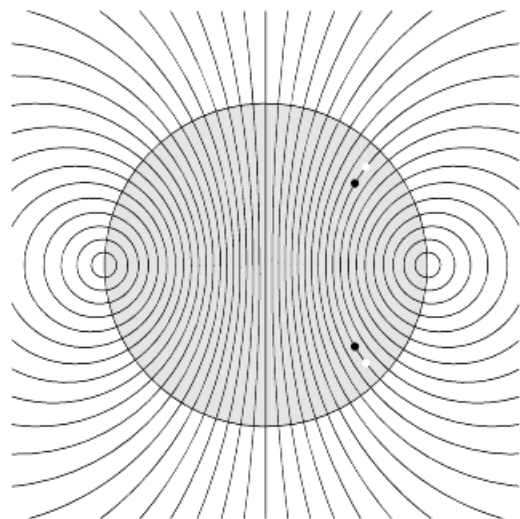
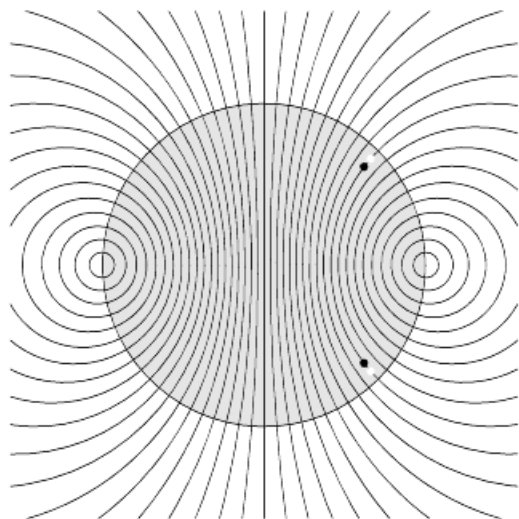


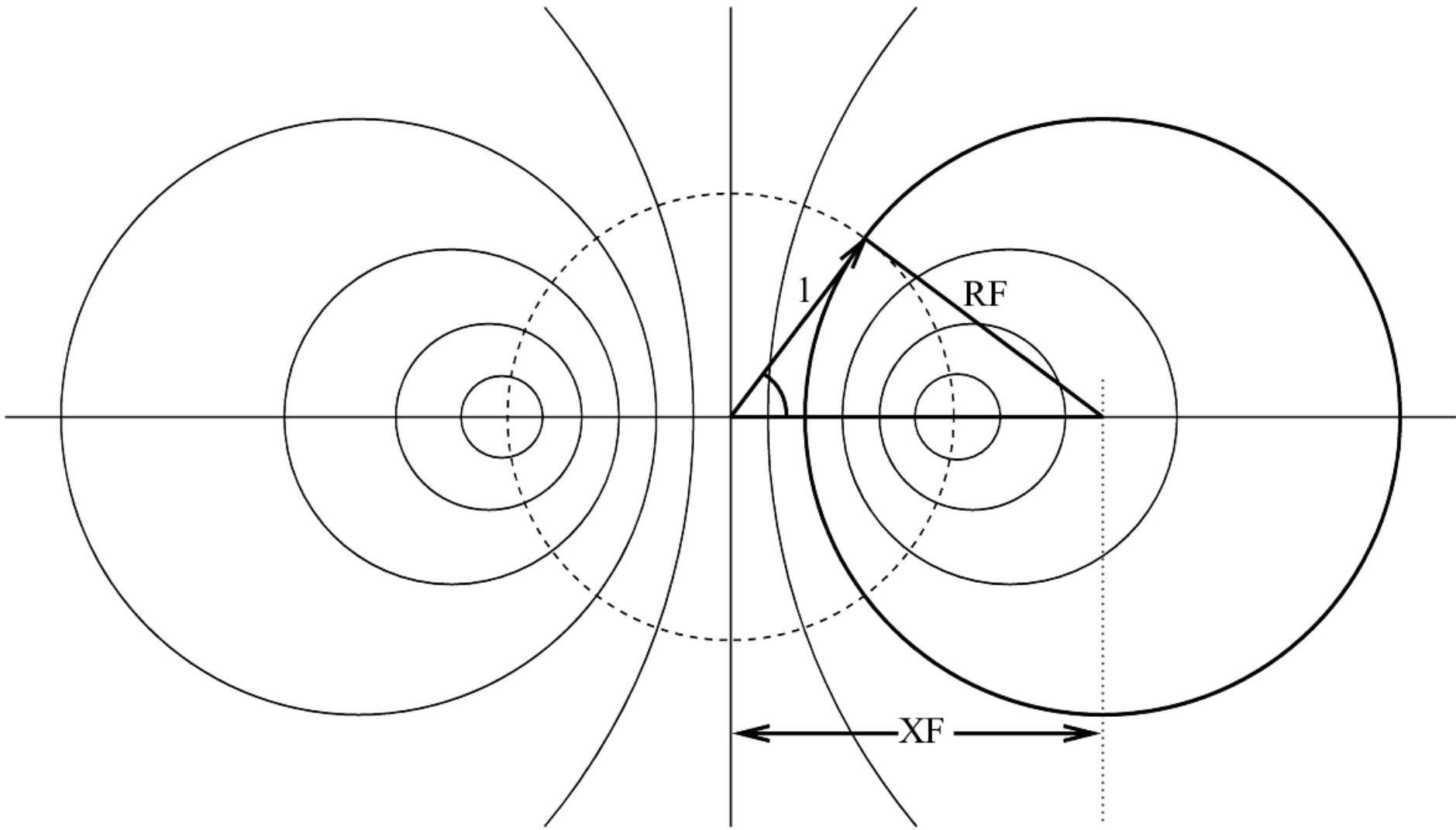






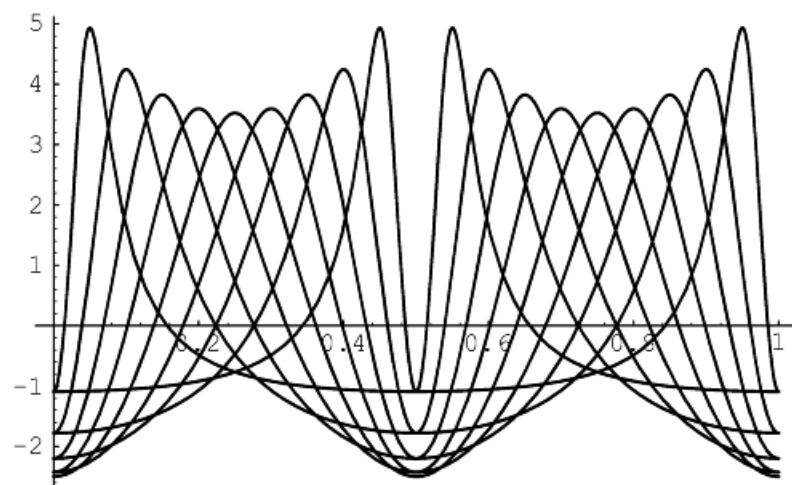
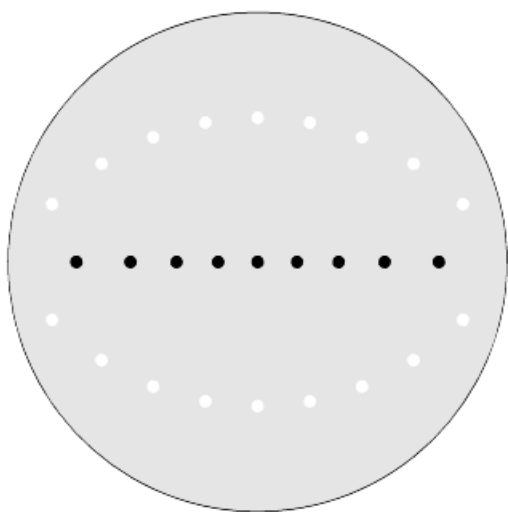


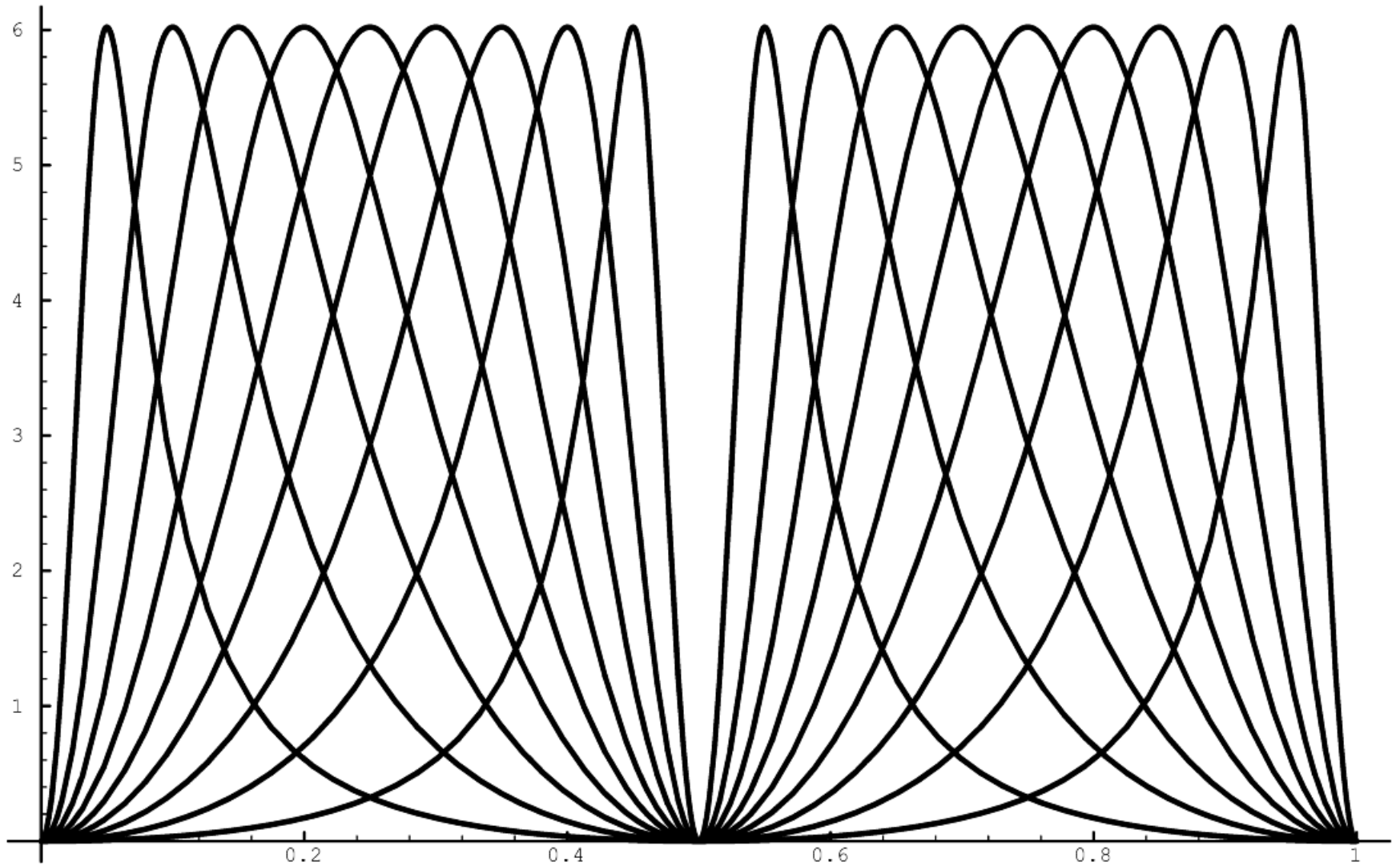


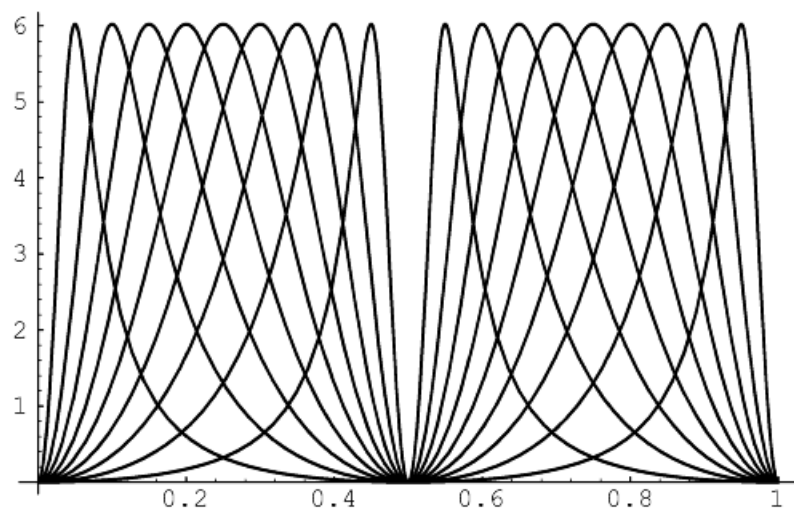
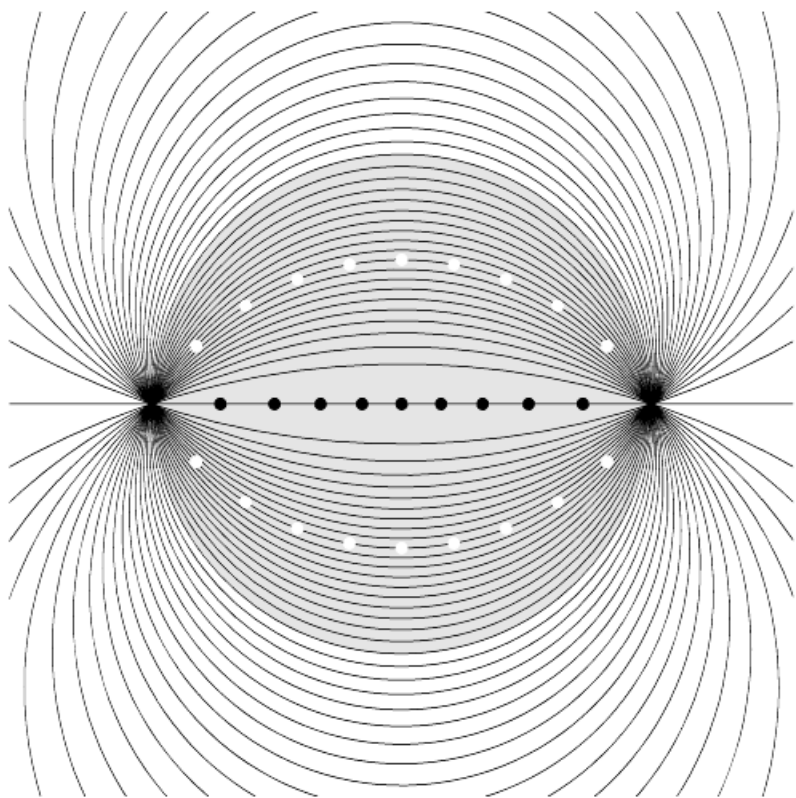


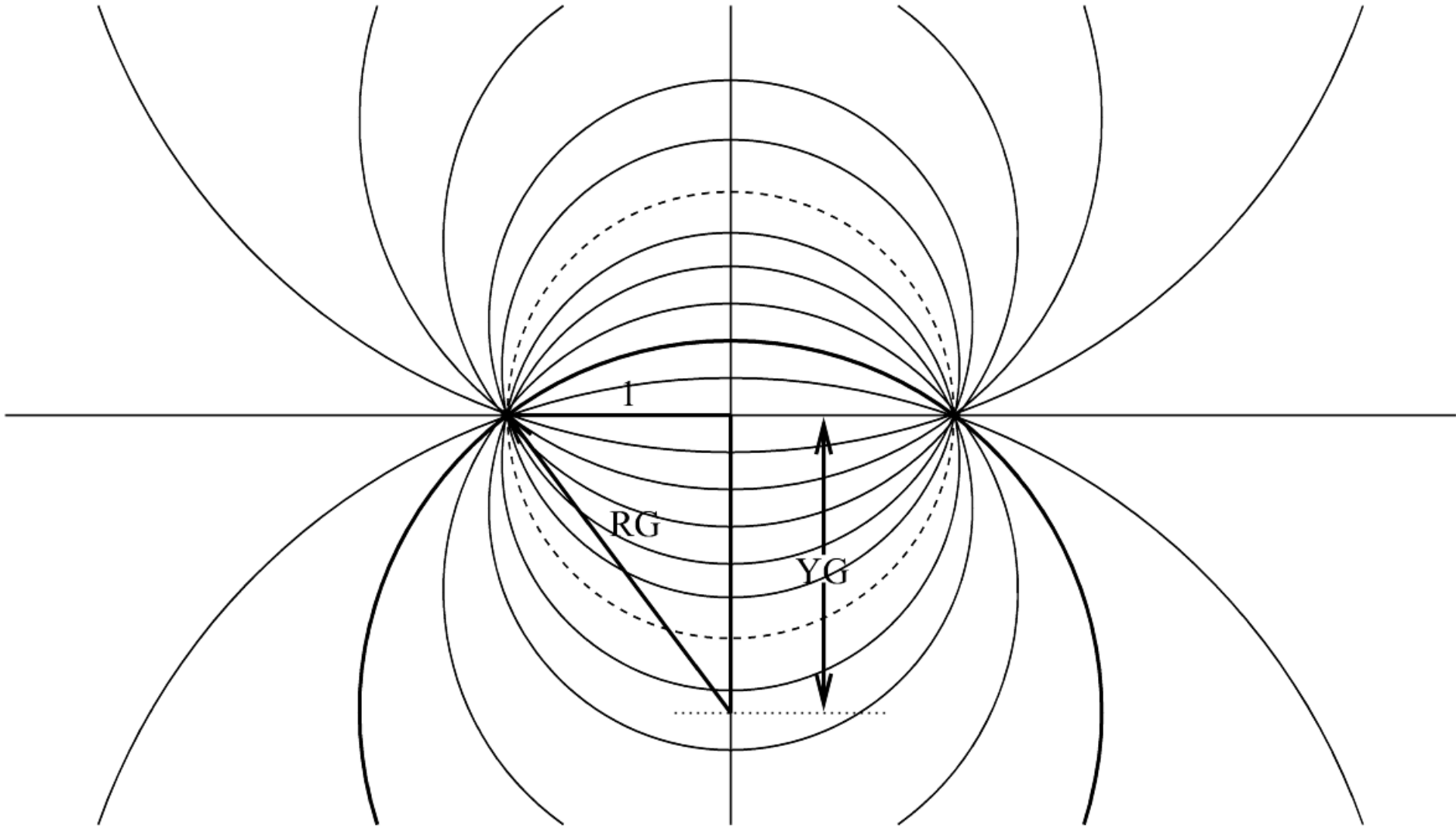
$$RF = \tan(2 * \pi * \text{Freq})$$

$$XF = 1 / \cos(2 * \pi * \text{Freq})$$



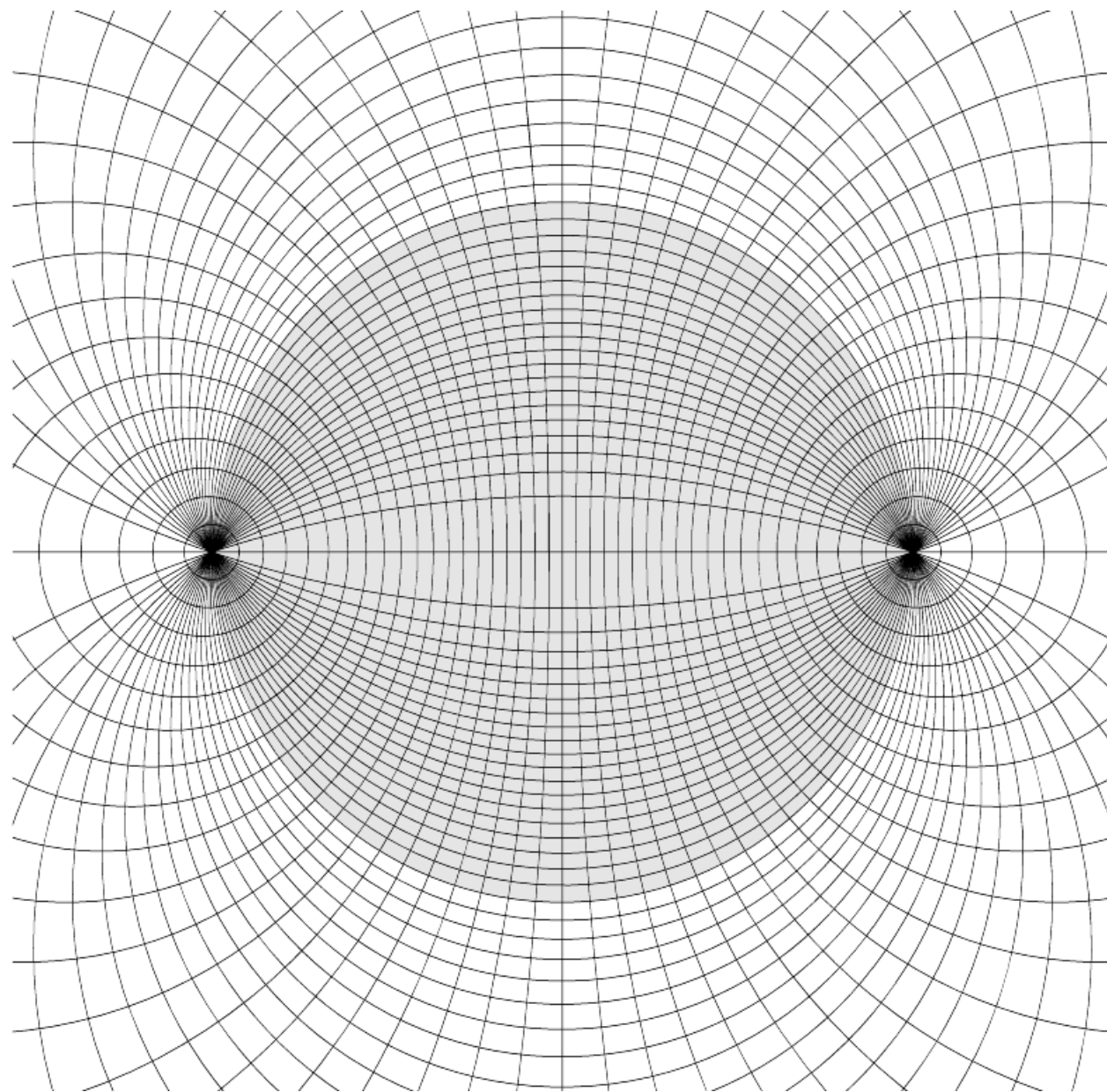


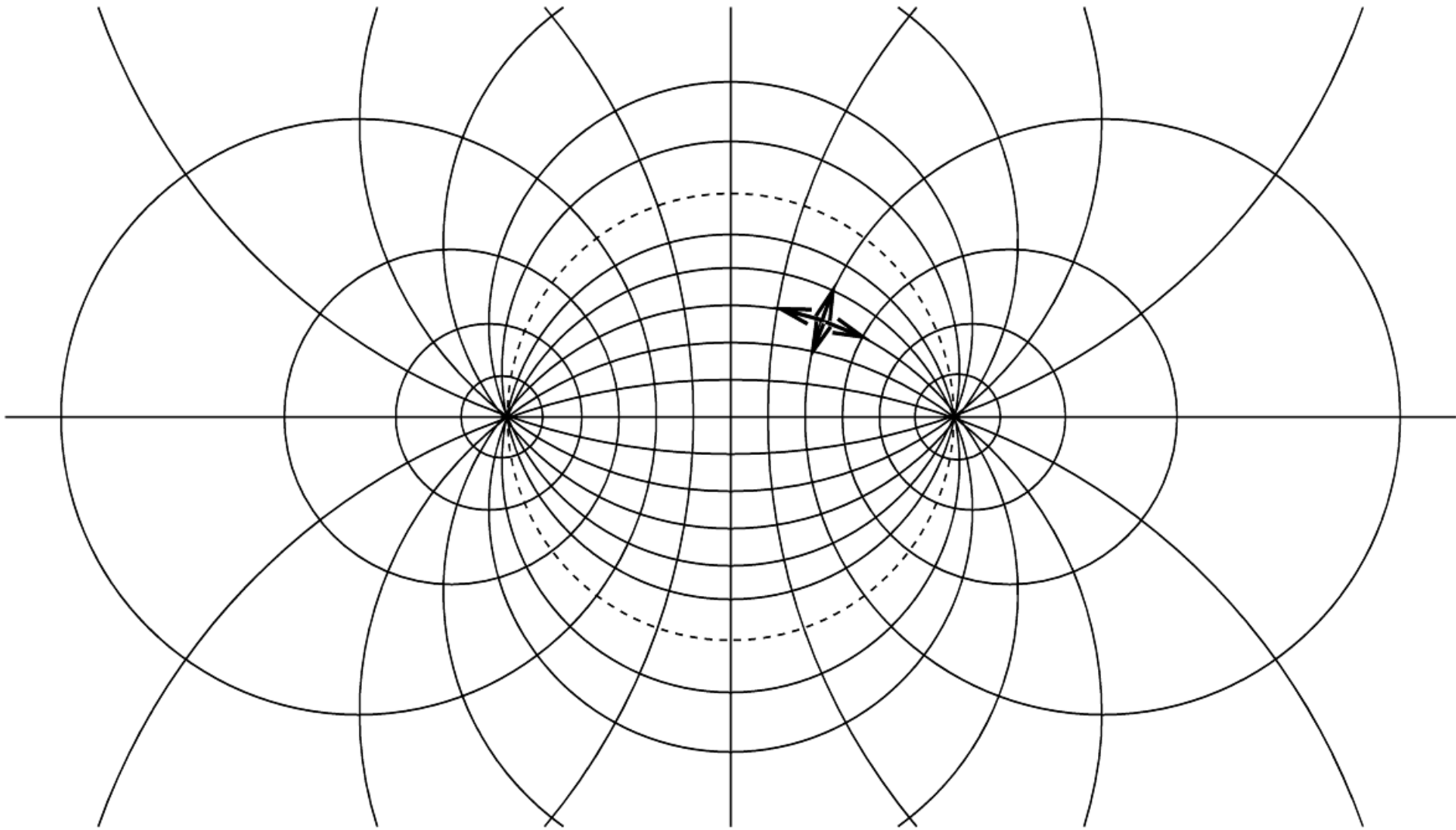




$$RG = 1 / \text{Sqrt}(1 - \text{Gain}^2)$$

$$YG = \text{Sqrt}(\text{Gain}^2 / (1 - \text{Gain}^2))$$





$$T = \tan(\pi * \text{Freq}) \quad X = \frac{1 - T^2}{1 + 2 * G * T + T^2}$$

$$G = \text{Gain} \quad Y = \frac{2 * T * \sqrt{1 - G^2}}{1 + 2 * G * T + T^2}$$

$$T1 = \tan(\pi * \text{ZeroFreq}) \quad T2 = \tan(\pi * \text{PoleFreq})$$

$$G1 = \text{ZeroGain} \quad G2 = \text{PoleGain}$$

$$A1 = \frac{2 * (T1^2 - 1)}{1 + 2 * G1 * T1 + T1^2}$$

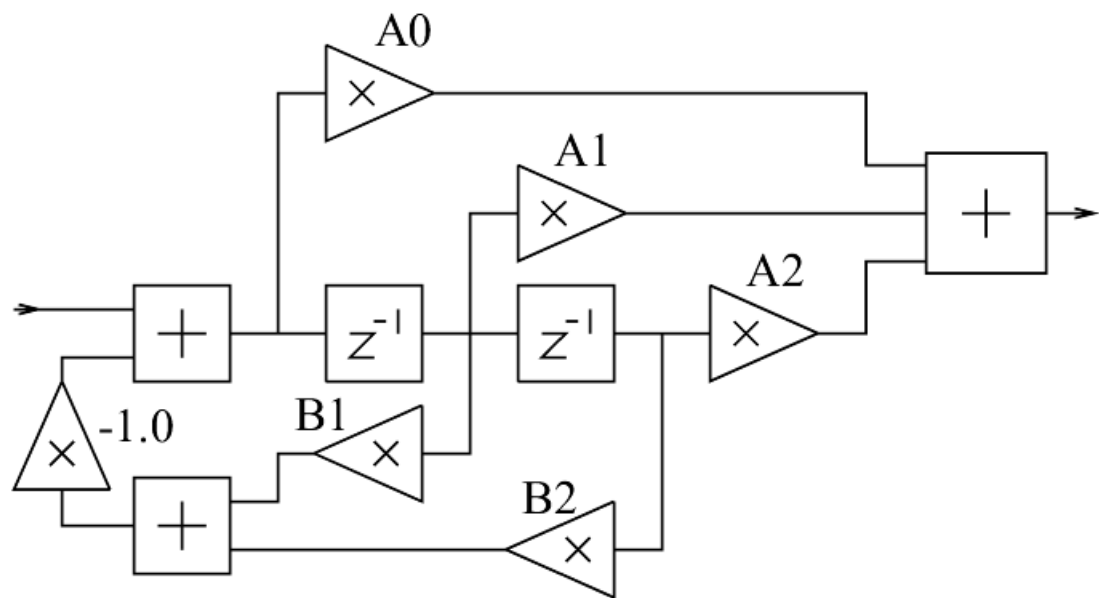
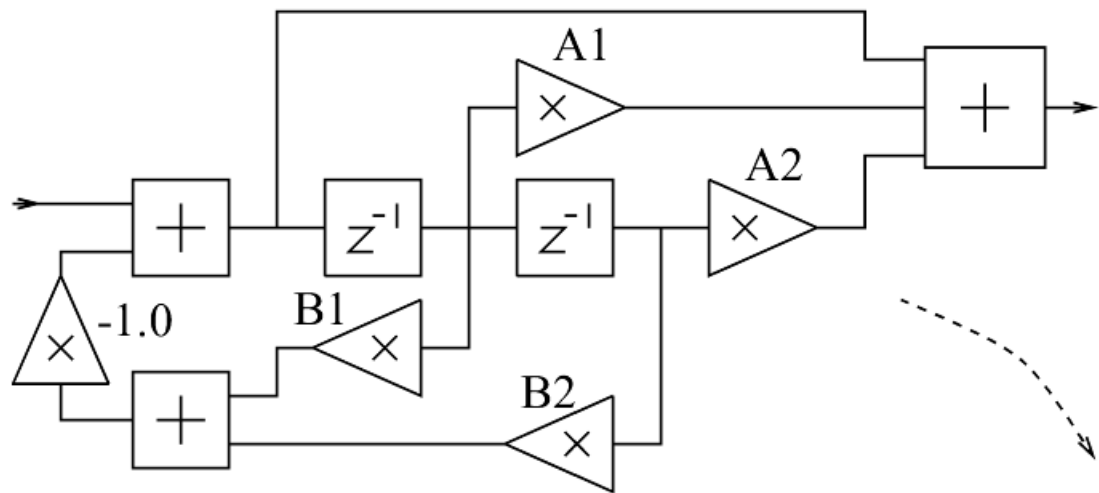
$$A2 = \frac{1 - 2 * G1 * T1 + T1^2}{1 + 2 * G1 * T1 + T1^2}$$

$$B1 = \frac{2 * (T2^2 - 1)}{1 + 2 * G2 * T2 + T2^2}$$

$$B2 = \frac{1 - 2 * G2 * T2 + T2^2}{1 + 2 * G2 * T2 + T2^2}$$

$$\text{Gain at DC} = \frac{(1 + 2 * G2 * T2 + T2^2)}{(1 + 2 * G1 * T1 + T1^2)} * \left(\frac{T1}{T2}\right)^2$$

$$\text{Gain at 0.5} = \frac{1 + 2 * G2 * T2 + T2^2}{1 + 2 * G1 * T1 + T1^2}$$



$$\text{Gain at DC} = ((1 + 2 * G2 * T2 + T2^2) / (1 + 2 * G1 * T1 + T1^2)) * (T1 / T2)^2$$

$$\text{Gain at 0.5} = (1 + 2 * G2 * T2 + T2^2) / (1 + 2 * G1 * T1 + T1^2)$$

Gain Correction at DC

$$A0 = (1 + 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)$$

$$A1 = 2 * (T1^2 - 1) / (1 + 2 * G2 * T2 + T2^2)$$

$$A2 = (1 - 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)$$

$$B1 = 2 * (T2^2 - 1) / (1 + 2 * G2 * T2 + T2^2)$$

$$B2 = (1 - 2 * G2 * T2 + T2^2) / (1 + 2 * G2 * T2 + T2^2)$$

Gain Correction at Freq = 0.5

$$A2 = ((1 + 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

$$A1 = (2 * (T1^2 - 1) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

$$A2 = ((1 - 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

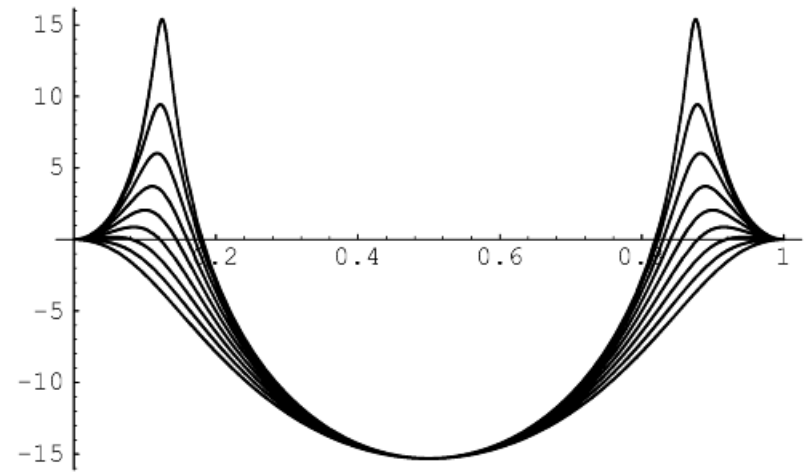
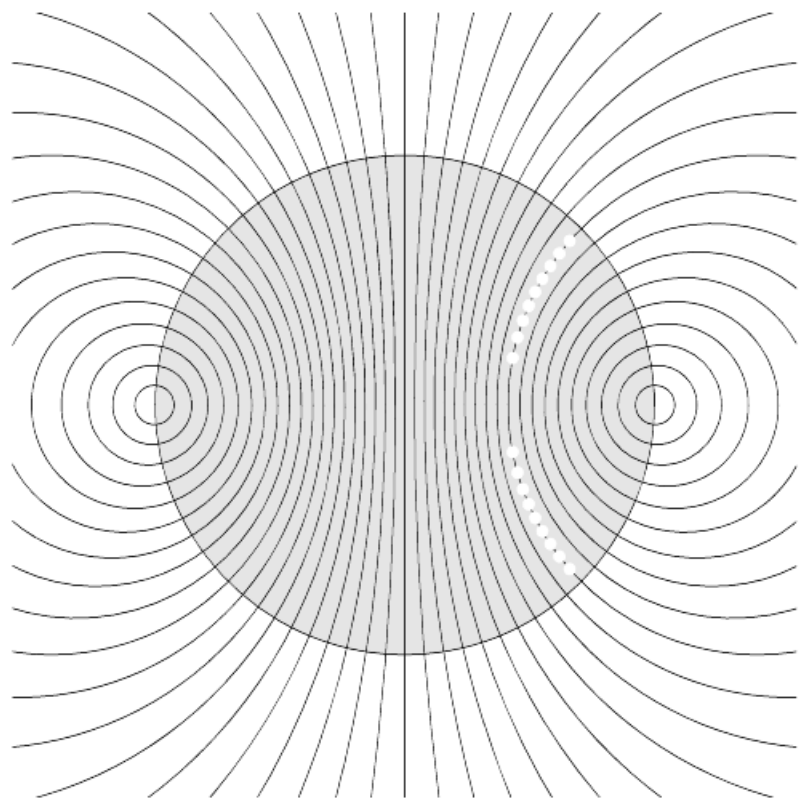
$$B1 = (2 * (T2^2 - 1) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

$$B2 = ((1 - 2 * G2 * T2 + T2^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T2)^2$$

```

// Use gain in dB, frequency, q and fs to make a0, a1, a2, b1, b2.
{ gainlin = exp(gain * 0.11512925); // linear gain i.e. 6dB = 2.0
  angularf = 6.2831853 * frequency / fs; // angular frequency
  t = tan(angularf * 0.5); // tan half angular frequency
  if (gain > 0.0)
  { g1 = (angularf / (sin(angularf) * q)) * gainlin;
    g2 = (angularf / (sin(angularf) * q));
  }
  else
  { g1 = (angularf / (sin(angularf) * q));
    g2 = (angularf / (sin(angularf) * q)) / gainlin;
  }
  a0 = (t * g1 + (t * t + 1)) / (t * g2 + (t * t + 1));
  a1 =      2 * (t * t - 1) / (t * g2 + (t * t + 1));
  a2 = -(t * g1 - (t * t + 1)) / (t * g2 + (t * t + 1));
  b1 =      -2 * (t * t - 1) / (t * g2 + (t * t + 1));
  b2 = (t * g2 - (t * t + 1)) / (t * g2 + (t * t + 1));
}

```



$$\text{Gain at DC} / \text{Gain at 0.5} = (T1 / T2)^2$$

$$\text{Gain at DC} = ((1 + 2 * G2 * T2 + T2^2) / (1 + 2 * G1 * T1 + T1^2)) * (T1 / T2)^2$$

$$\text{Gain at 0.5} = (1 + 2 * G2 * T2 + T2^2) / (1 + 2 * G1 * T1 + T1^2)$$

Gain Correction at DC

$$A0 = (1 + 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)$$

$$A1 = \frac{2 * (T1^2 - 1)}{(1 + 2 * G2 * T2 + T2^2)}$$

$$A2 = (1 - 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)$$

$$B1 = \frac{2 * (T2^2 - 1)}{(1 + 2 * G2 * T2 + T2^2)}$$

$$B2 = (1 - 2 * G2 * T2 + T2^2) / (1 + 2 * G2 * T2 + T2^2)$$

Gain Correction at Freq = 0.5

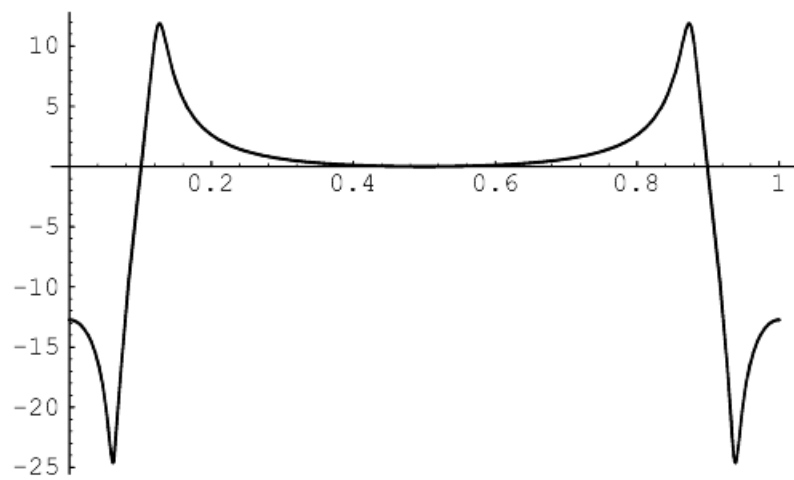
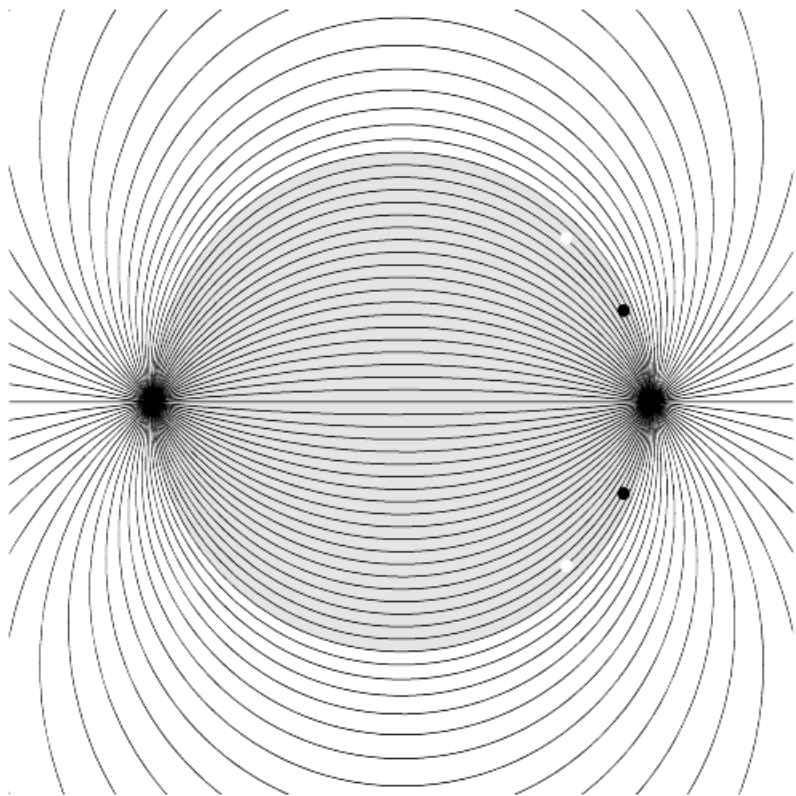
$$A2 = ((1 + 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

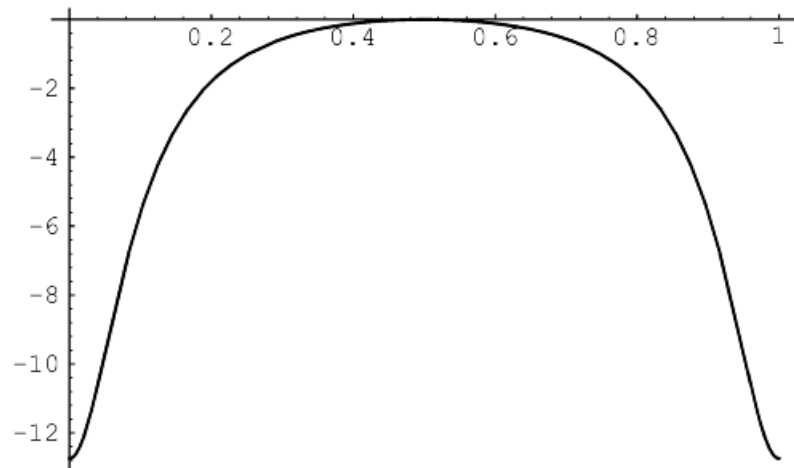
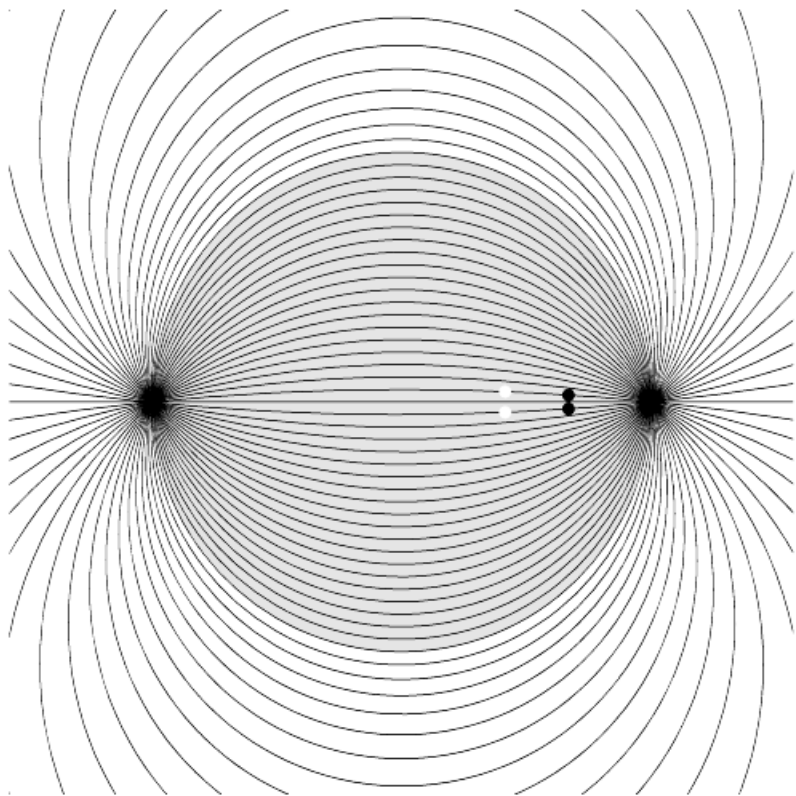
$$A1 = \frac{(2 * (T1^2 - 1))}{(1 + 2 * G2 * T2 + T2^2)} * (T2 / T1)^2$$

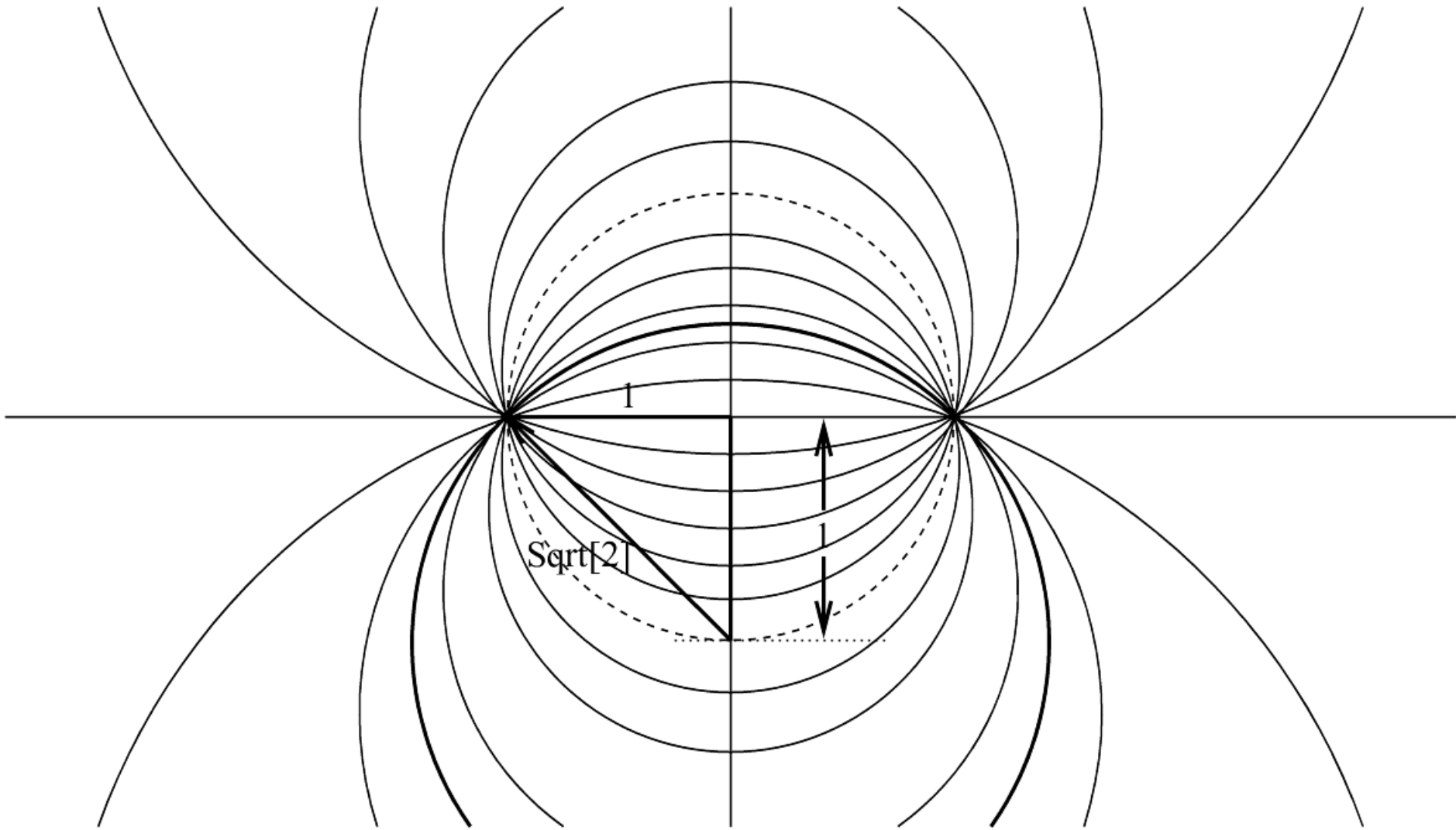
$$A2 = ((1 - 2 * G1 * T1 + T1^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T1)^2$$

$$B1 = \frac{(2 * (T2^2 - 1))}{(1 + 2 * G2 * T2 + T2^2)} * (T2 / T1)^2$$

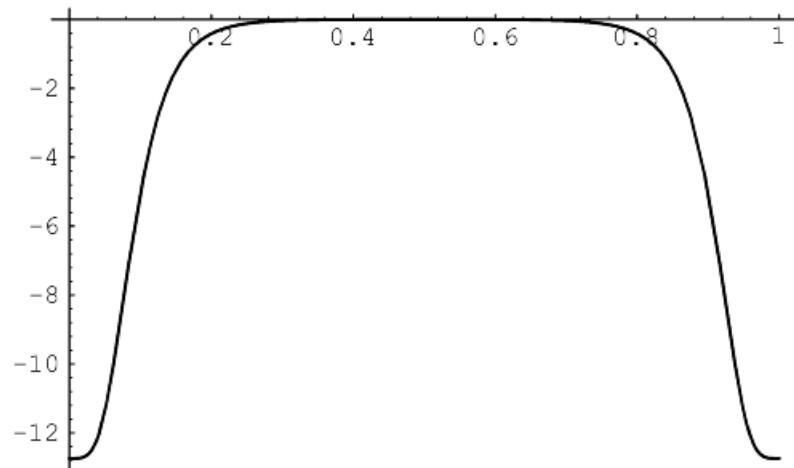
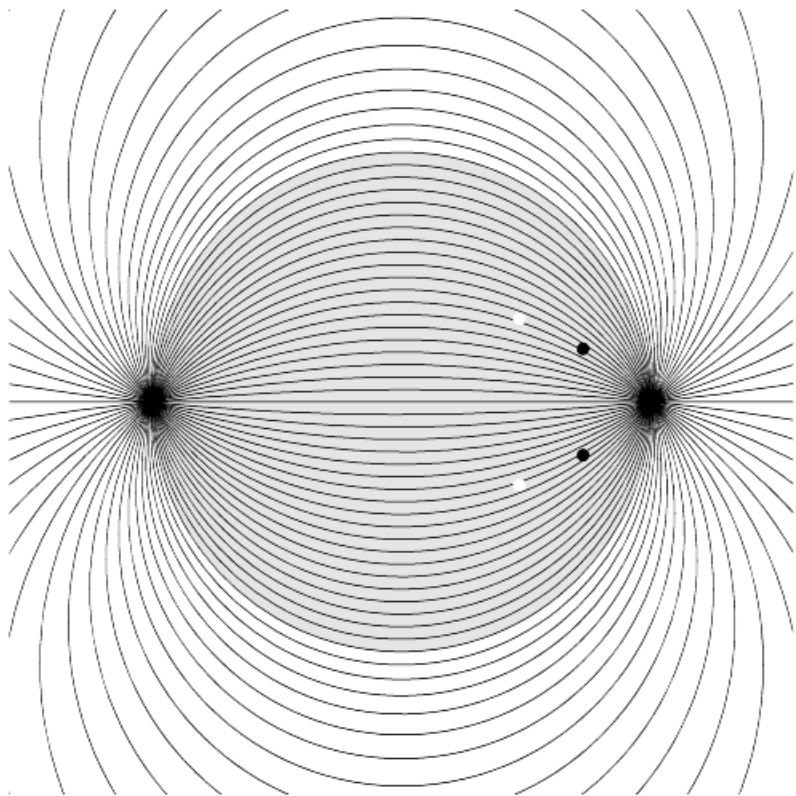
$$B2 = ((1 - 2 * G2 * T2 + T2^2) / (1 + 2 * G2 * T2 + T2^2)) * (T2 / T2)^2$$

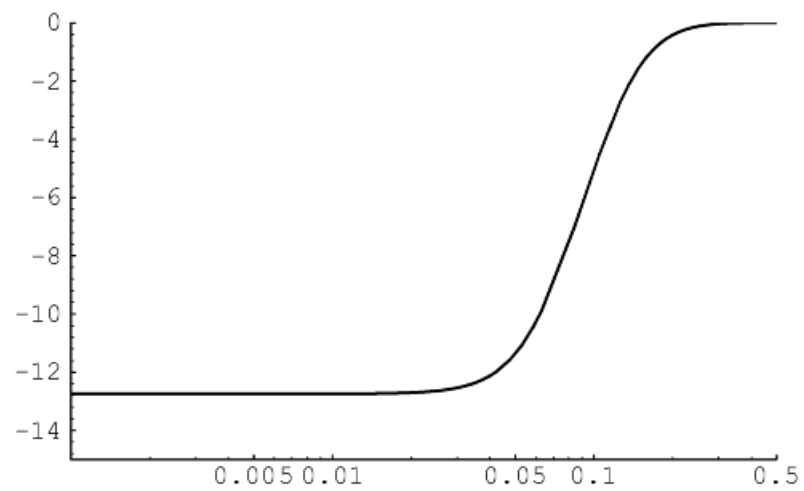
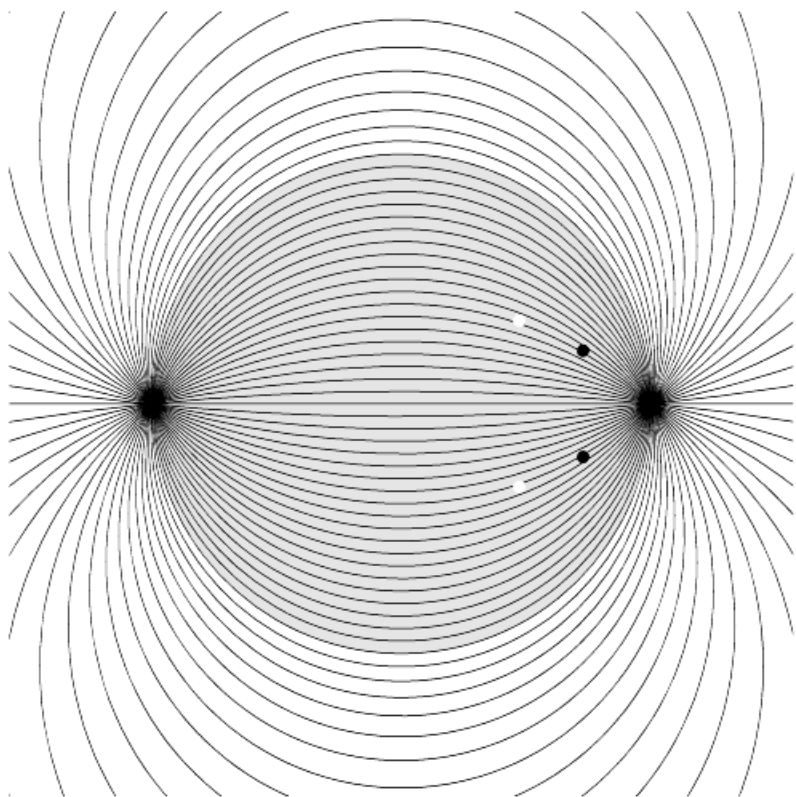


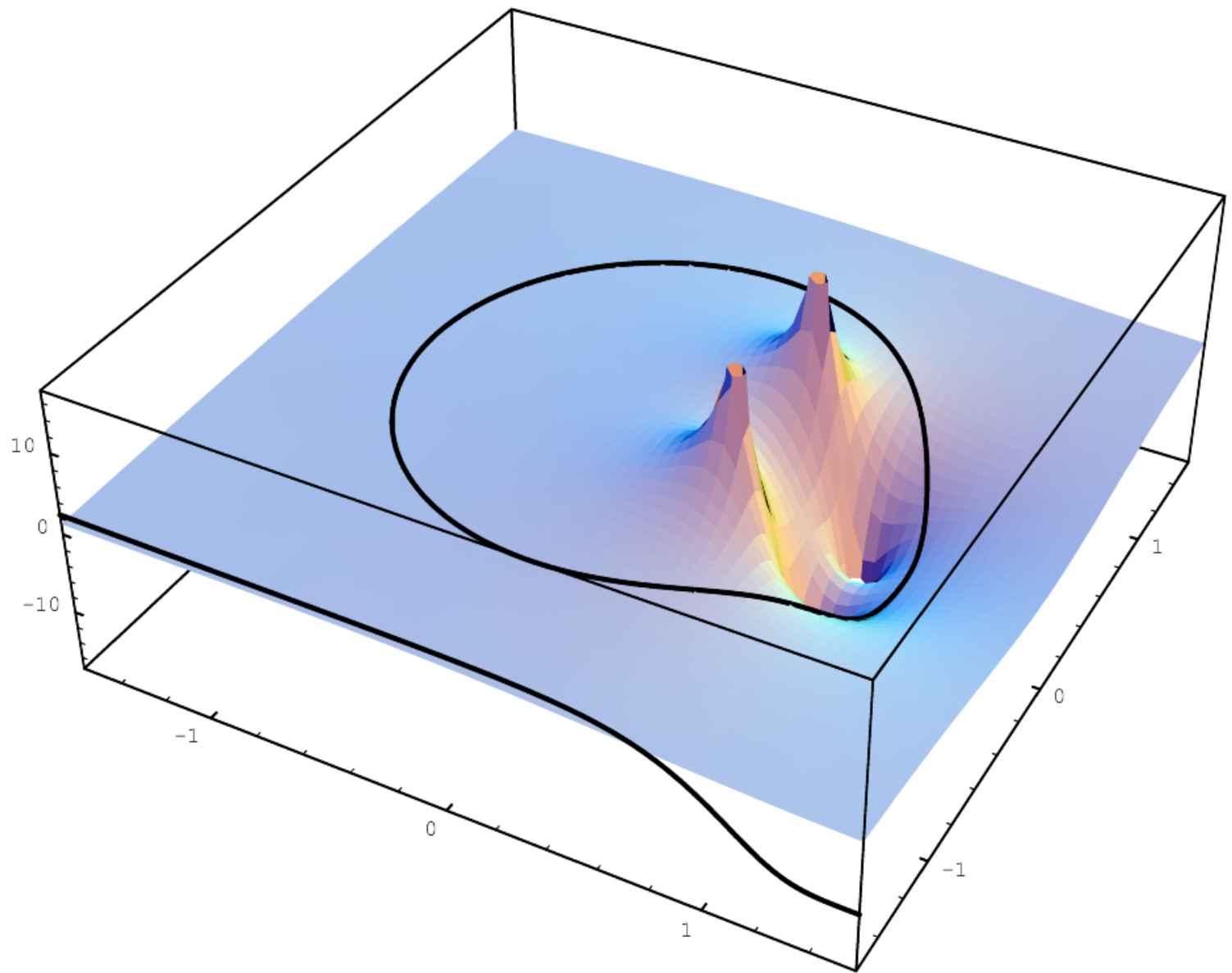


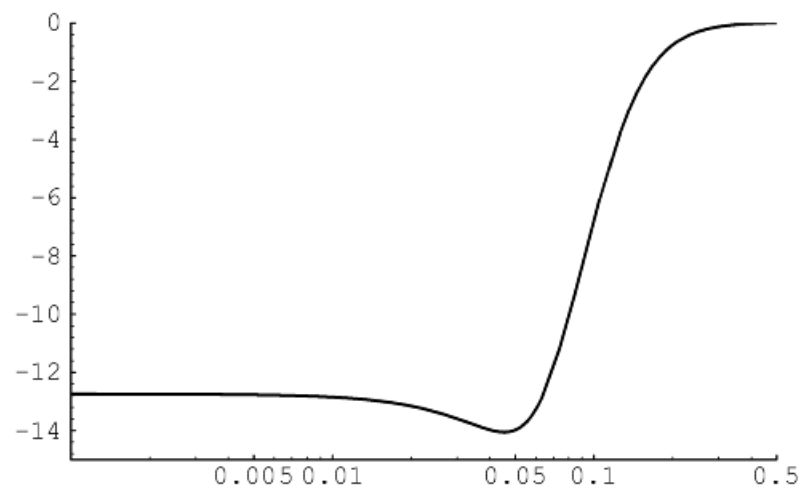
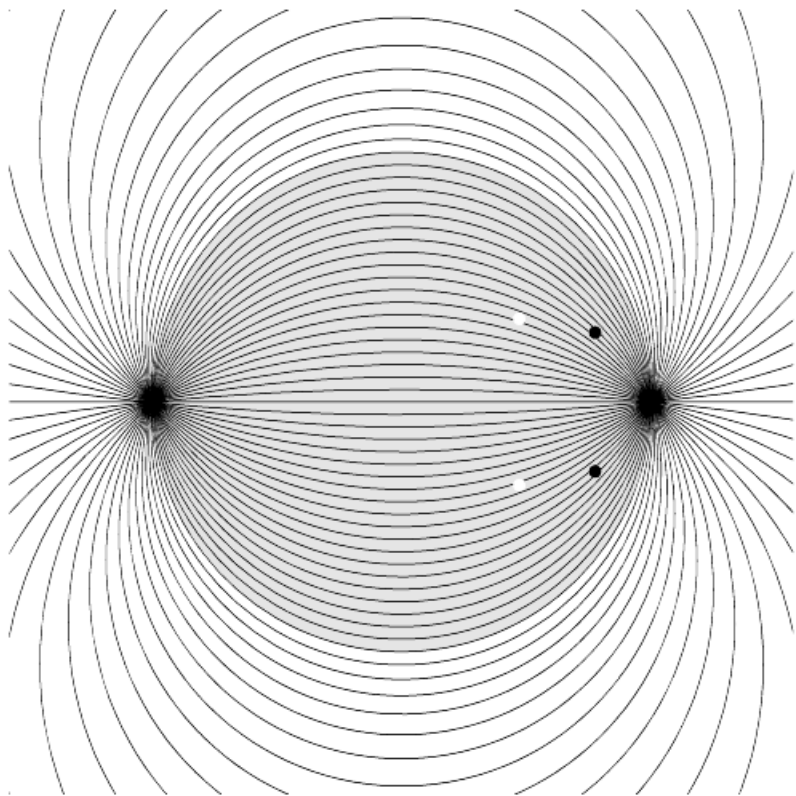


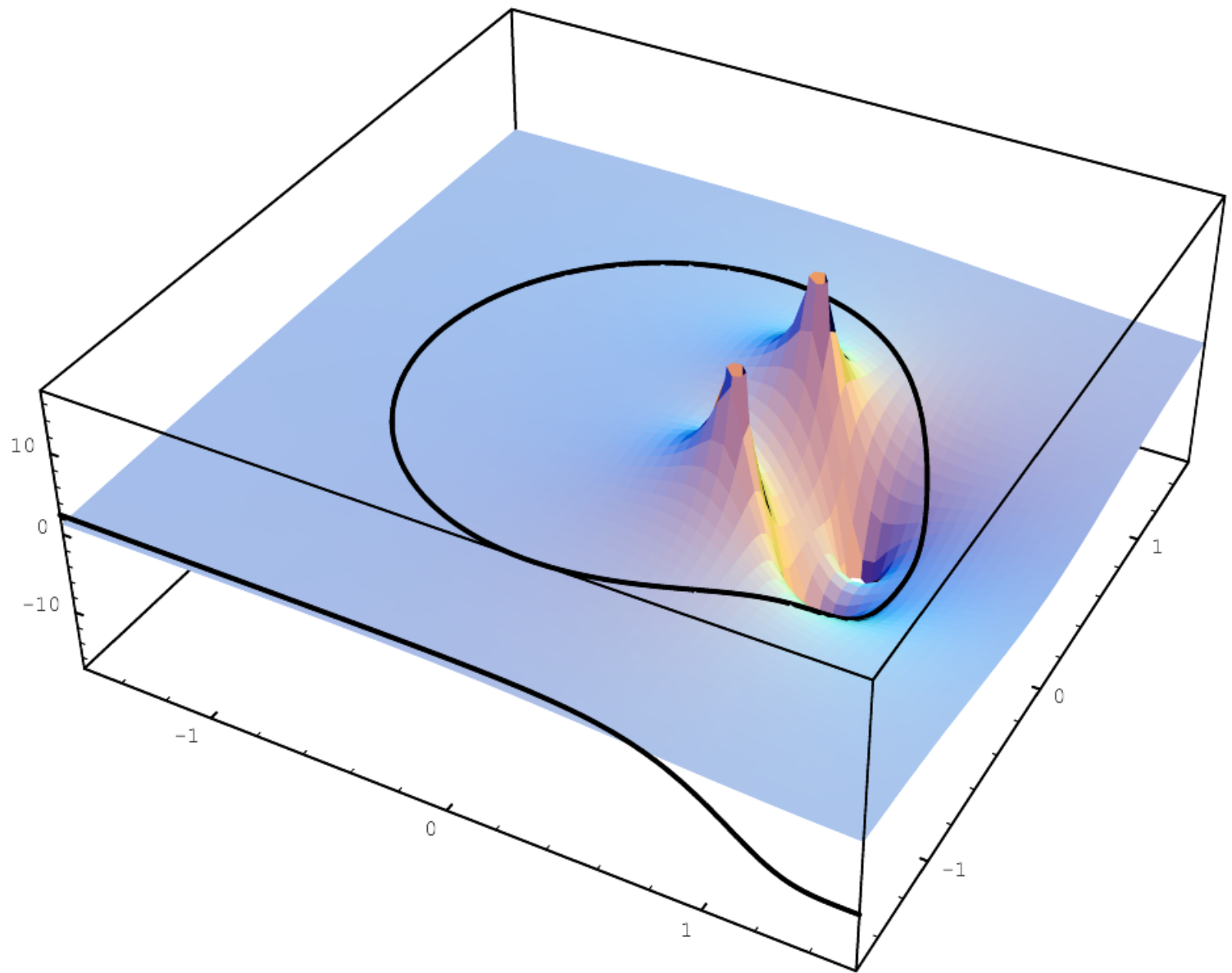
Gain = $1 / \text{Sqrt}[2] = 0.707\dots$

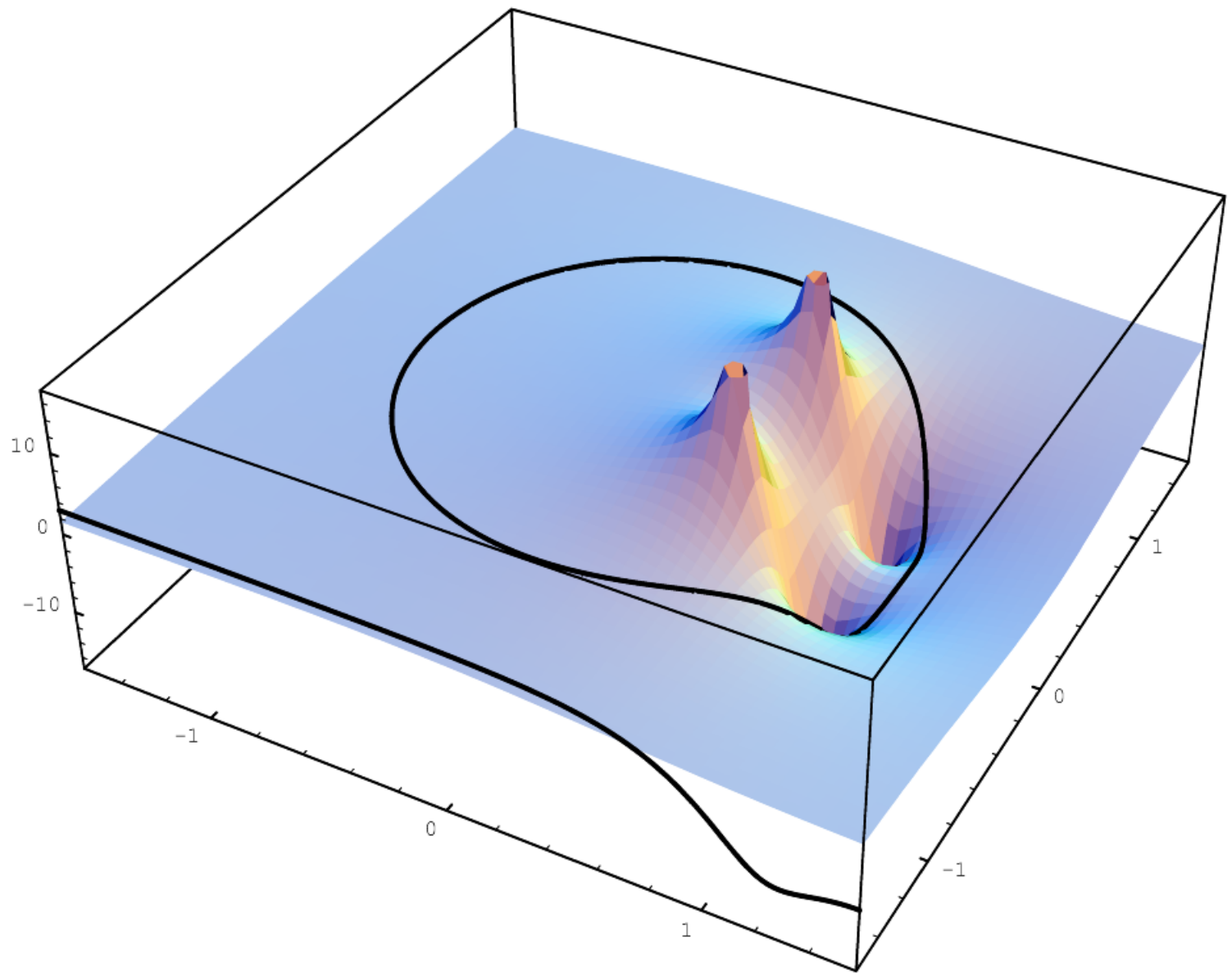












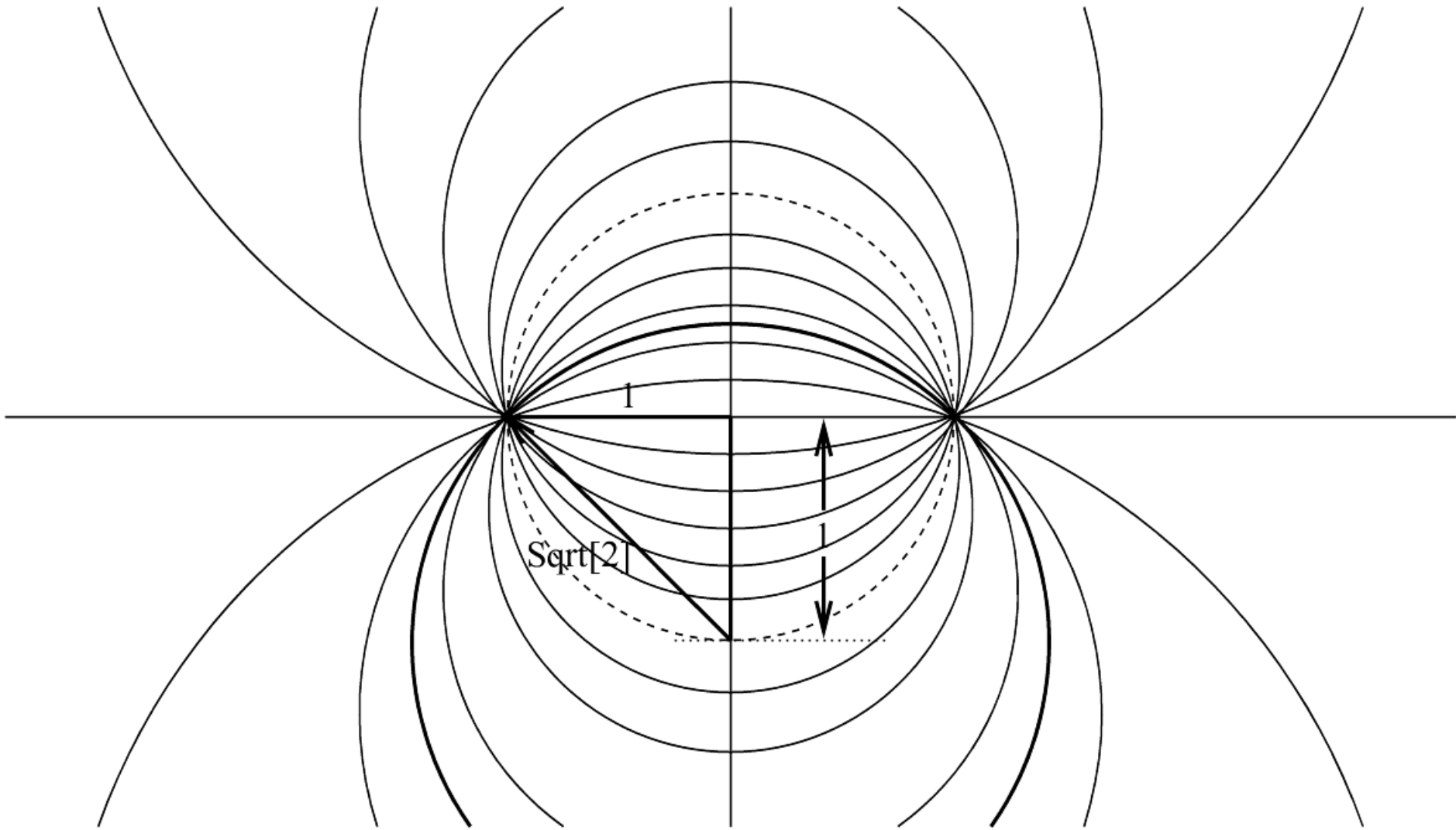
```

// Uses hf, gain in dB, frequency, over and fs to make a0, a1, a2, b1, b2.
{ if (((gain < 0.0) && (hf == 1)) || ((gain > 0.0) && (hf == 0)))
    sqrtgainlin = exp( gain * 0.057564);
else
    sqrtgainlin = exp(-gain * 0.057564);
ov
    = exp( gain * 0.115129 * over); // over = 1.0 gives ov = gainlin

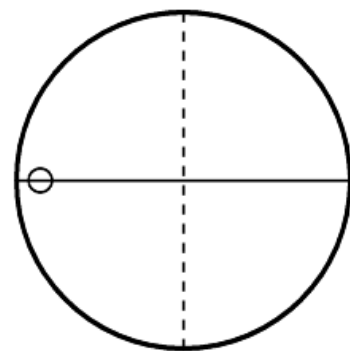
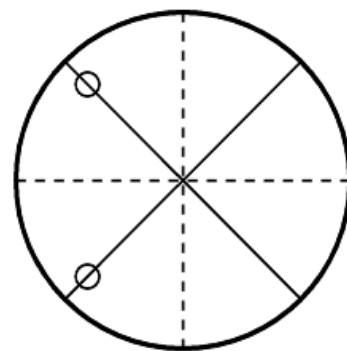
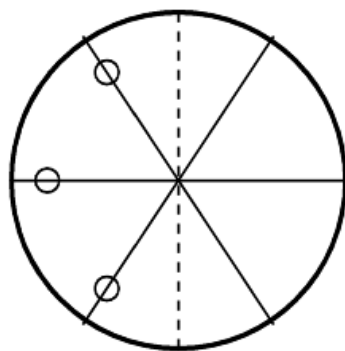
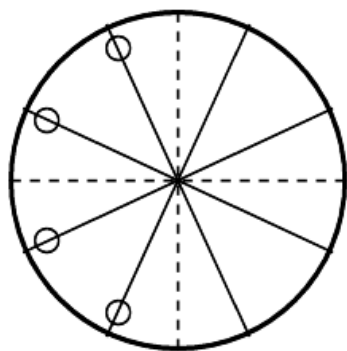
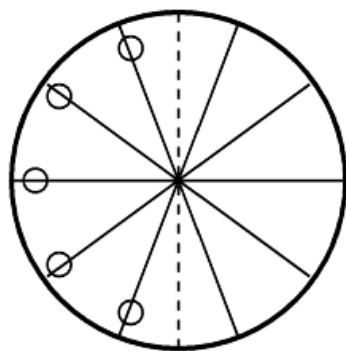
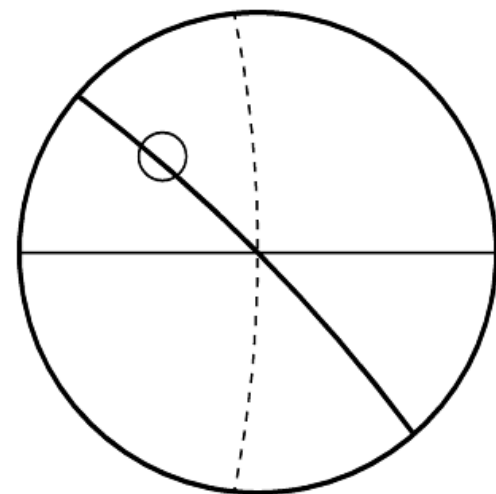
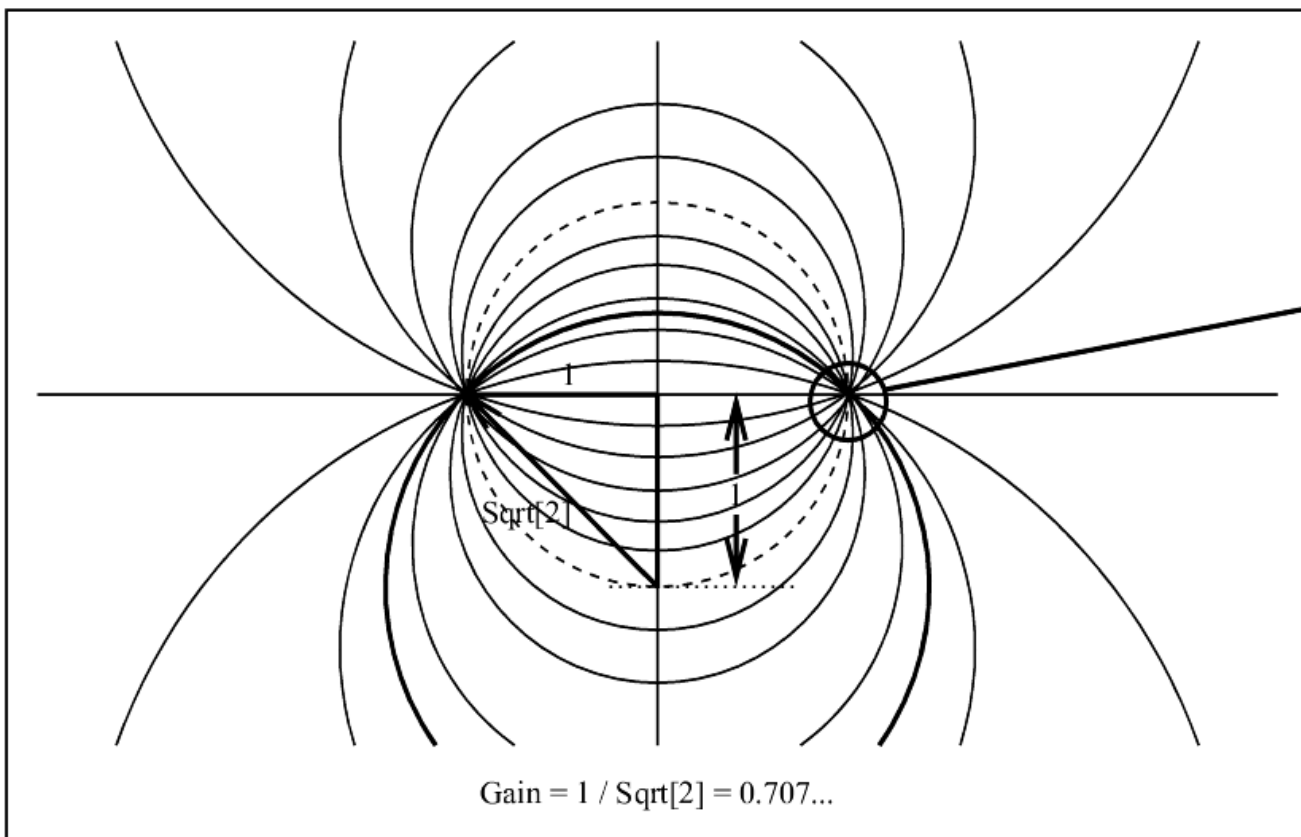
if (gain > 0.0)
{ t1 = tan(3.141592 * frequency / fs) * sqrtgainlin;
  t2 = tan(3.141592 * frequency / fs);
  g1 = 1.4142136 / ov;
  g2 = 1.4142136;
}
else
{ t1 = tan(3.141592 * frequency / fs);
  t2 = tan(3.141592 * frequency / fs) * sqrtgainlin;
  g1 = 1.4142136;
  g2 = 1.4142136 * ov;
}

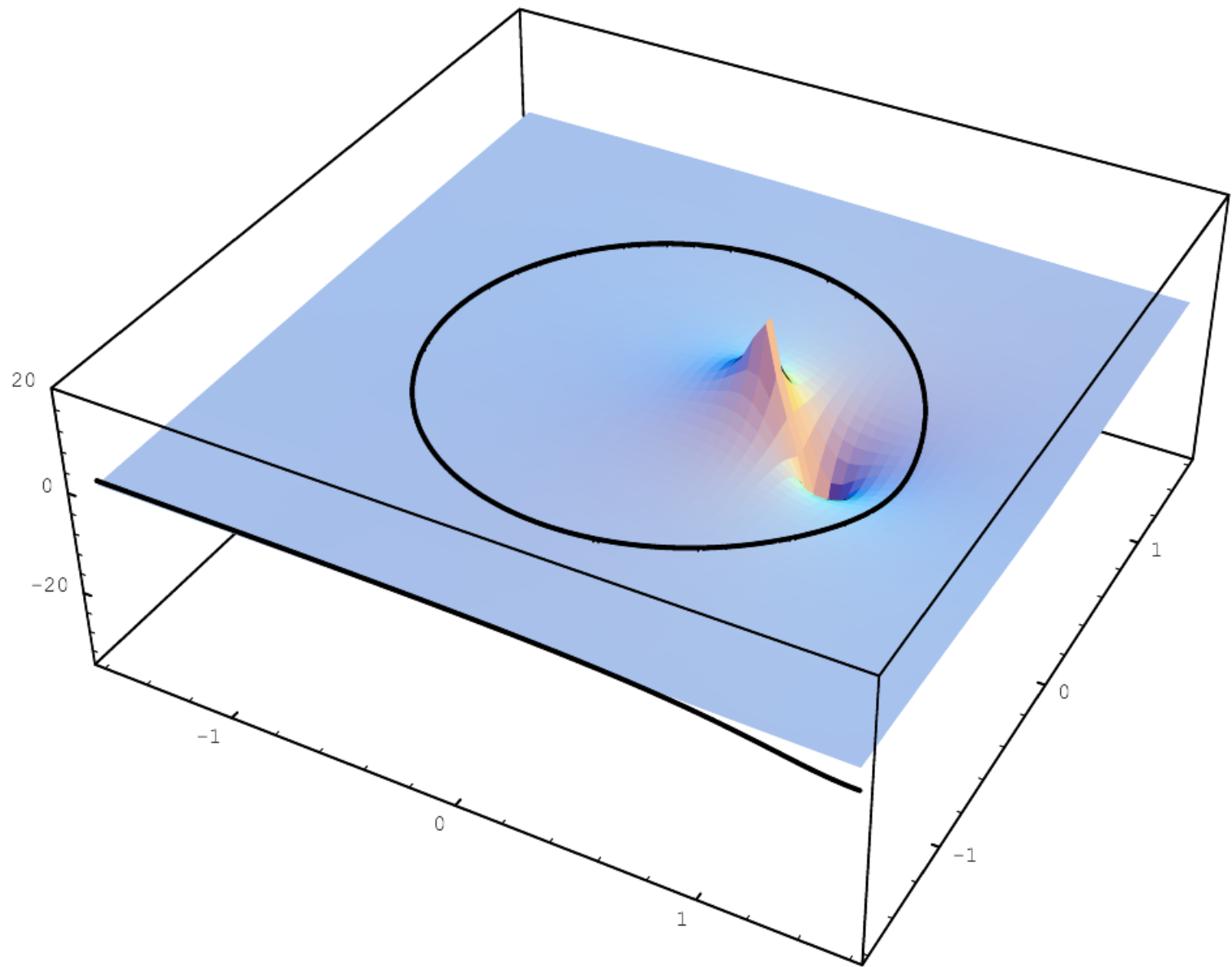
b1 = -2.0 * (t2 * t2 - 1.0) / (1.0 + t2 * t2 + t2 * g2);
b2 =      -(t2 * t2 + 1.0 - t2 * g2) / (1.0 + t2 * t2 + t2 * g2);
a0 =      (t1 * t1 + 1.0 + t1 * g1) / (1.0 + t2 * t2 + t2 * g2);
a1 =  2.0 * (t1 * t1 - 1.0) / (1.0 + t2 * t2 + t2 * g2);
a2 =      (t1 * t1 + 1.0 - t1 * g1) / (1.0 + t2 * t2 + t2 * g2);
if (hf)
{ a0 *= (t1 * t1) / (t2 * t2);
  a1 *= (t1 * t1) / (t2 * t2);
  a2 *= (t1 * t1) / (t2 * t2);
}
}
}

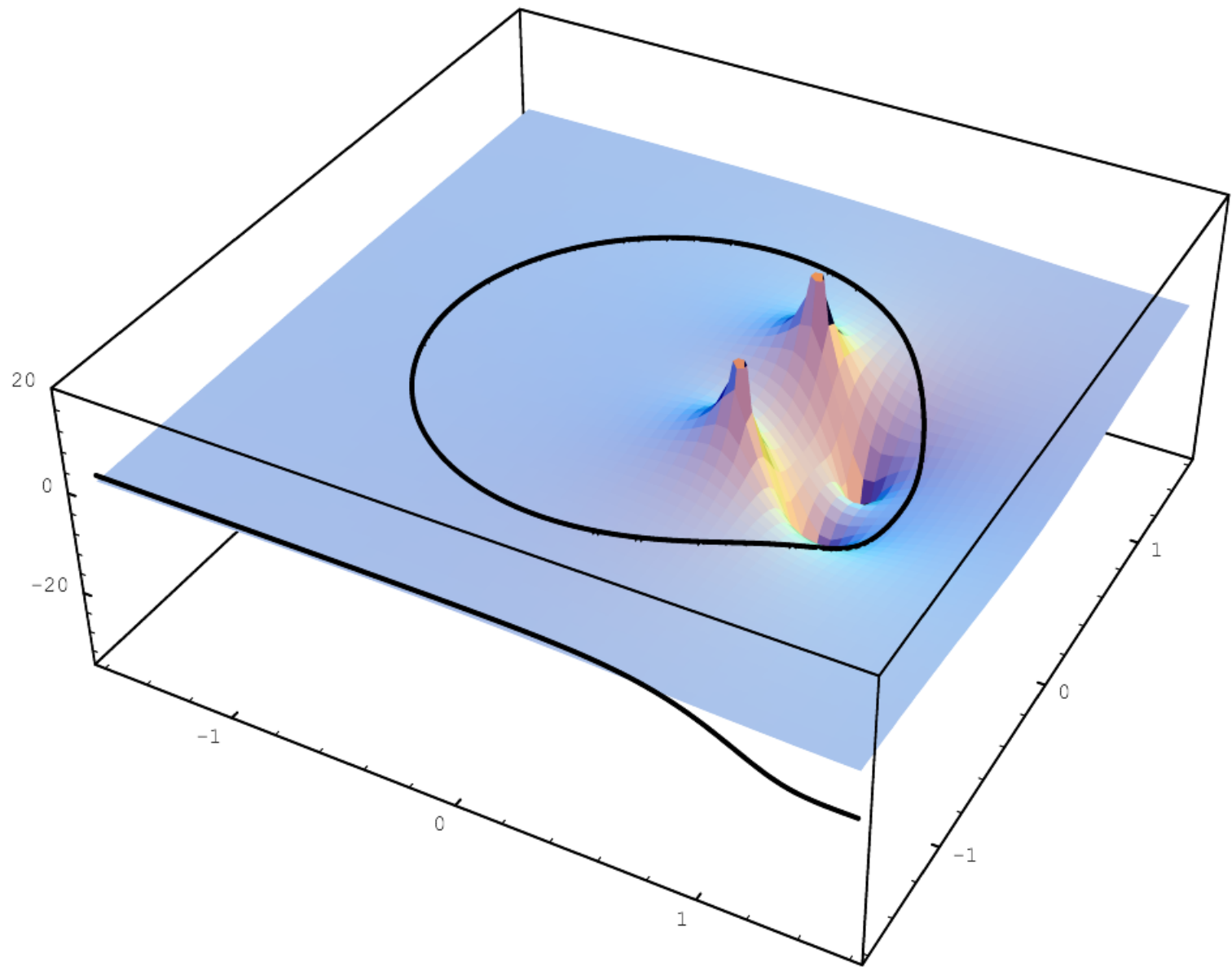
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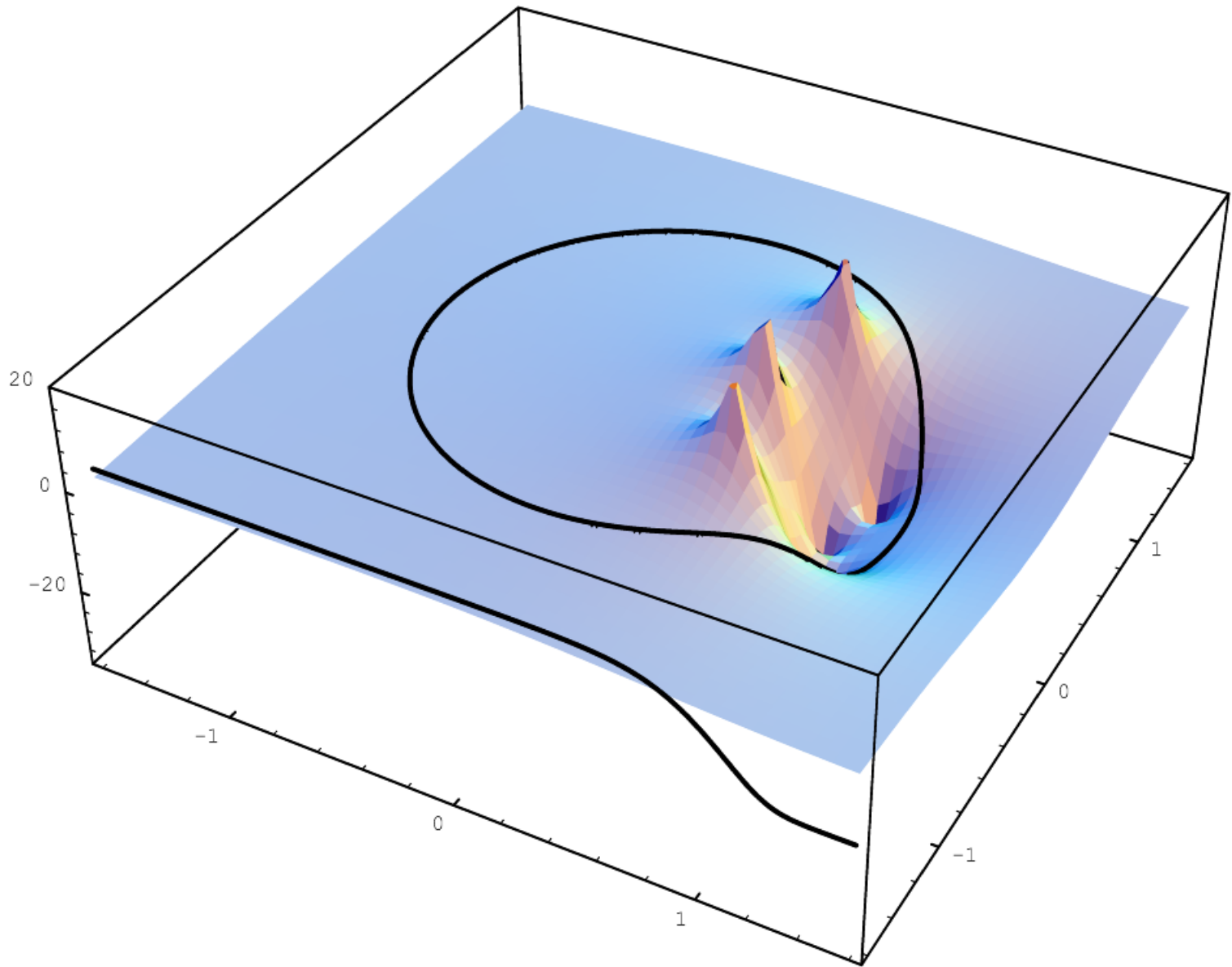


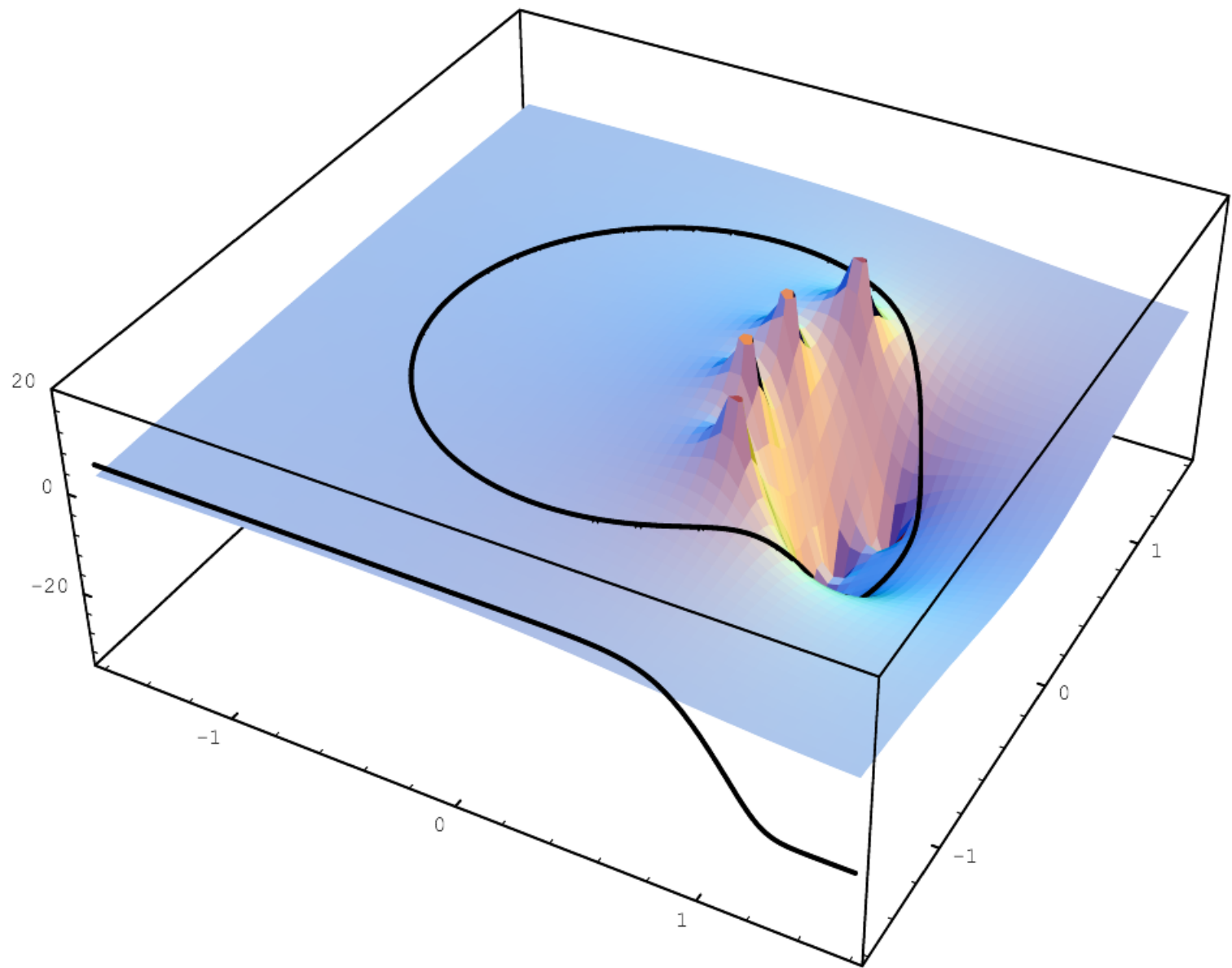
Gain = $1 / \text{Sqrt}[2] = 0.707\dots$

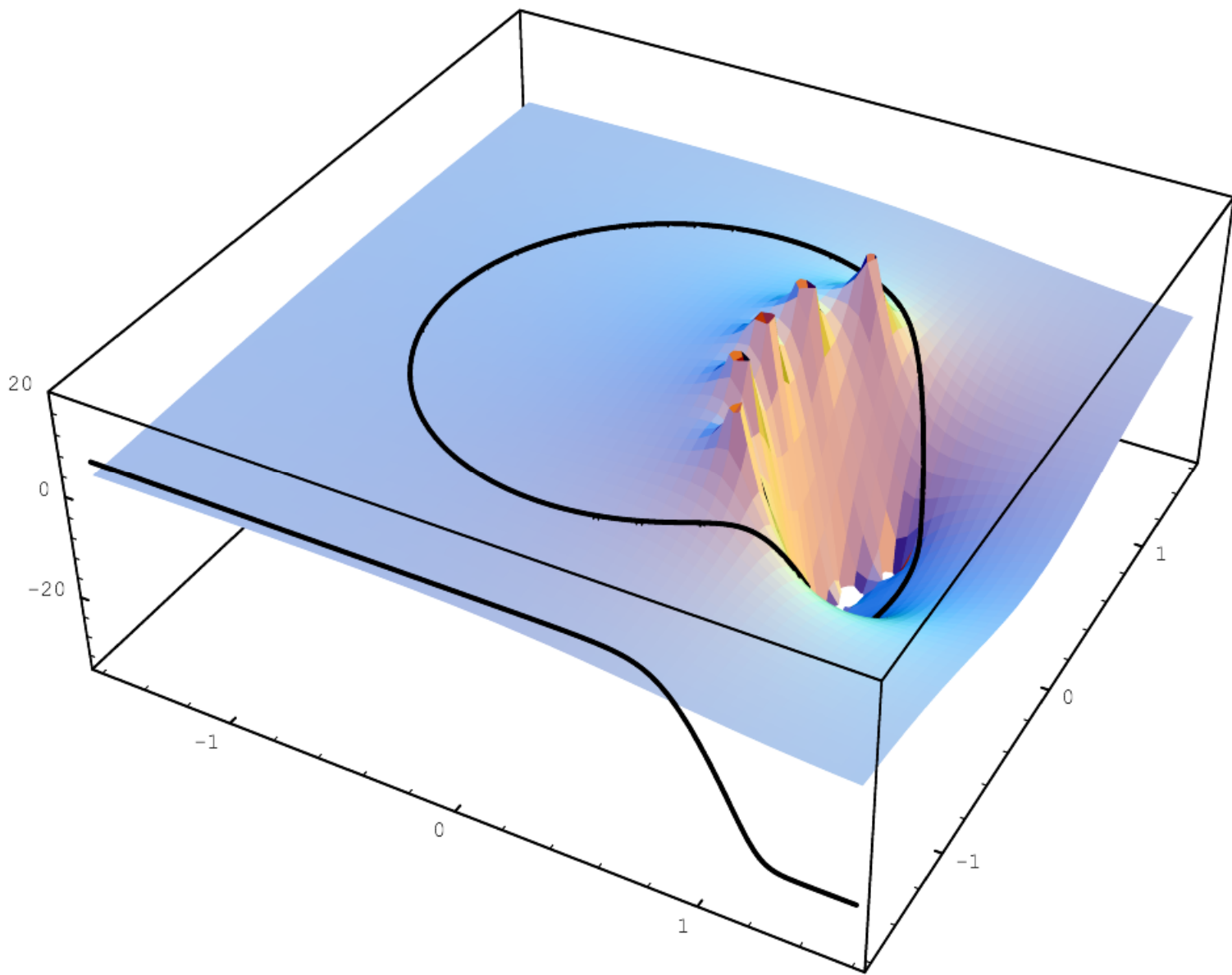


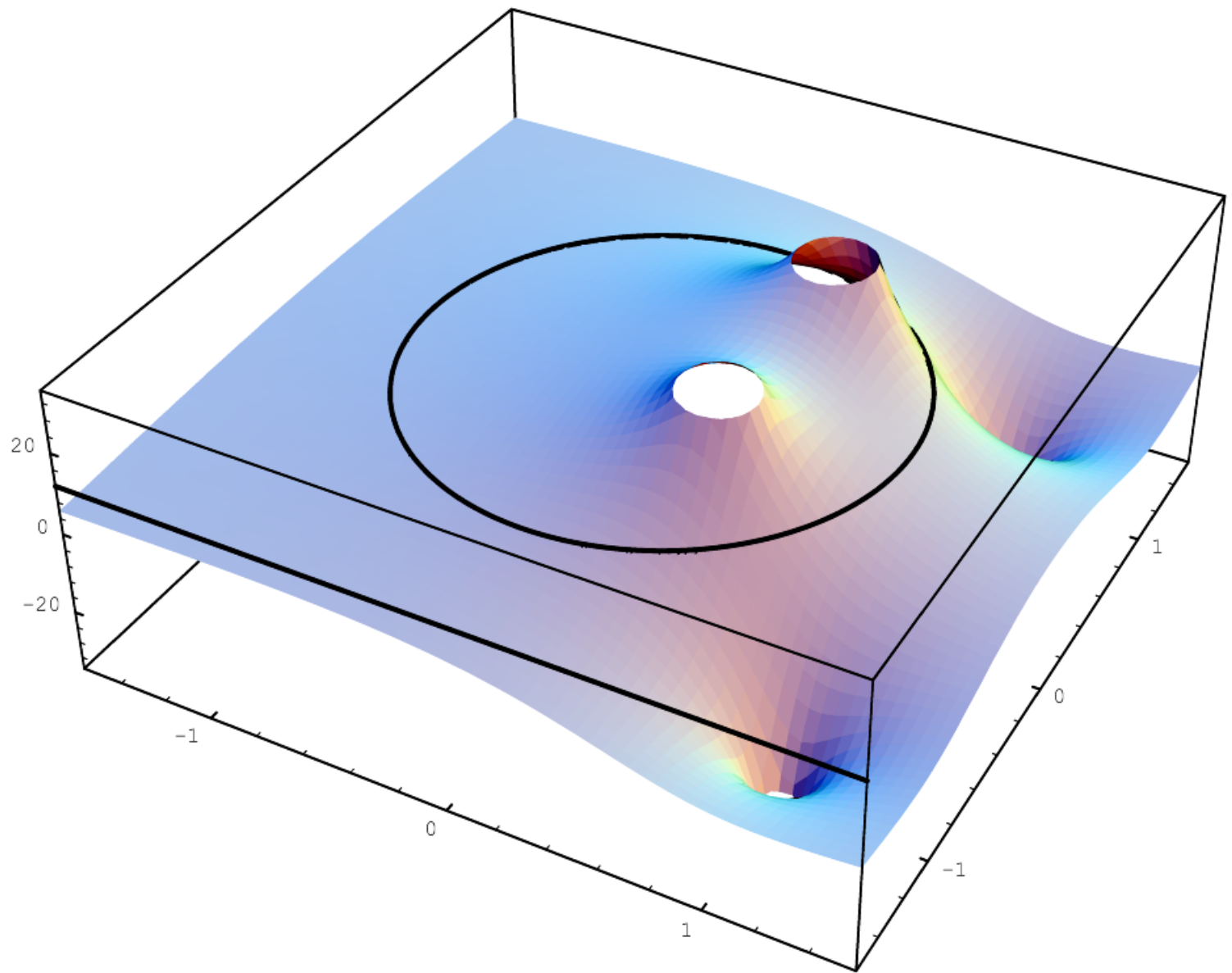


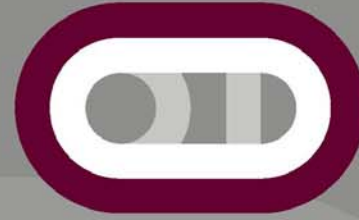












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