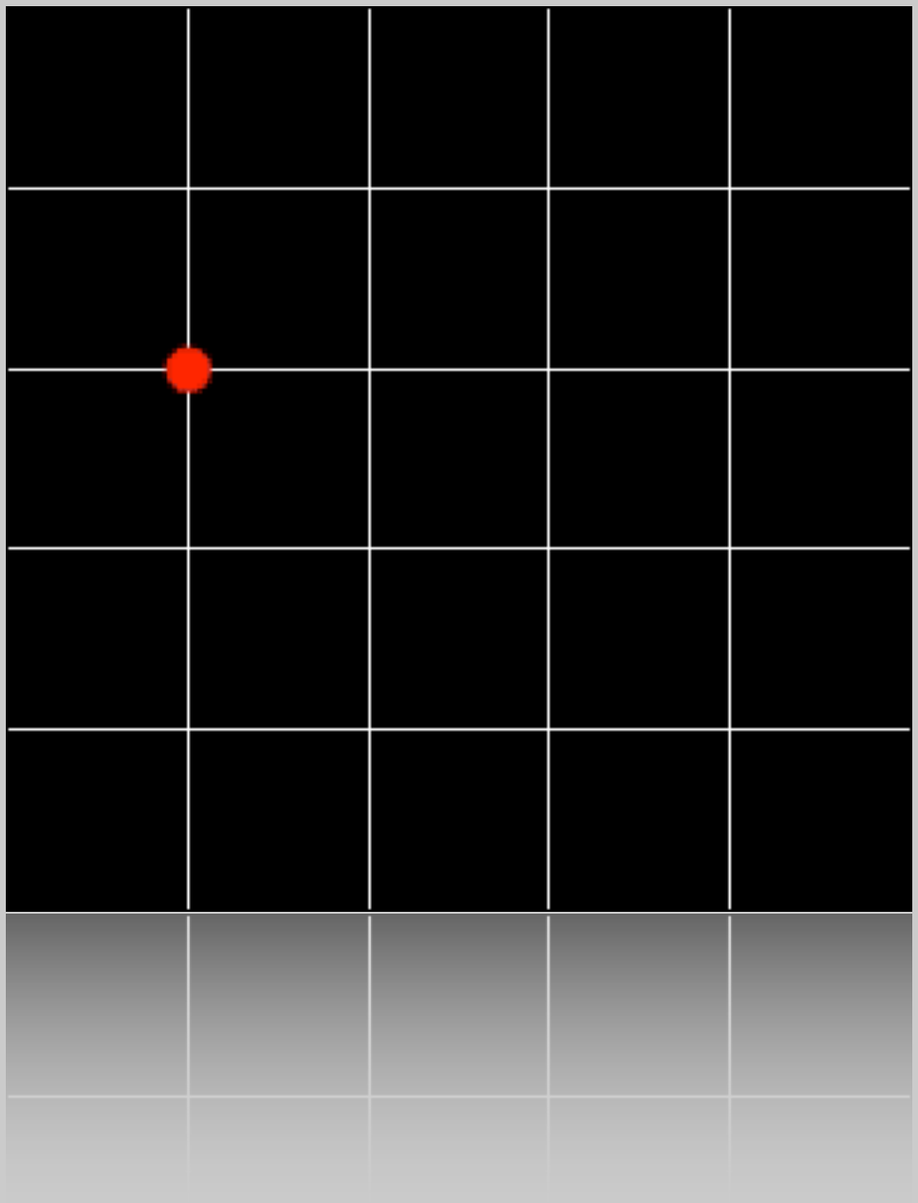
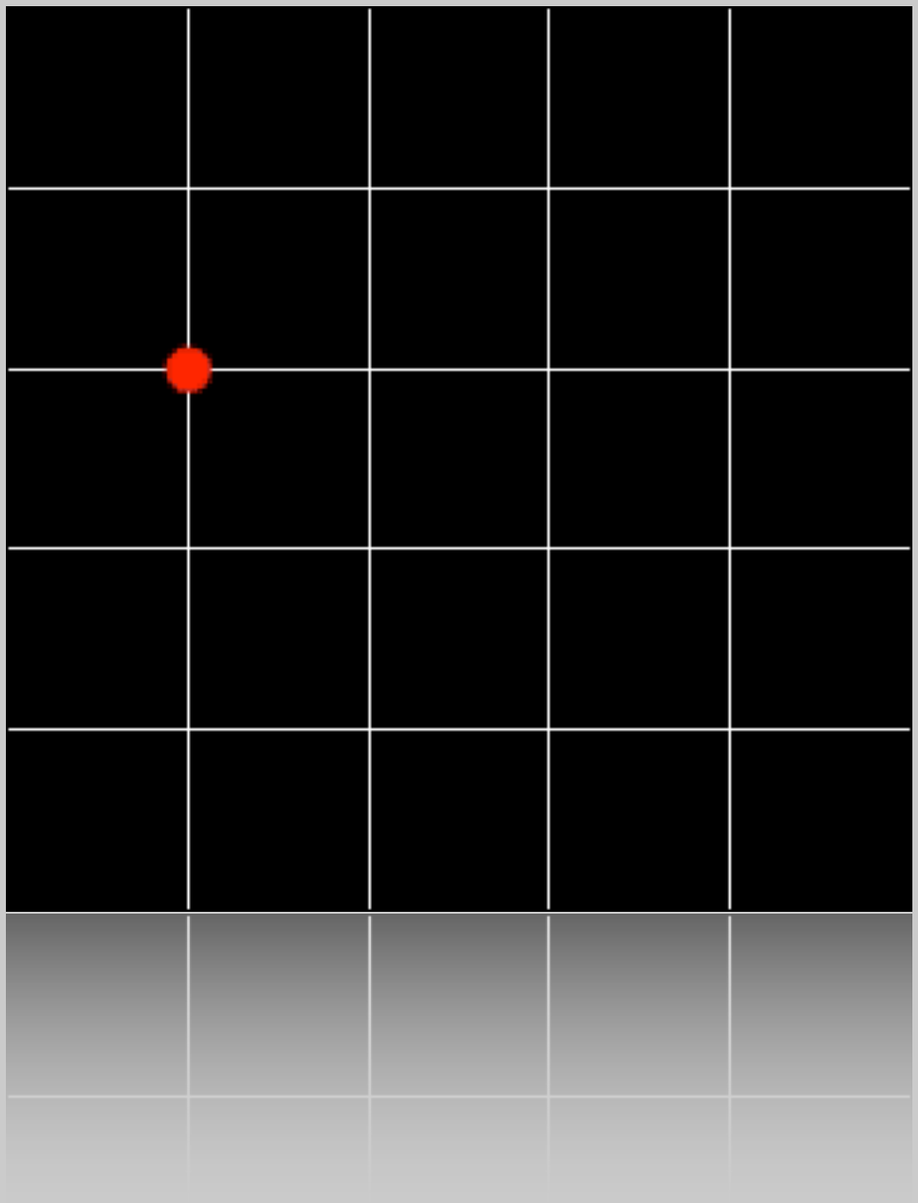
Particle-Wave Duality

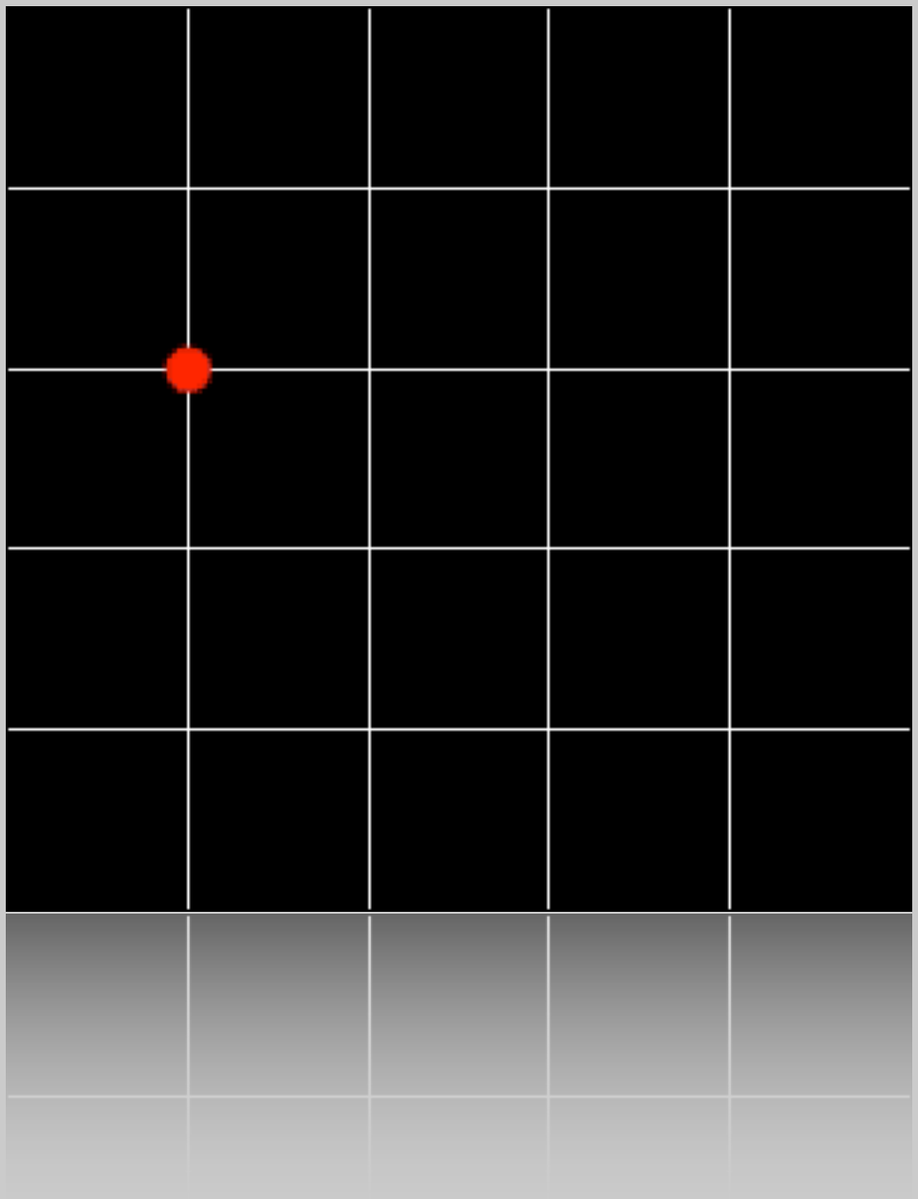
Mahn-Soo Choi
(Korea University)

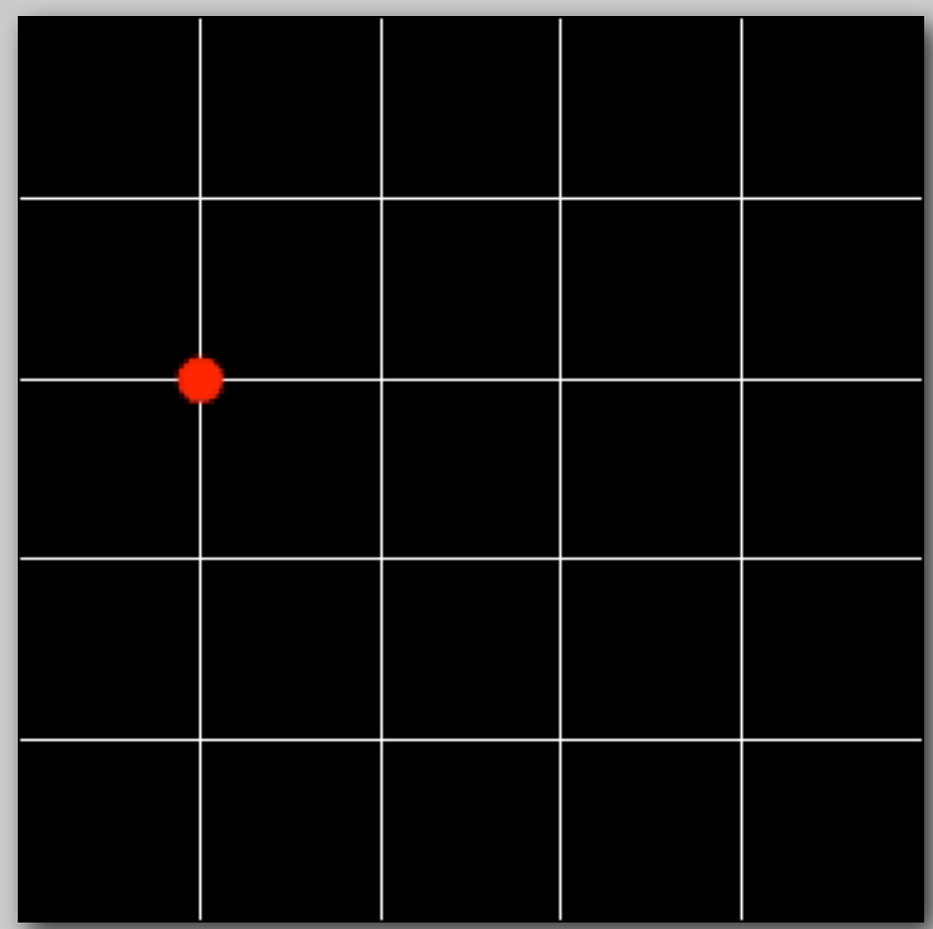
Particle

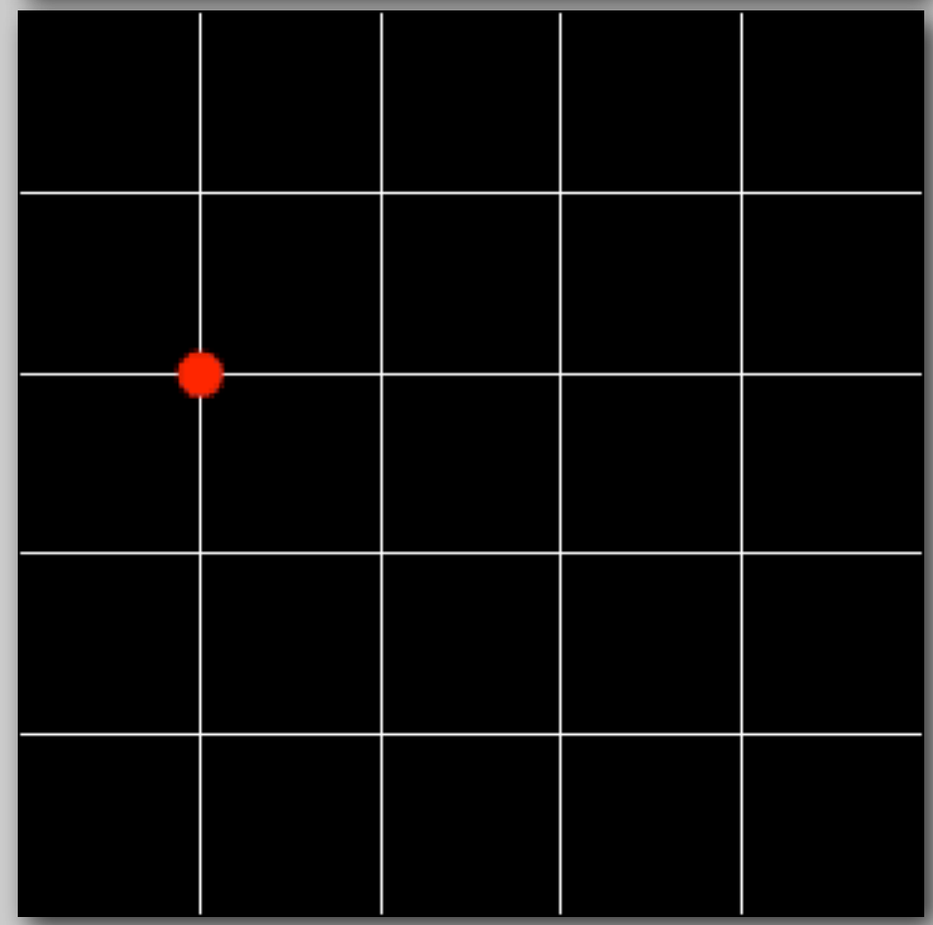
Wave

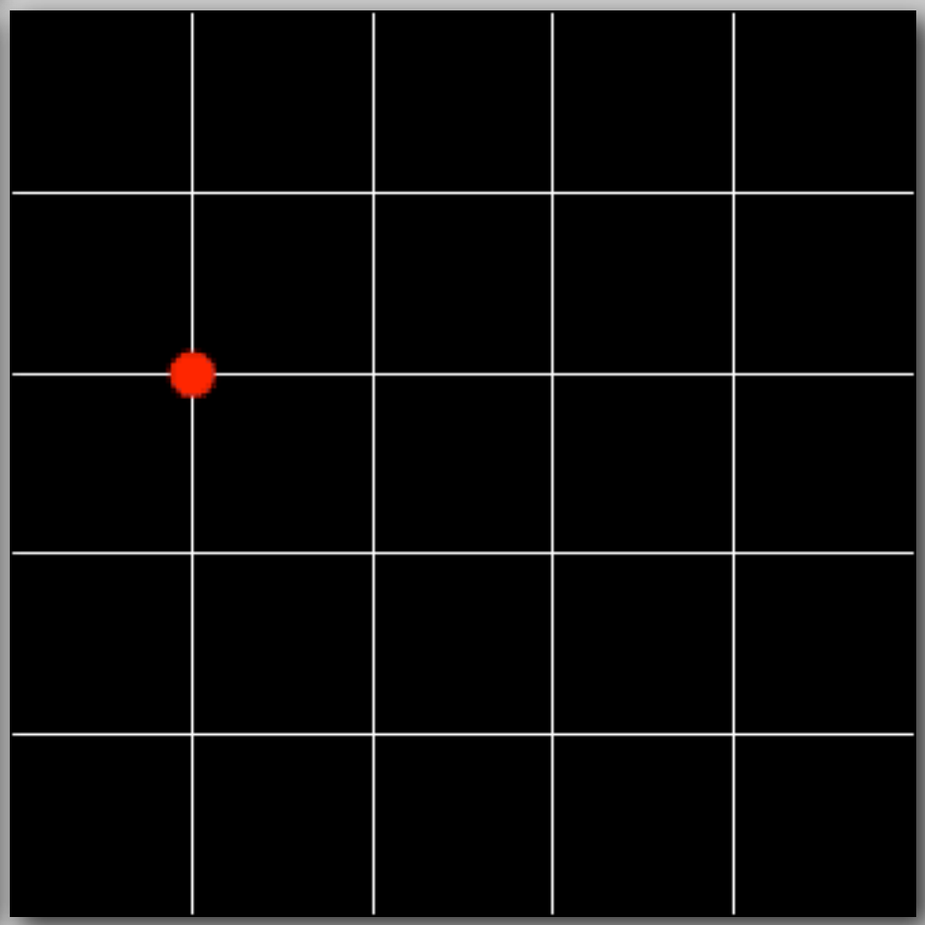


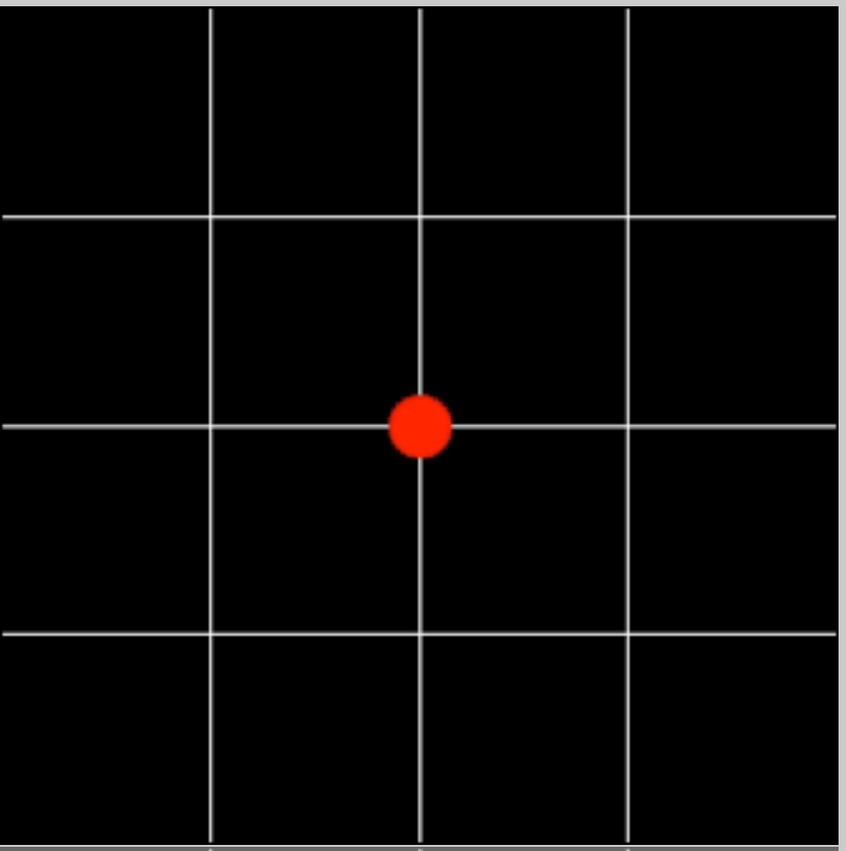
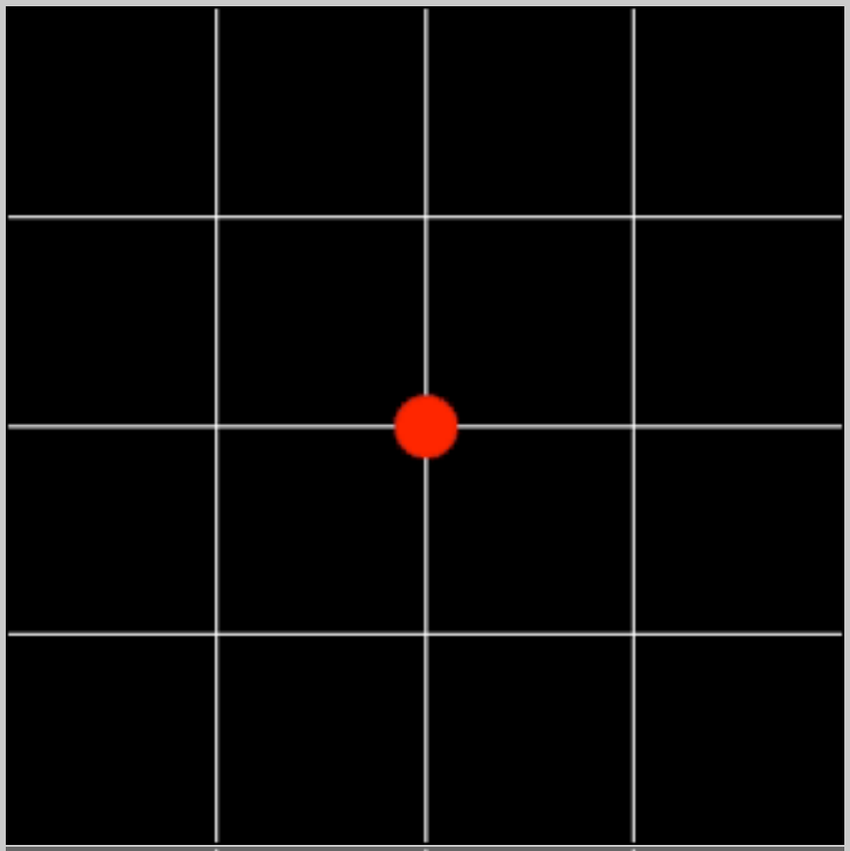
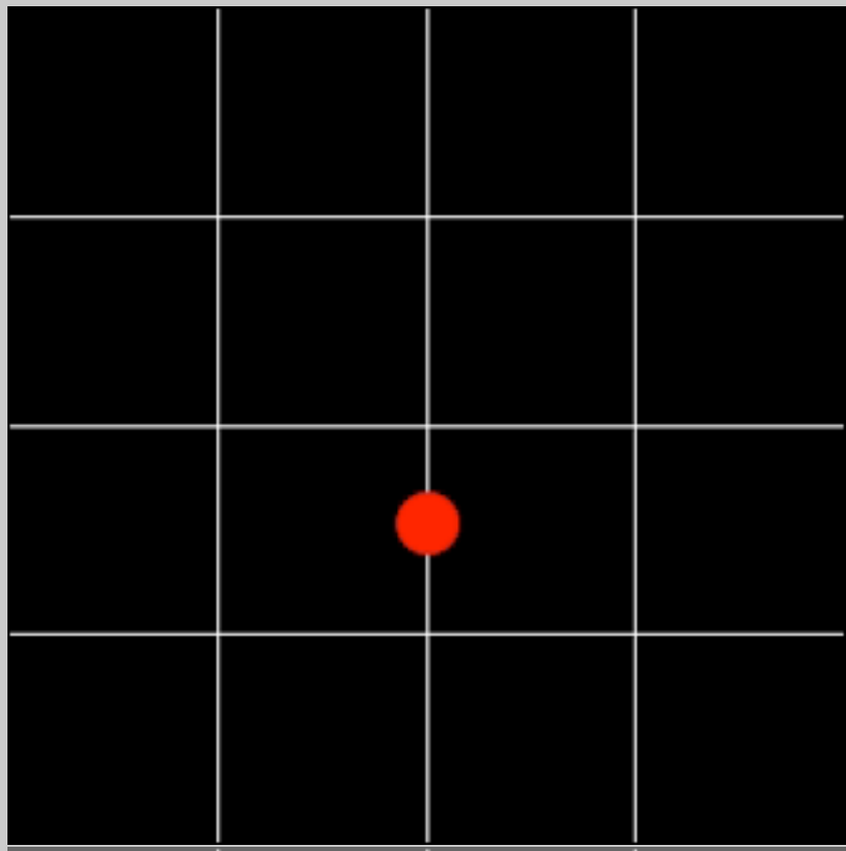


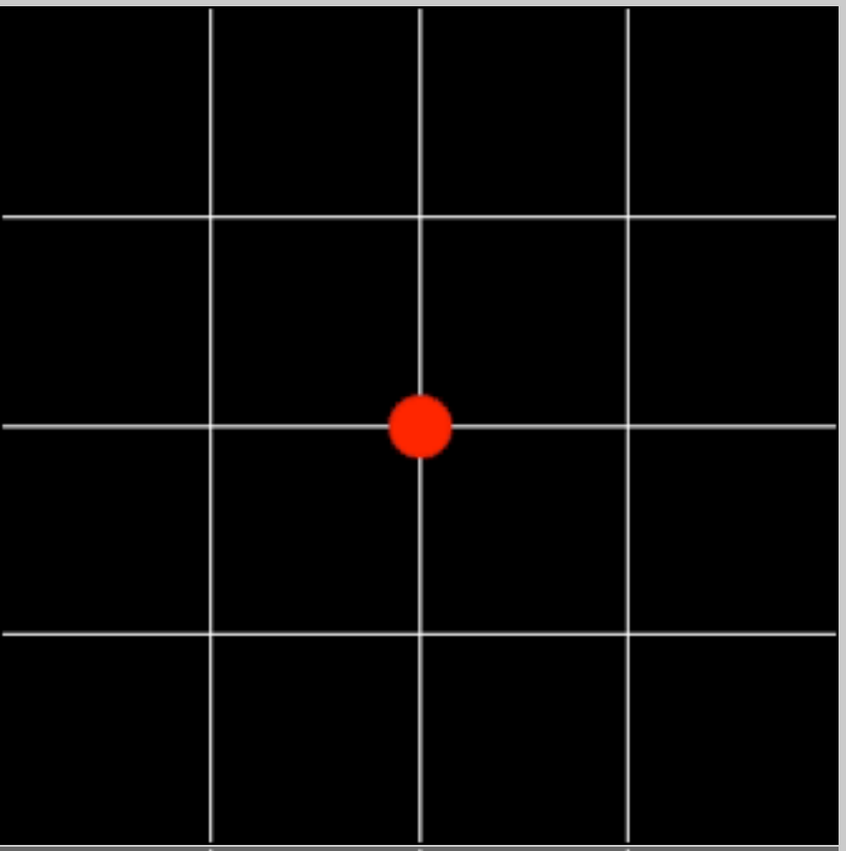


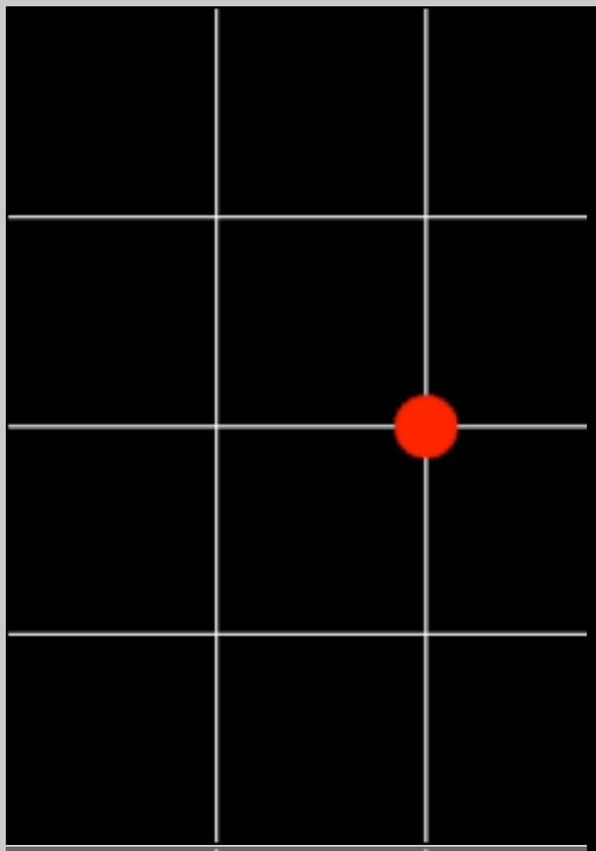


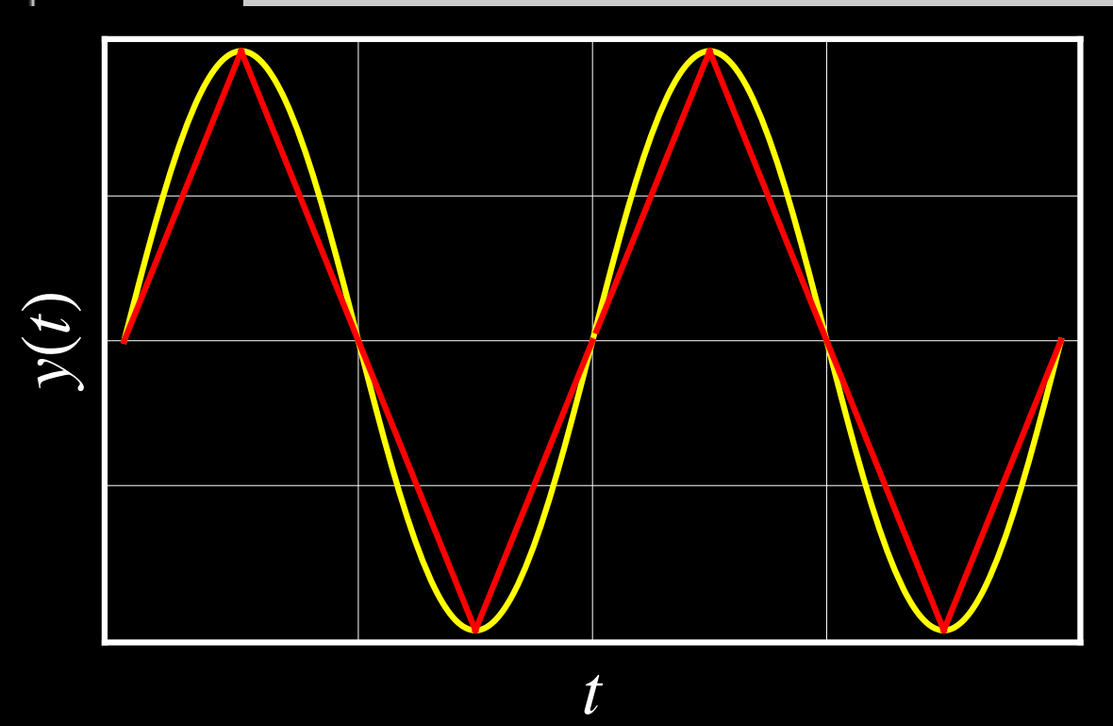






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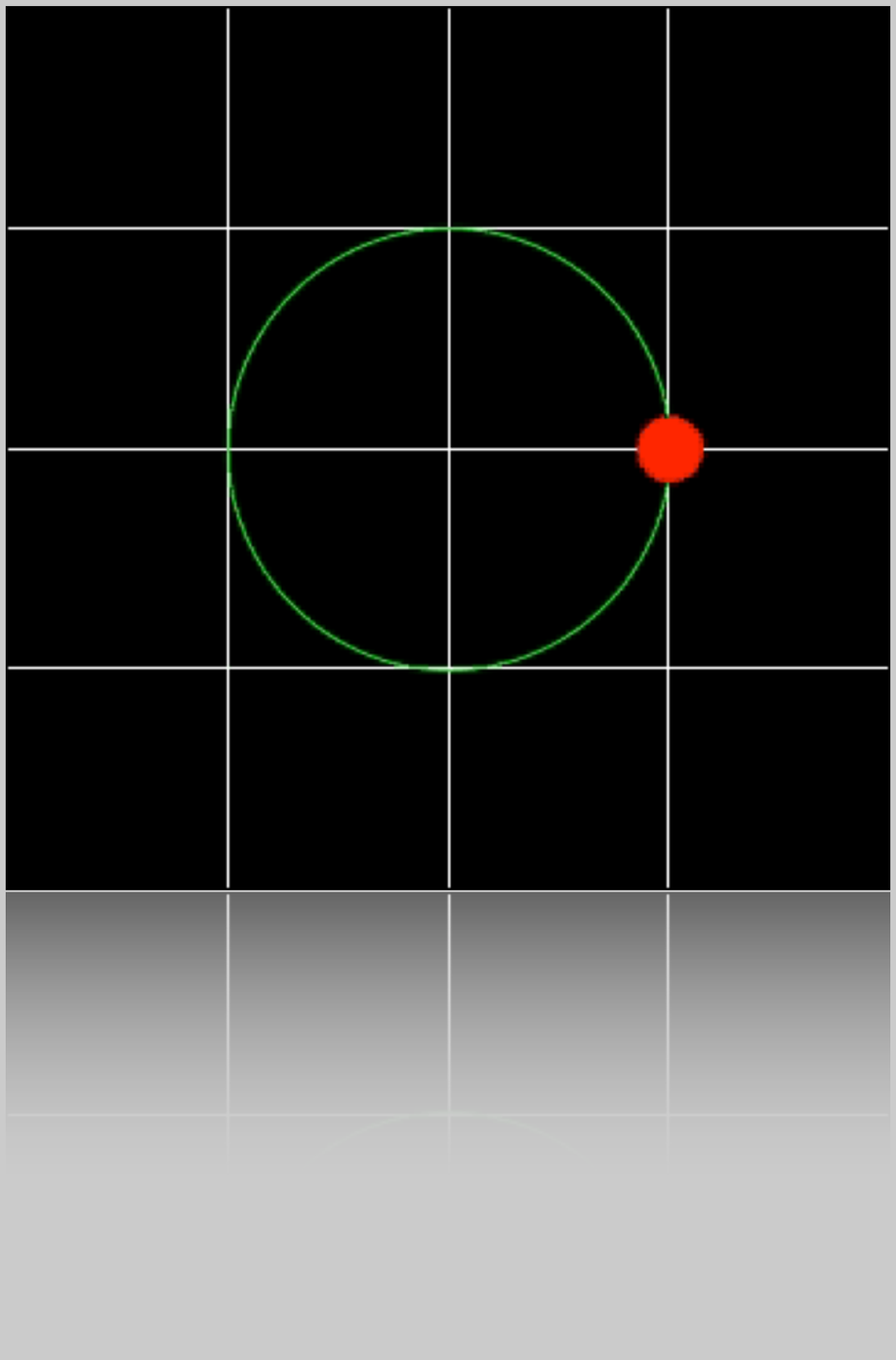
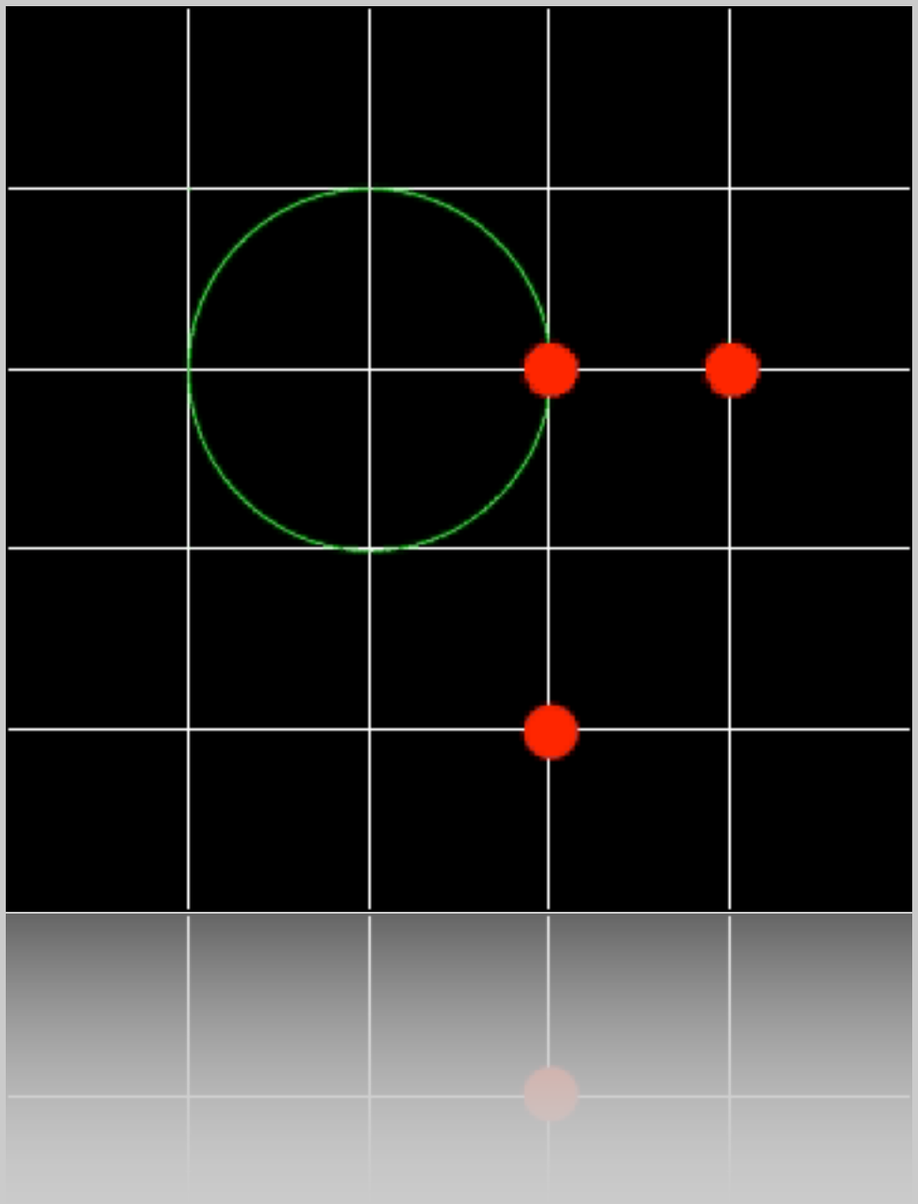
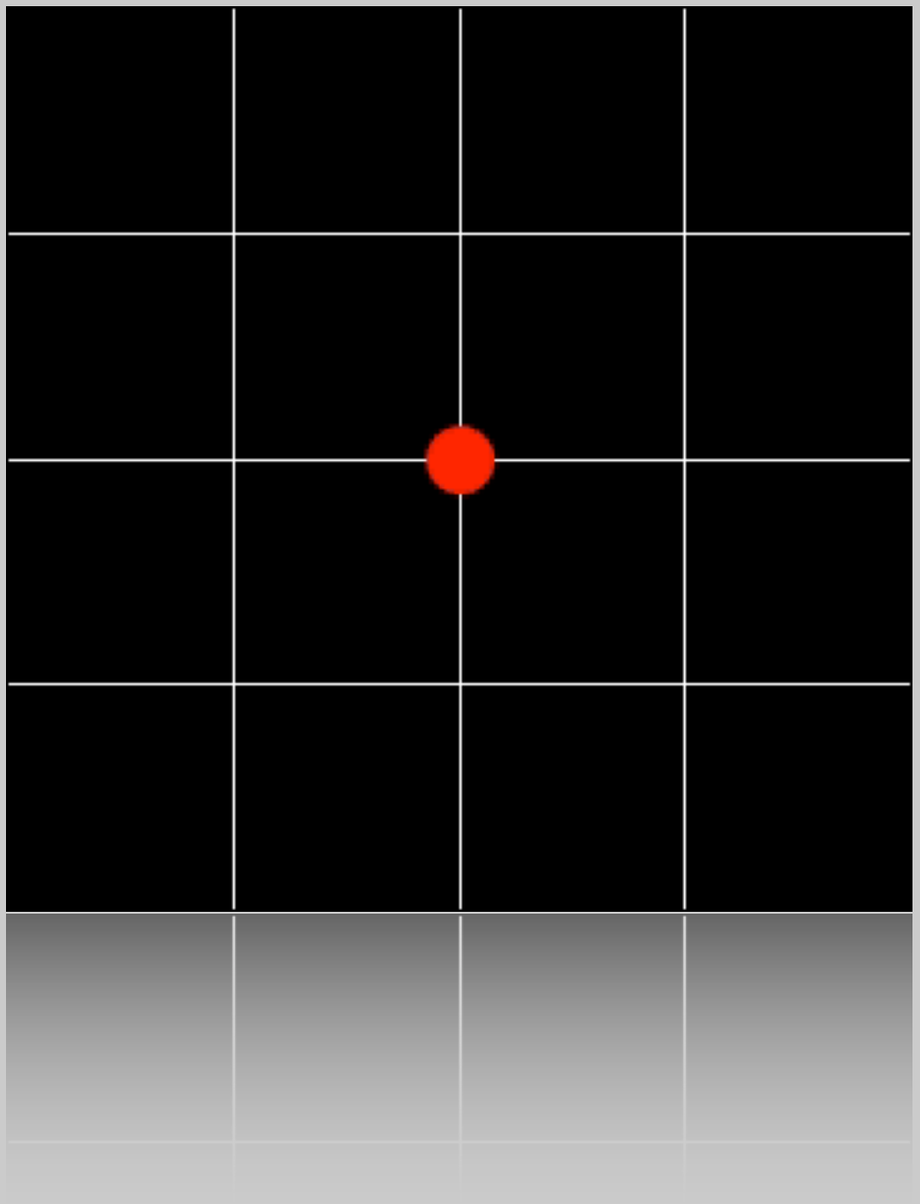
Crouching Tiger, Hidden Dragon (2000) directed by Ang Lee





How to Characterize an Oscillation



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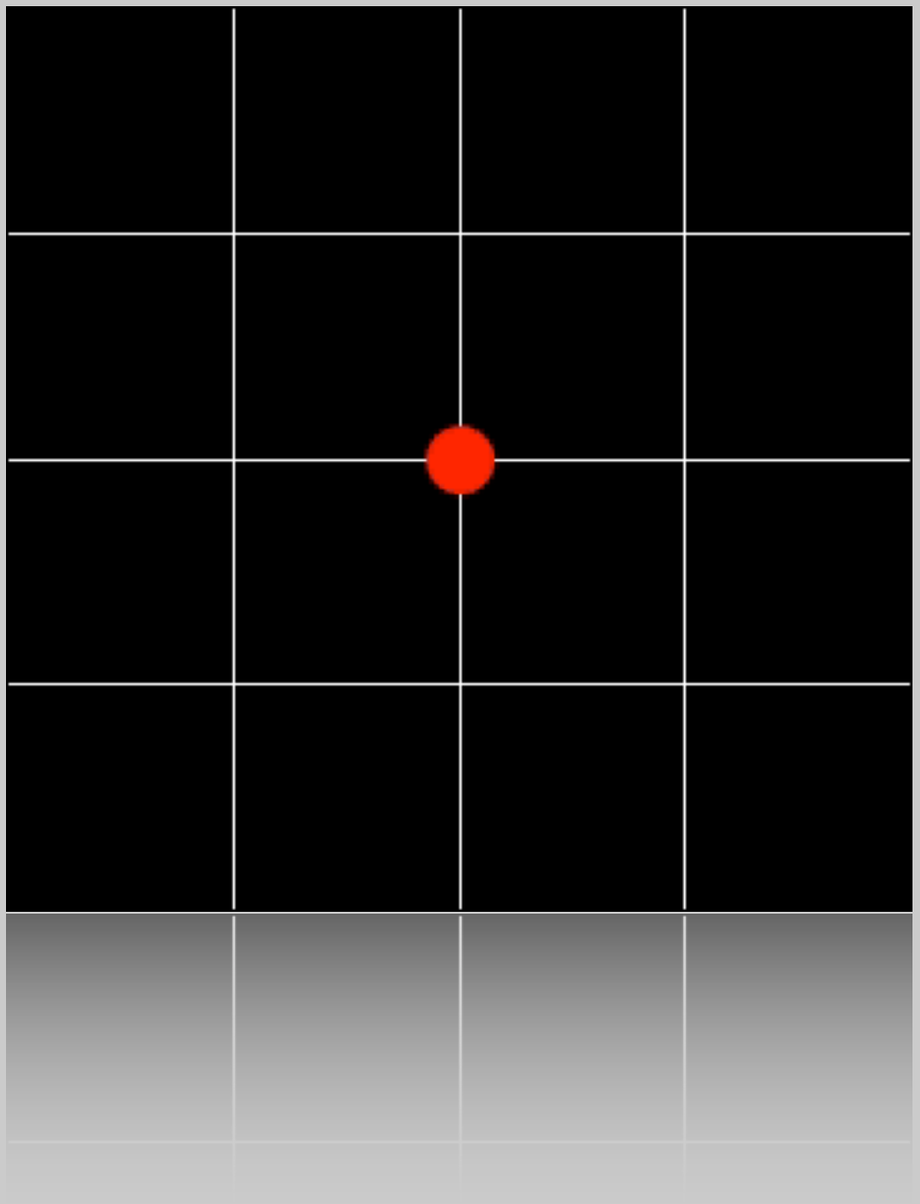
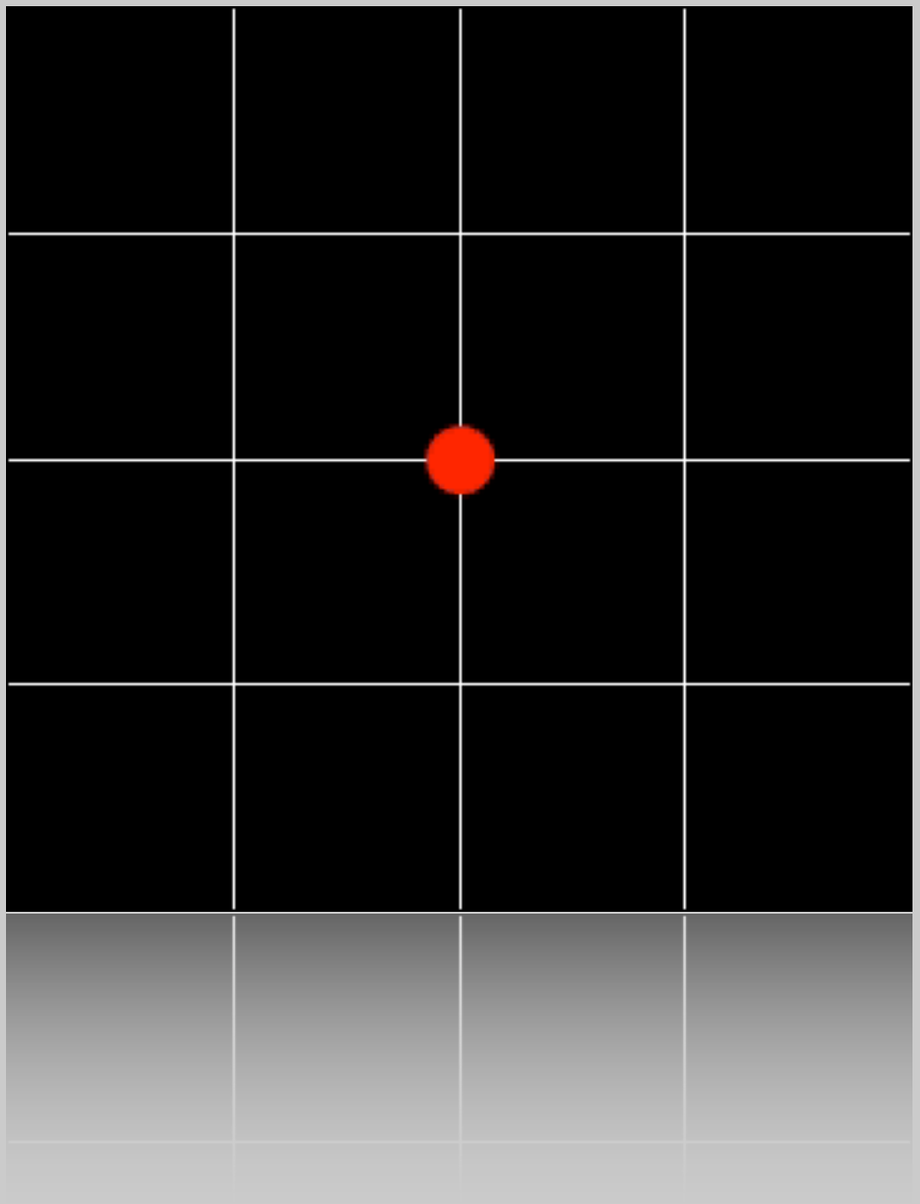


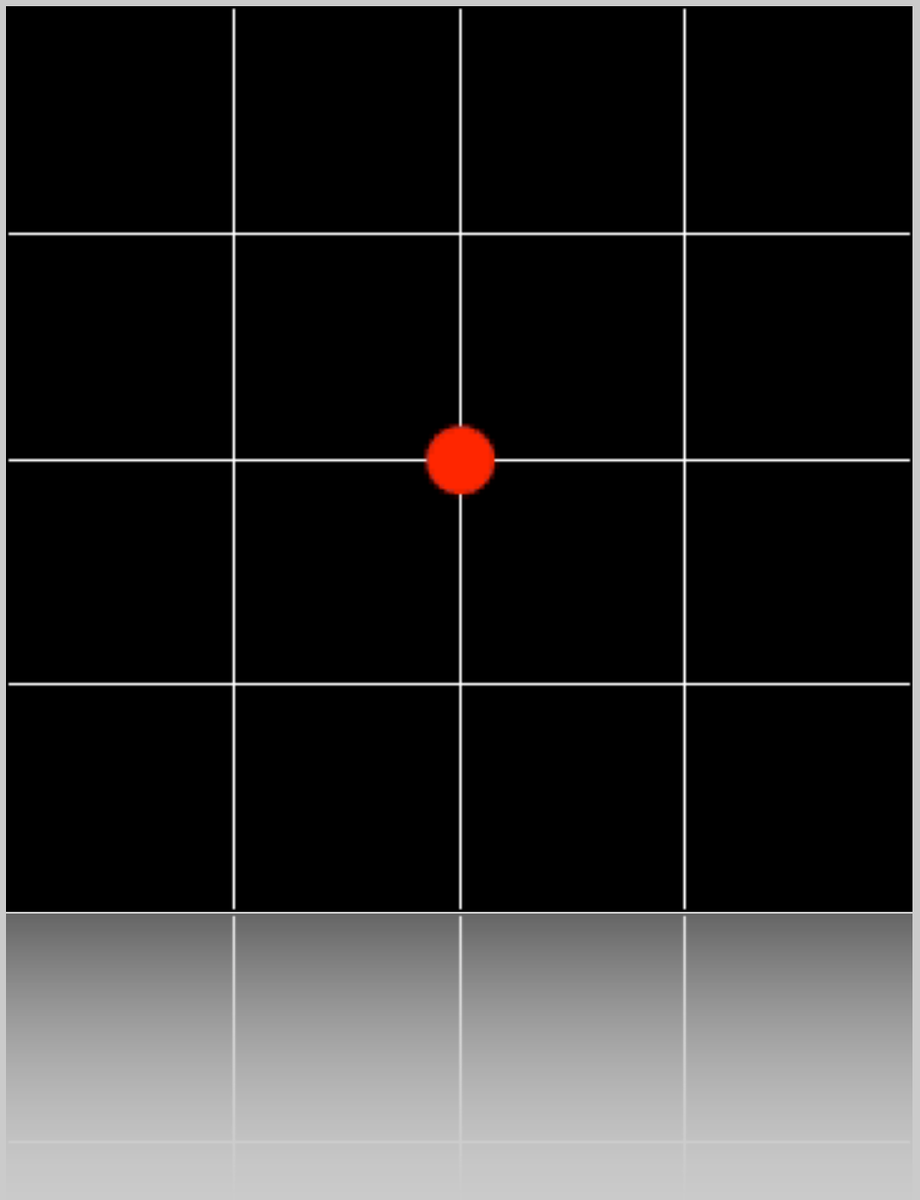
- Amplitude

How to Characterize an Oscillation

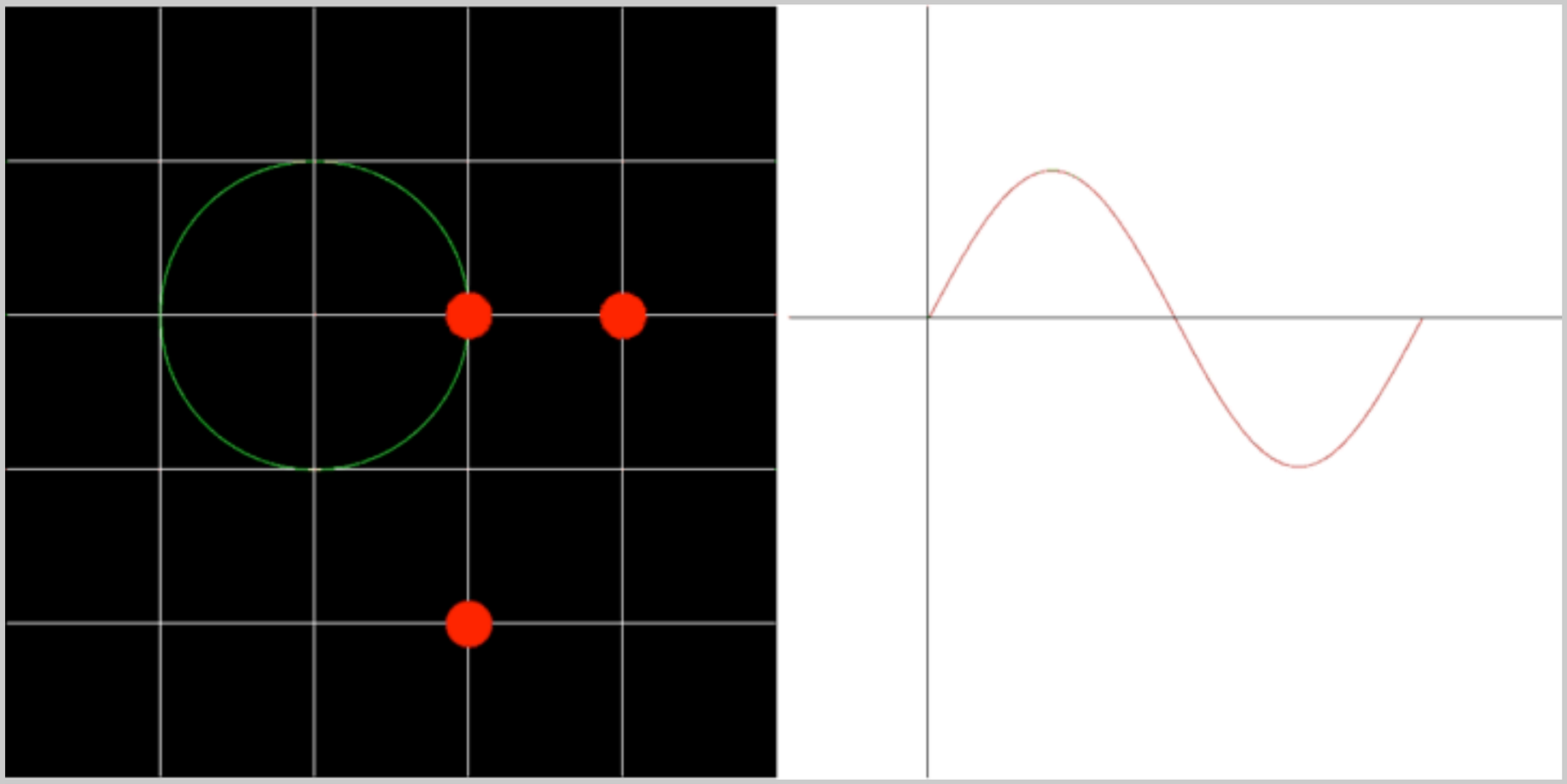


- Amplitude
- Frequency

State of an Oscillation

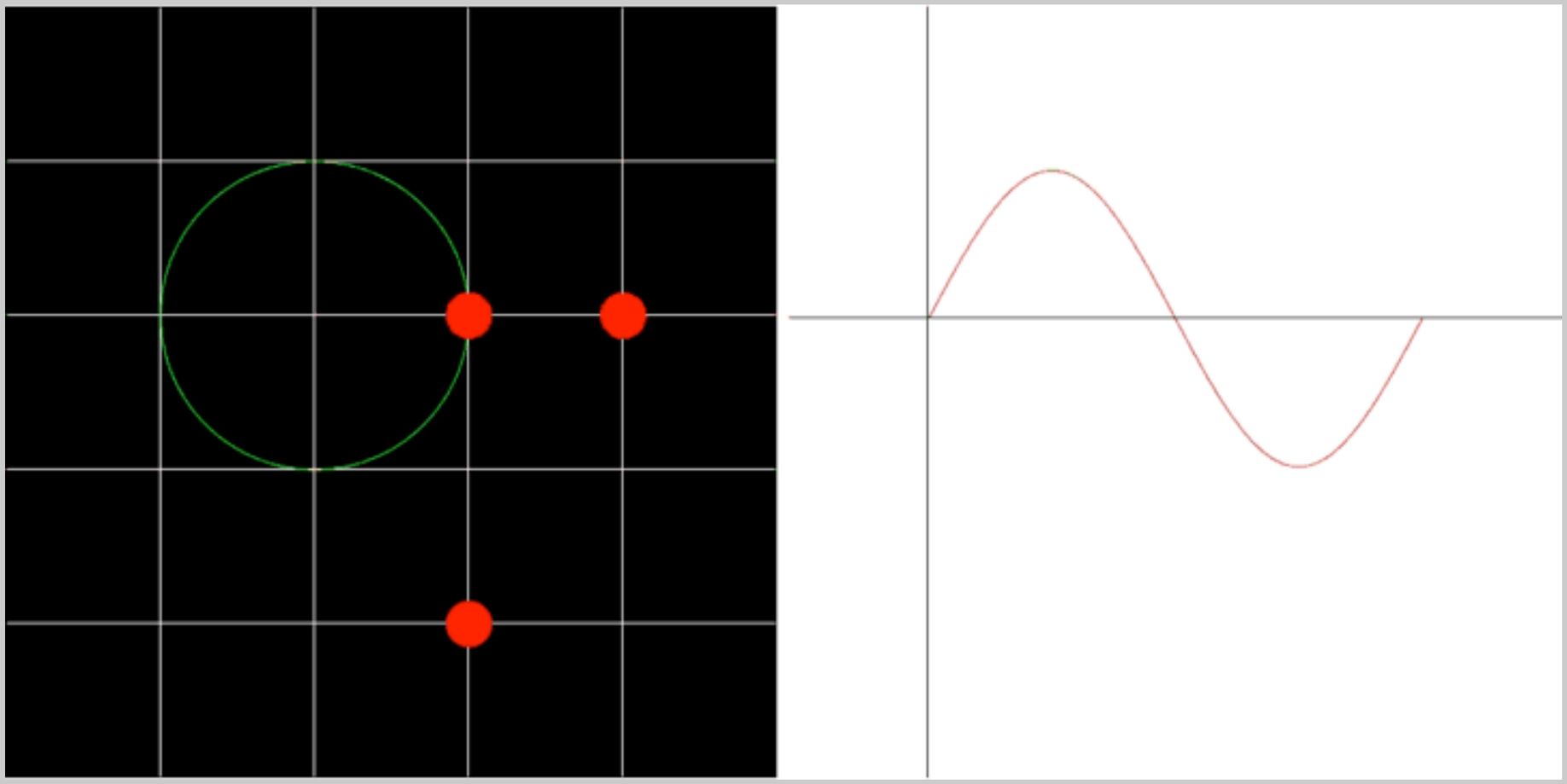


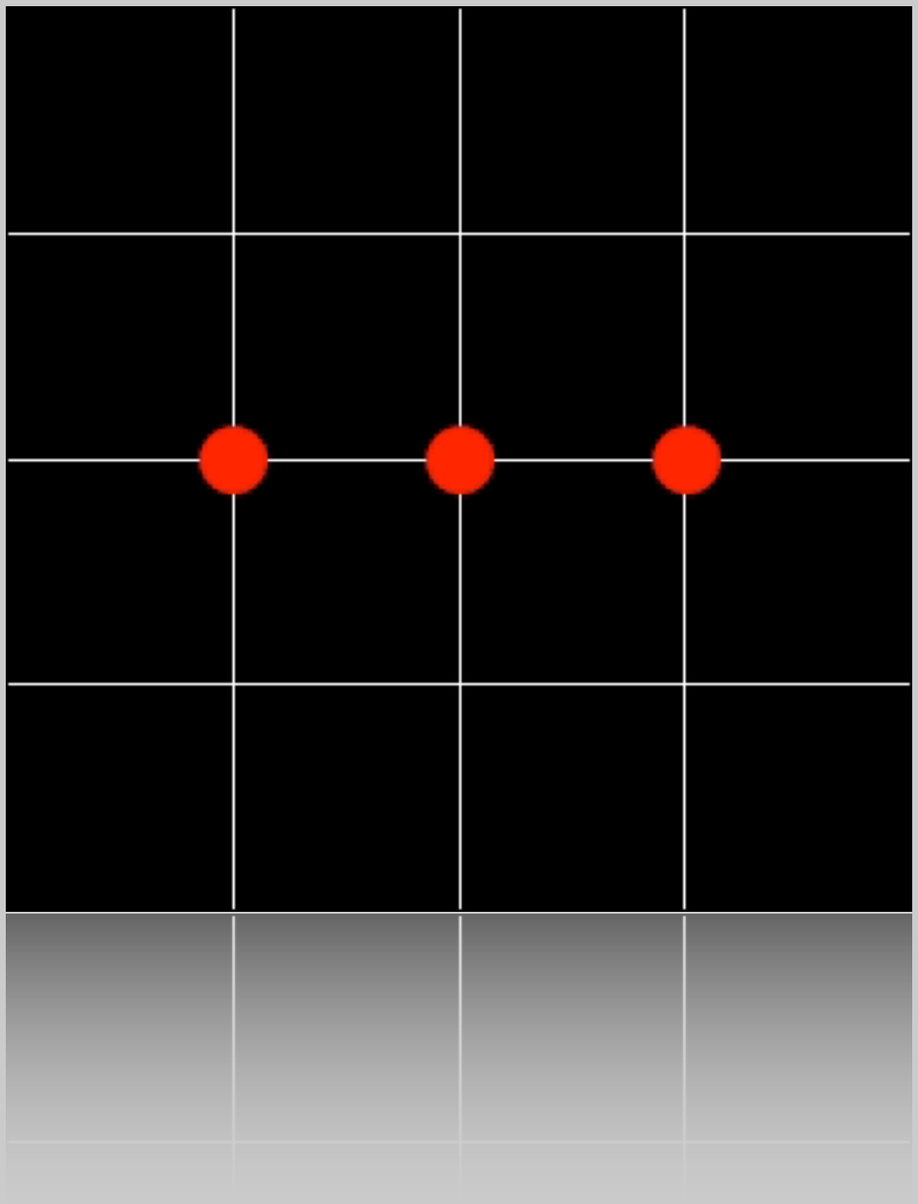
State of an Oscillation

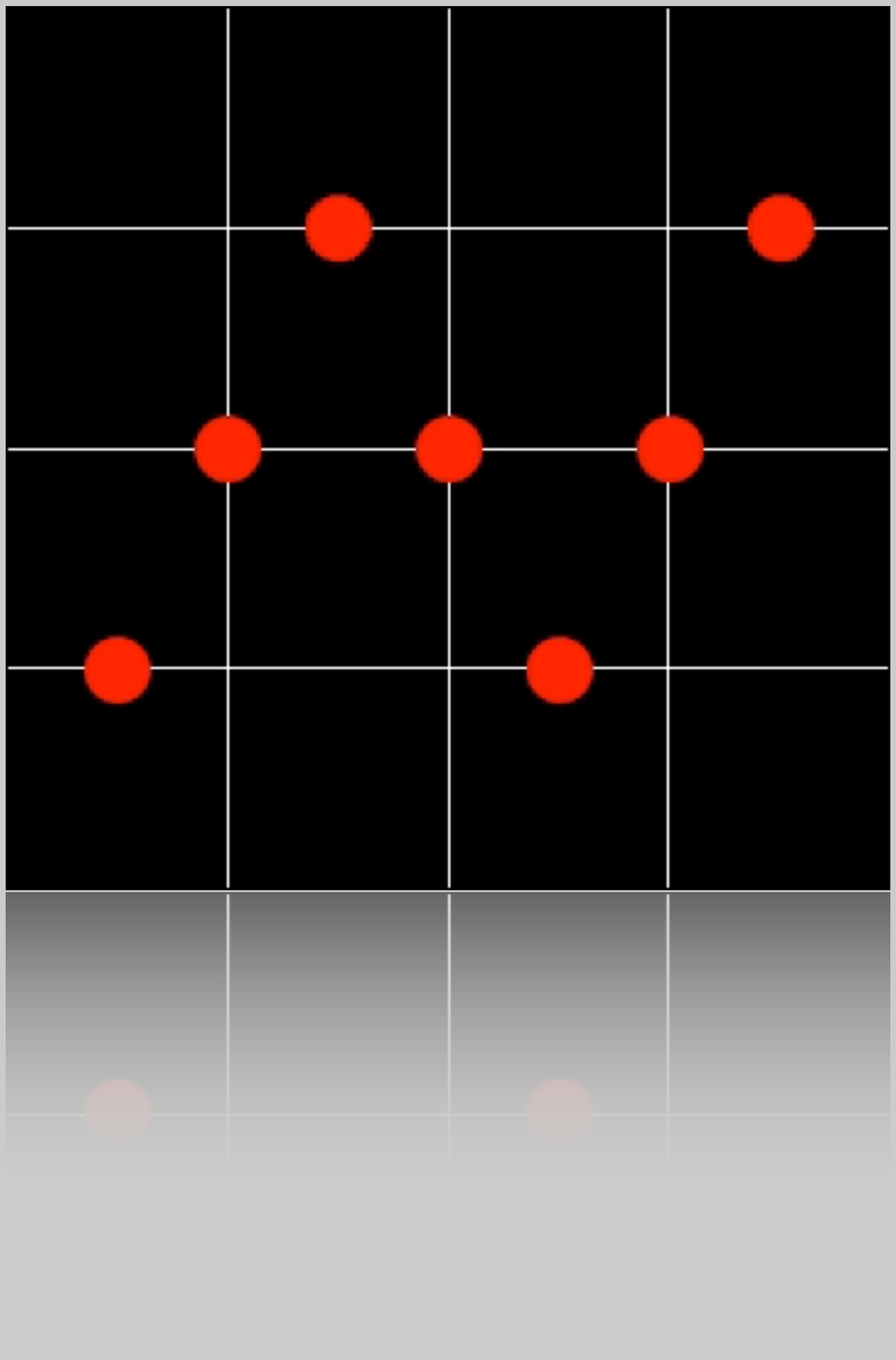


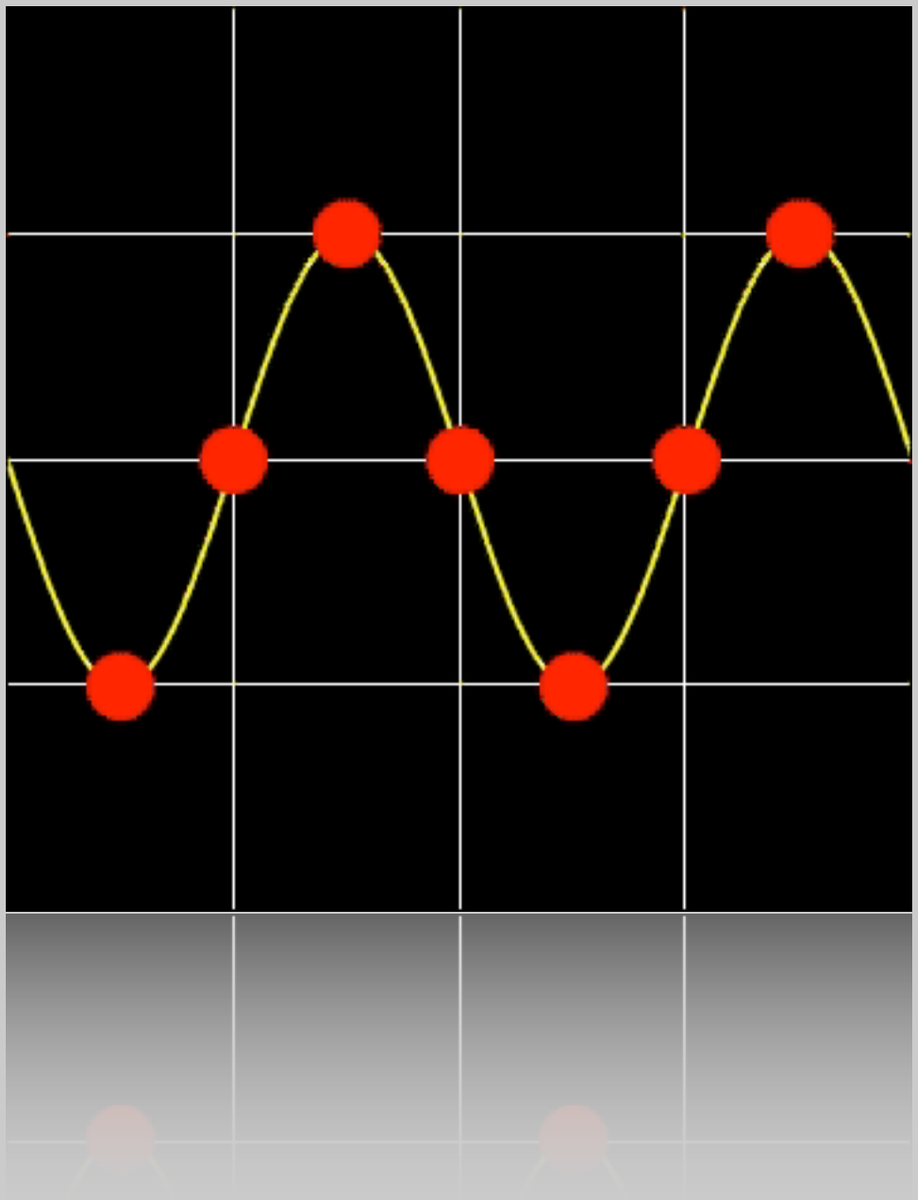
State of an Oscillation

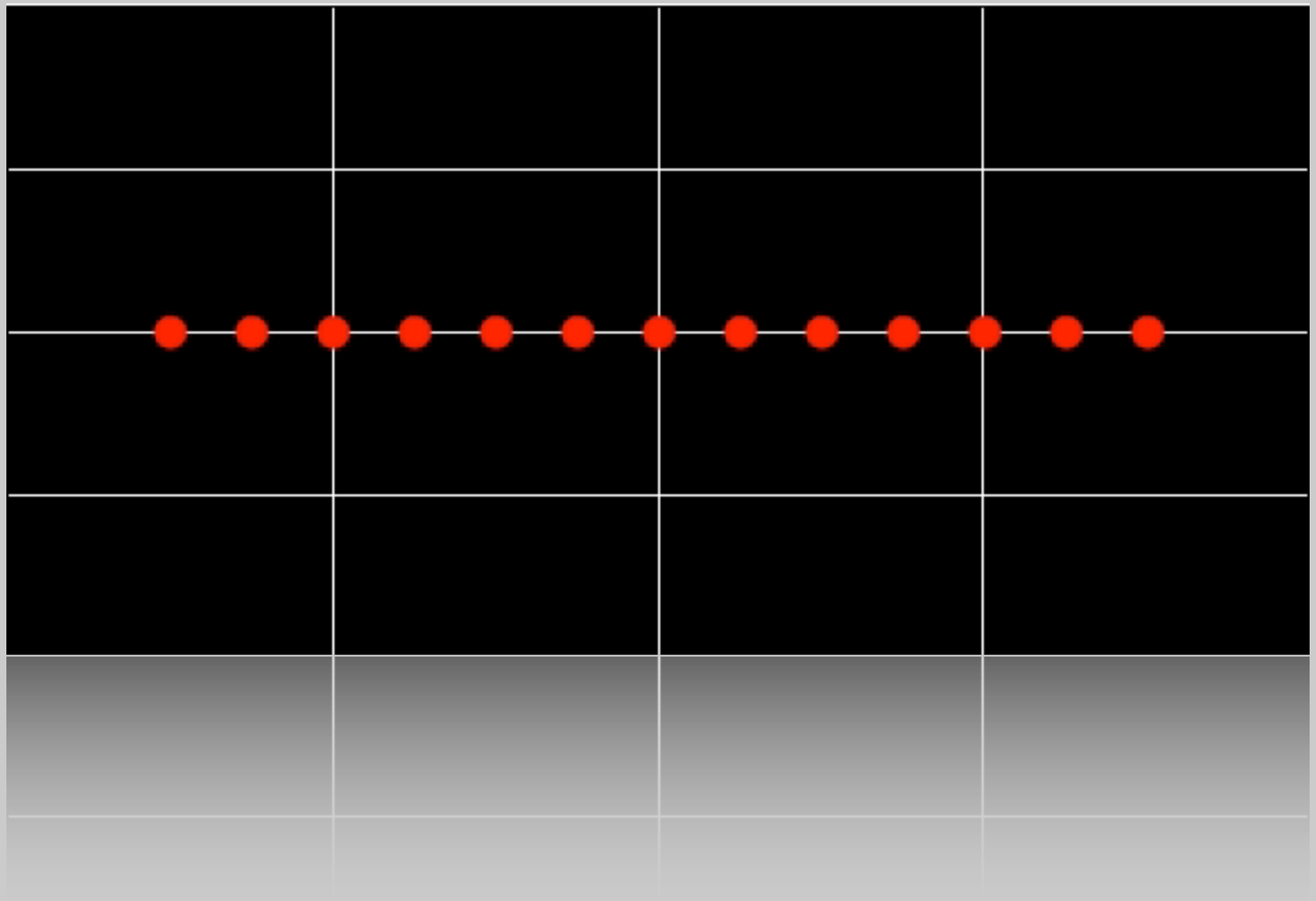
"Phase"

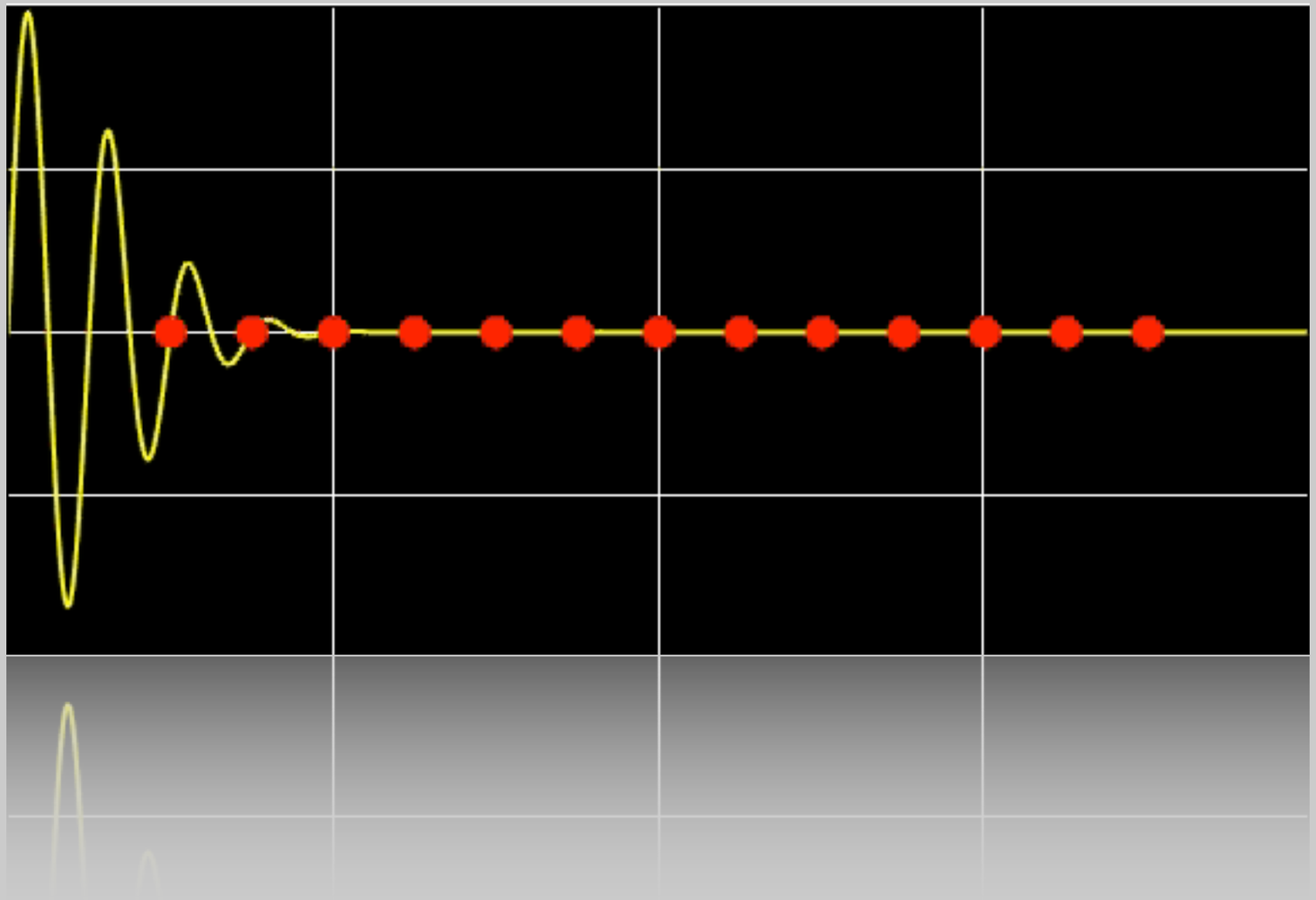


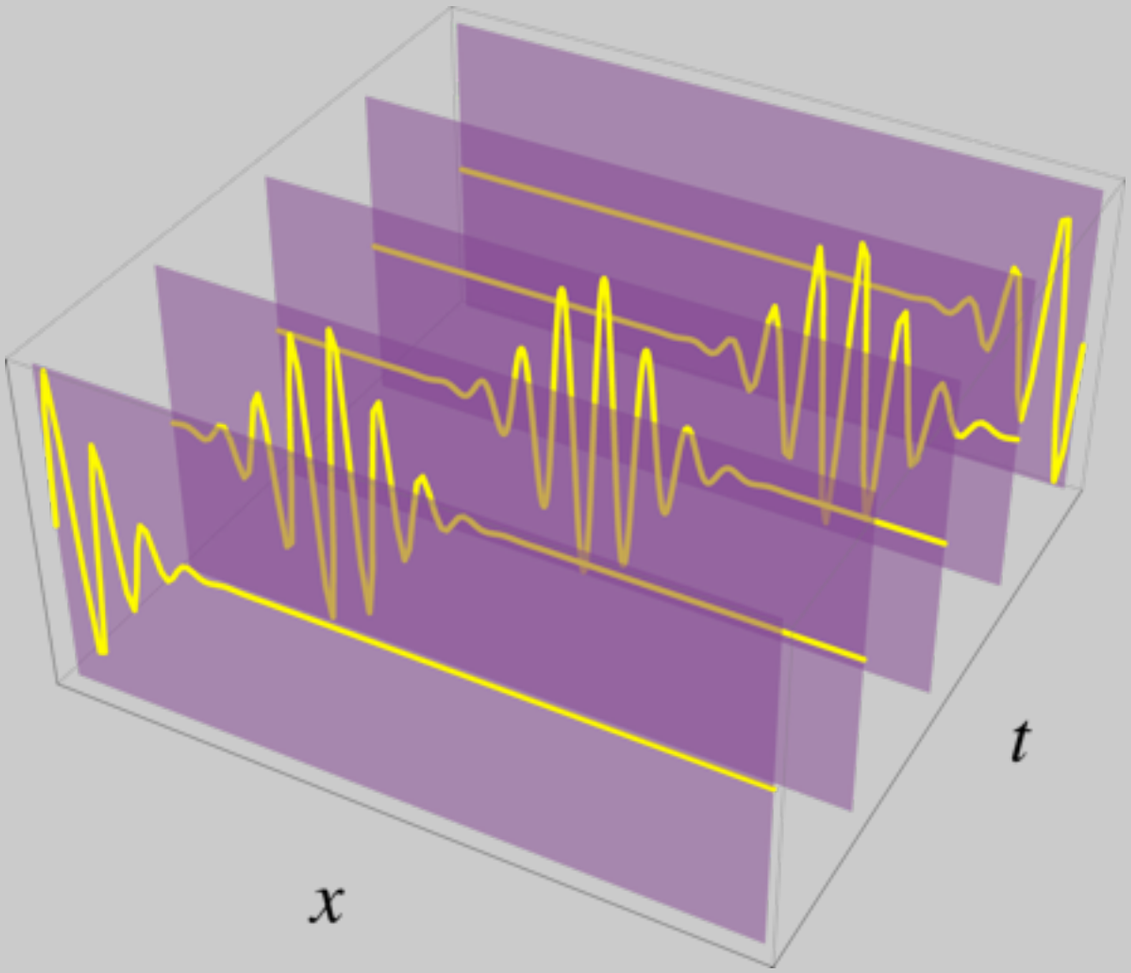








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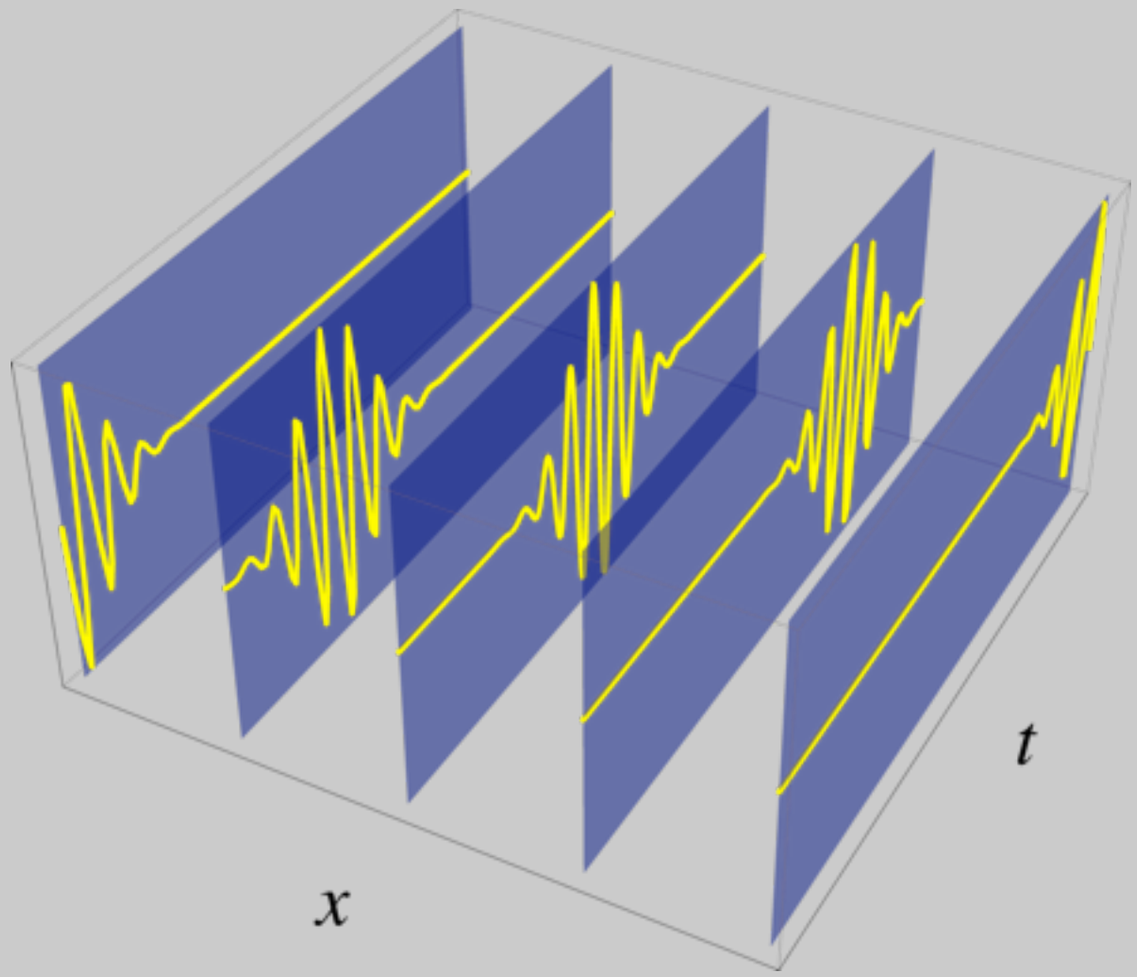
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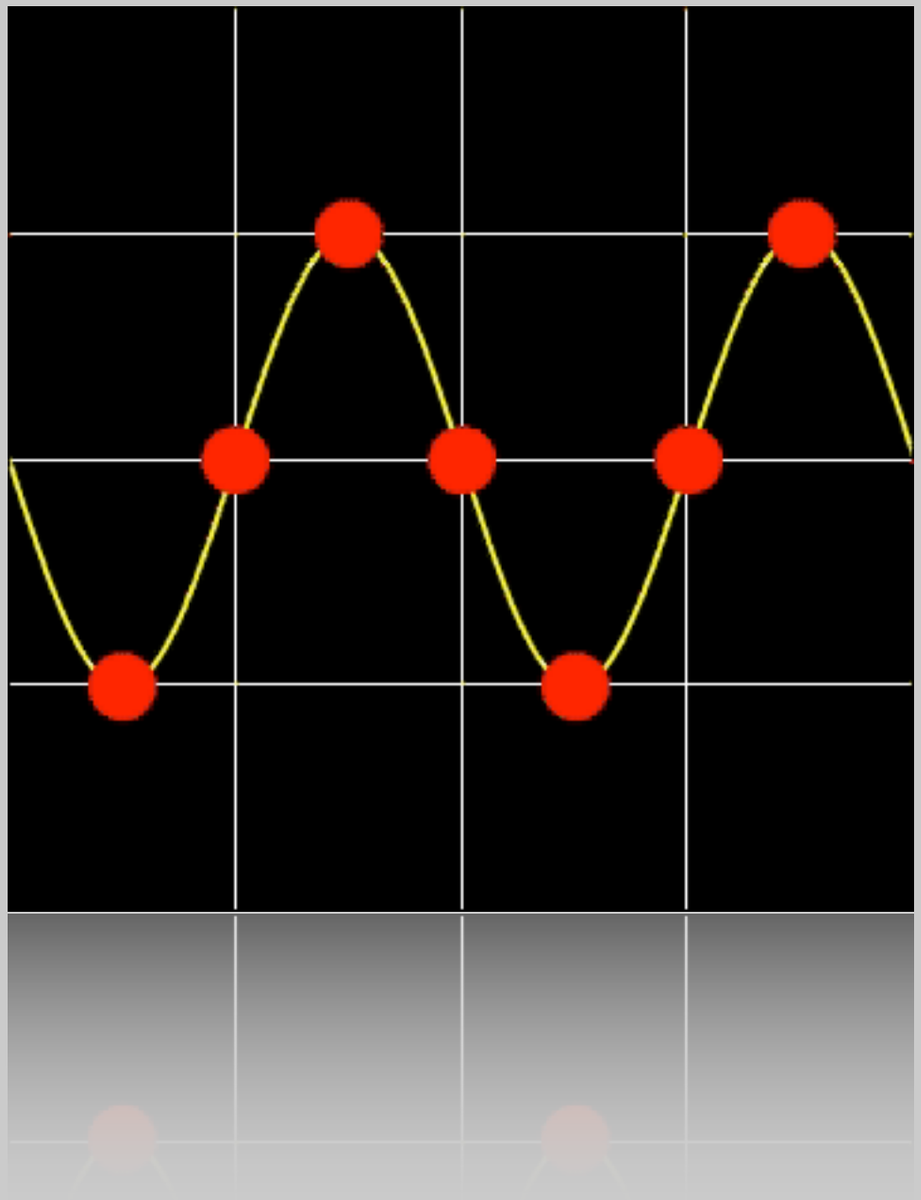
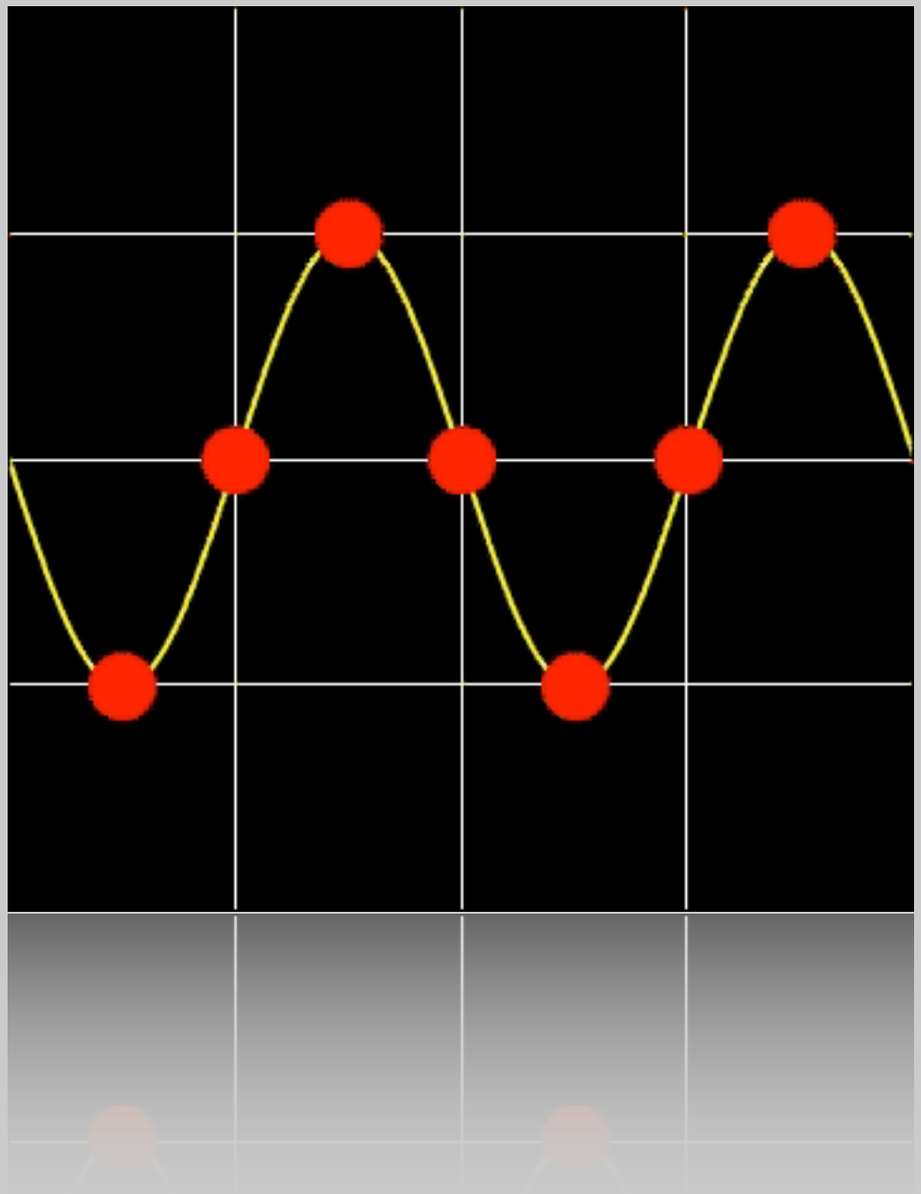
How to Characterize a Wave

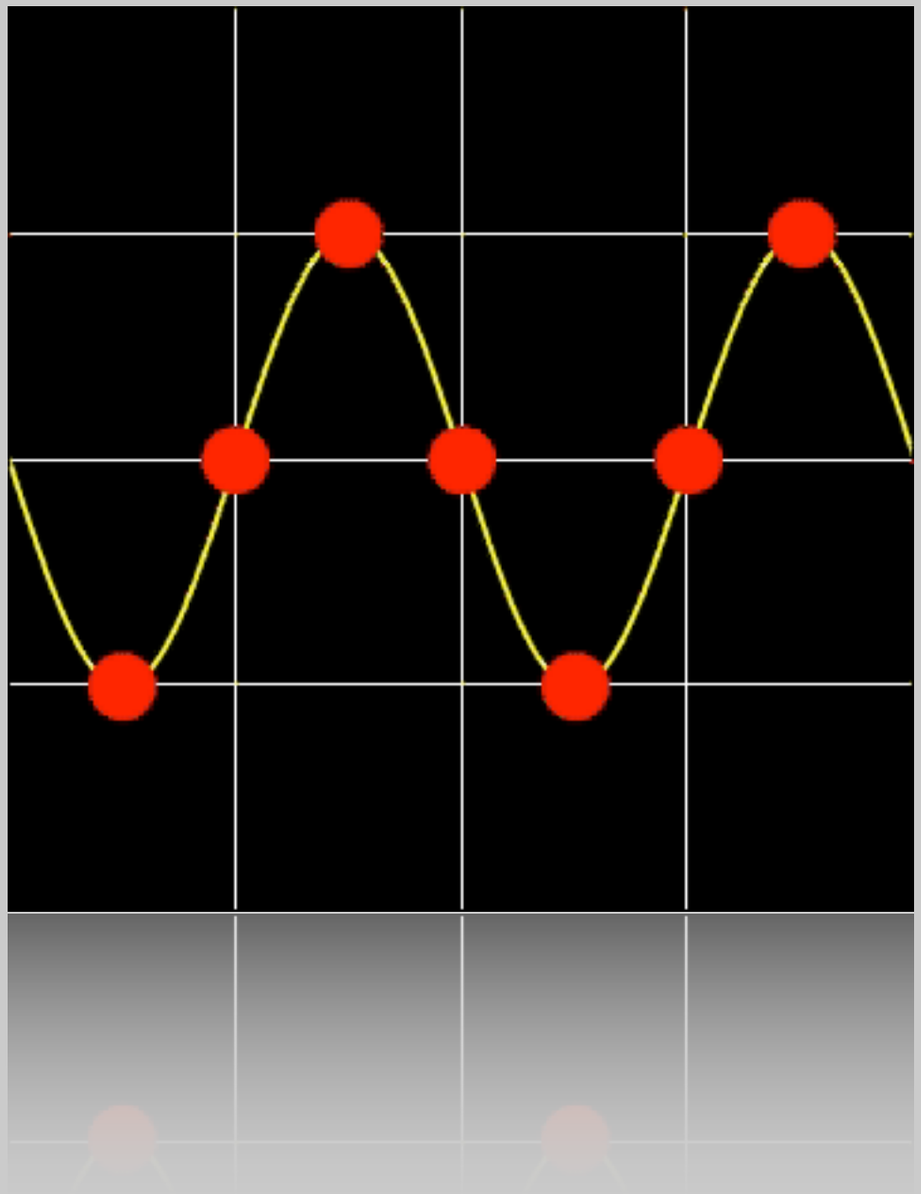


How to Characterize a Wave



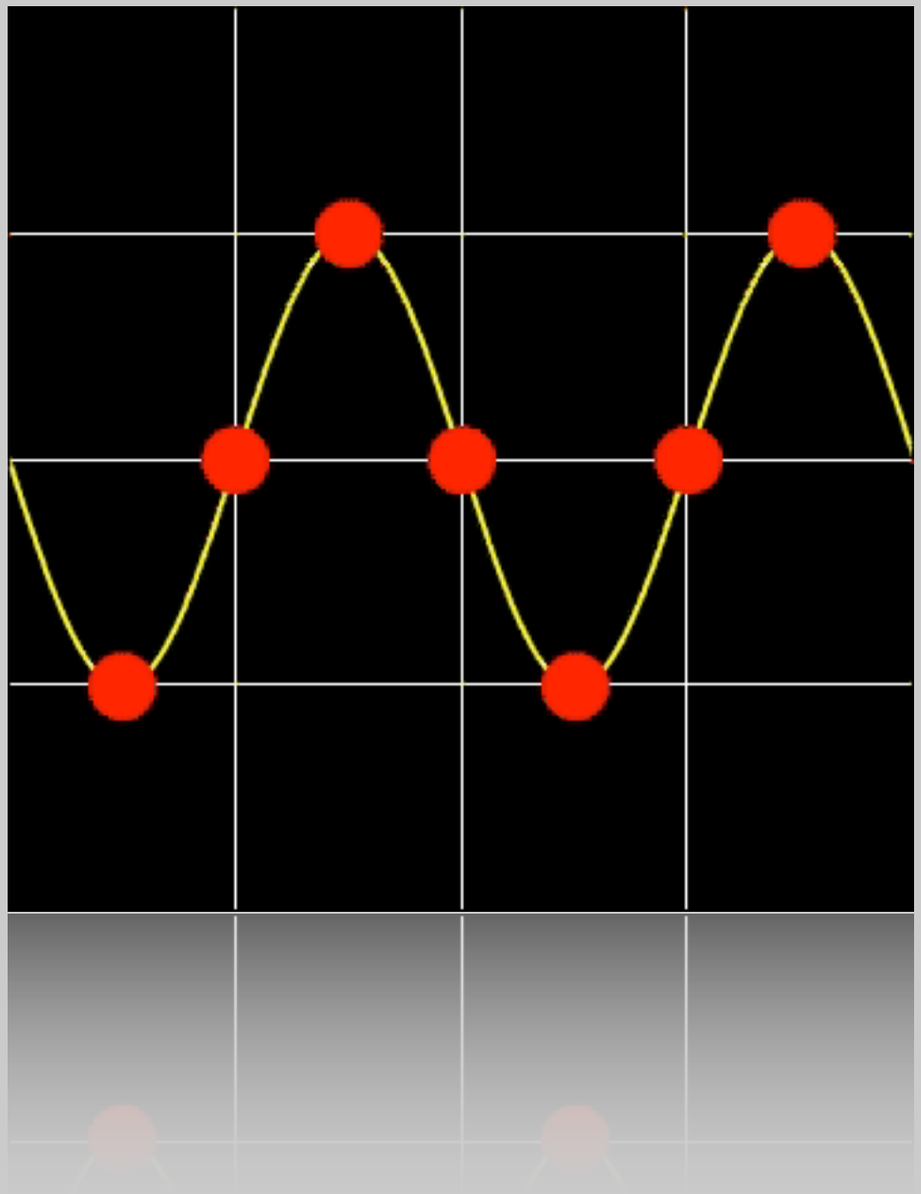
- Amplitude

How to Characterize a Wave



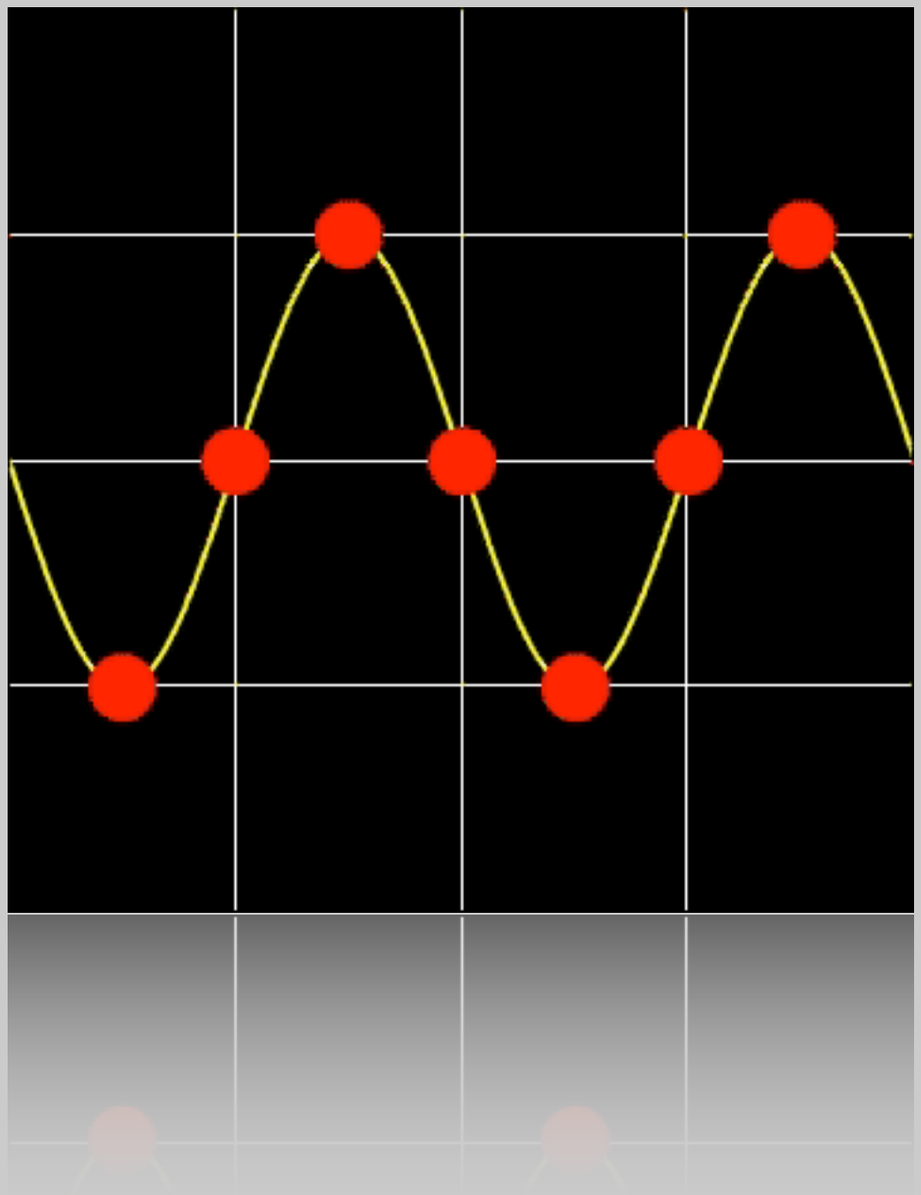
- Amplitude
- Wave length

How to Characterize a Wave



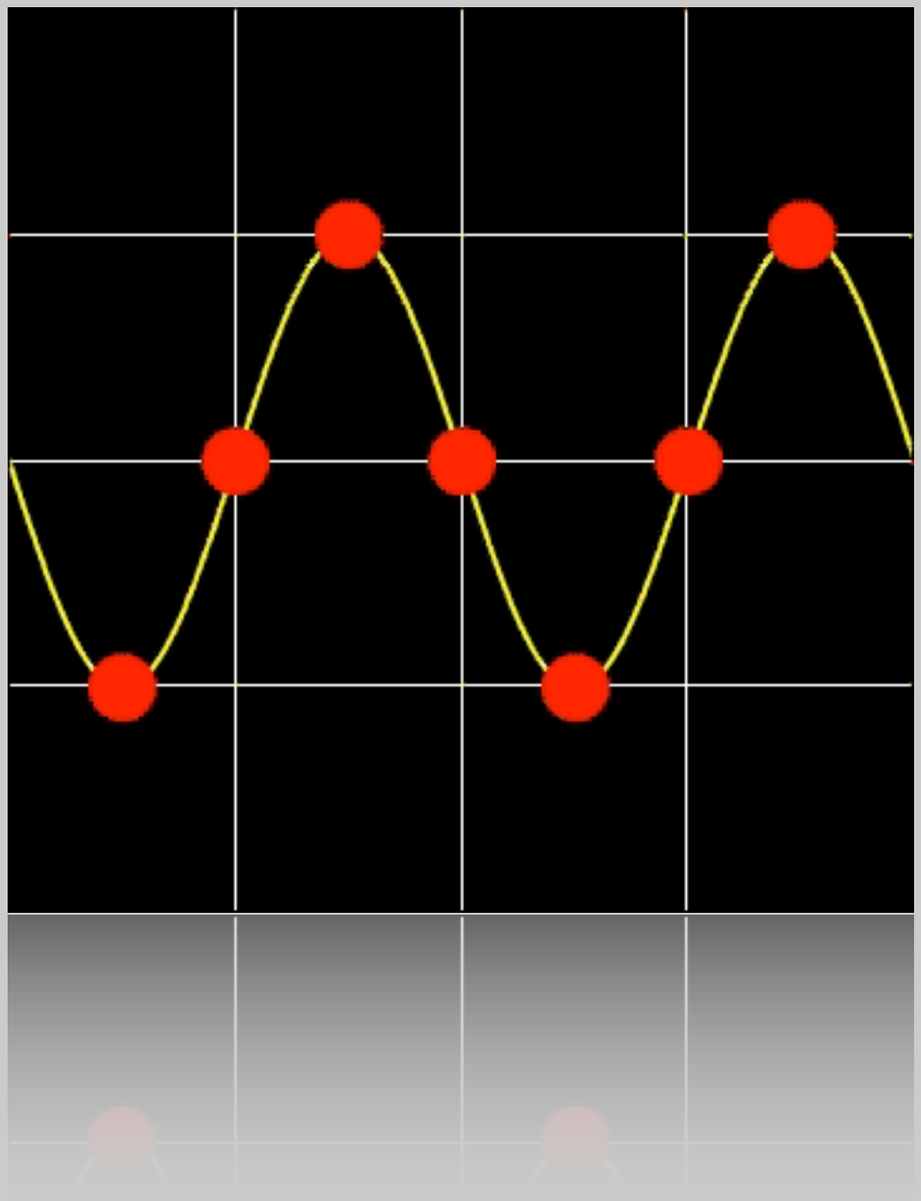
- Amplitude
- Wave length
- Frequency (or Period)

How to Characterize a Wave



- Amplitude
- Wave length
- Frequency (or Period)
- Velocity

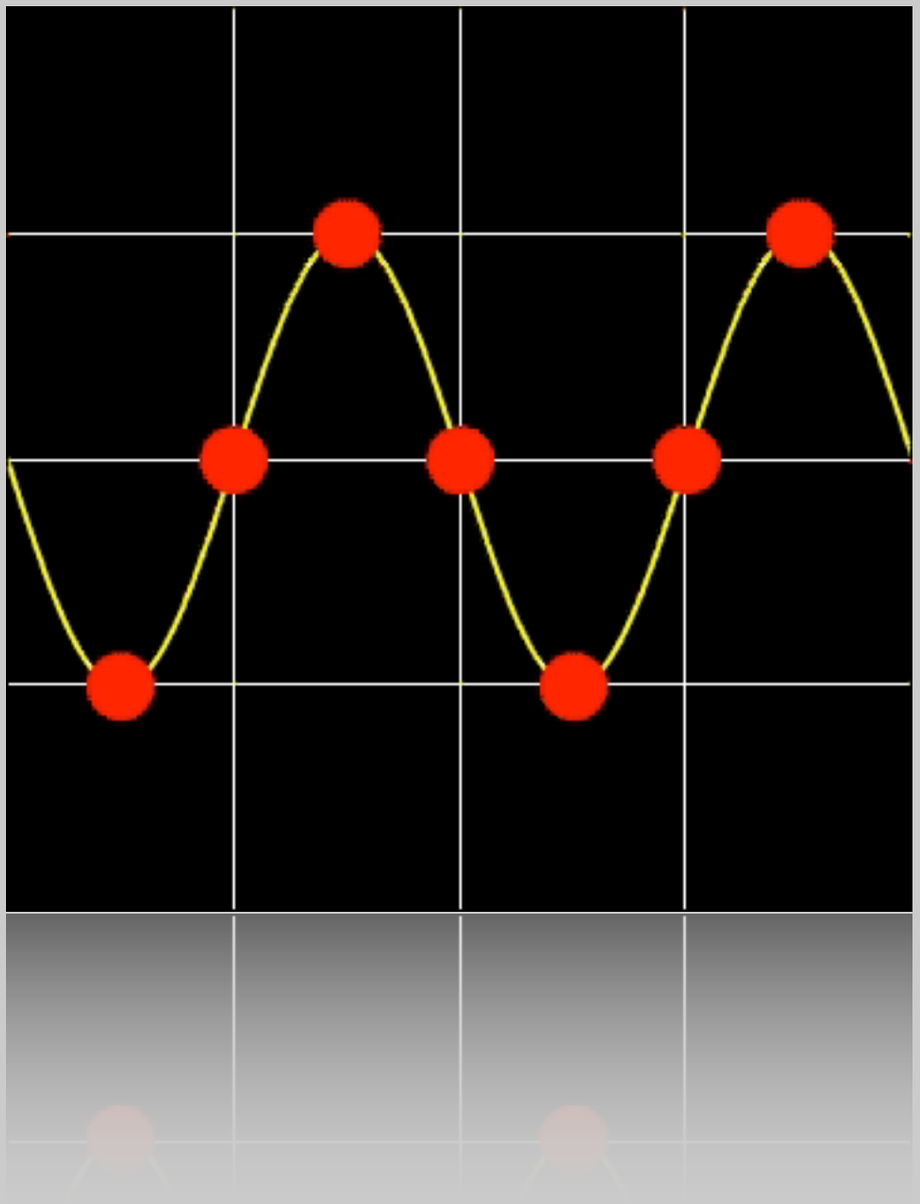
How to Characterize a Wave



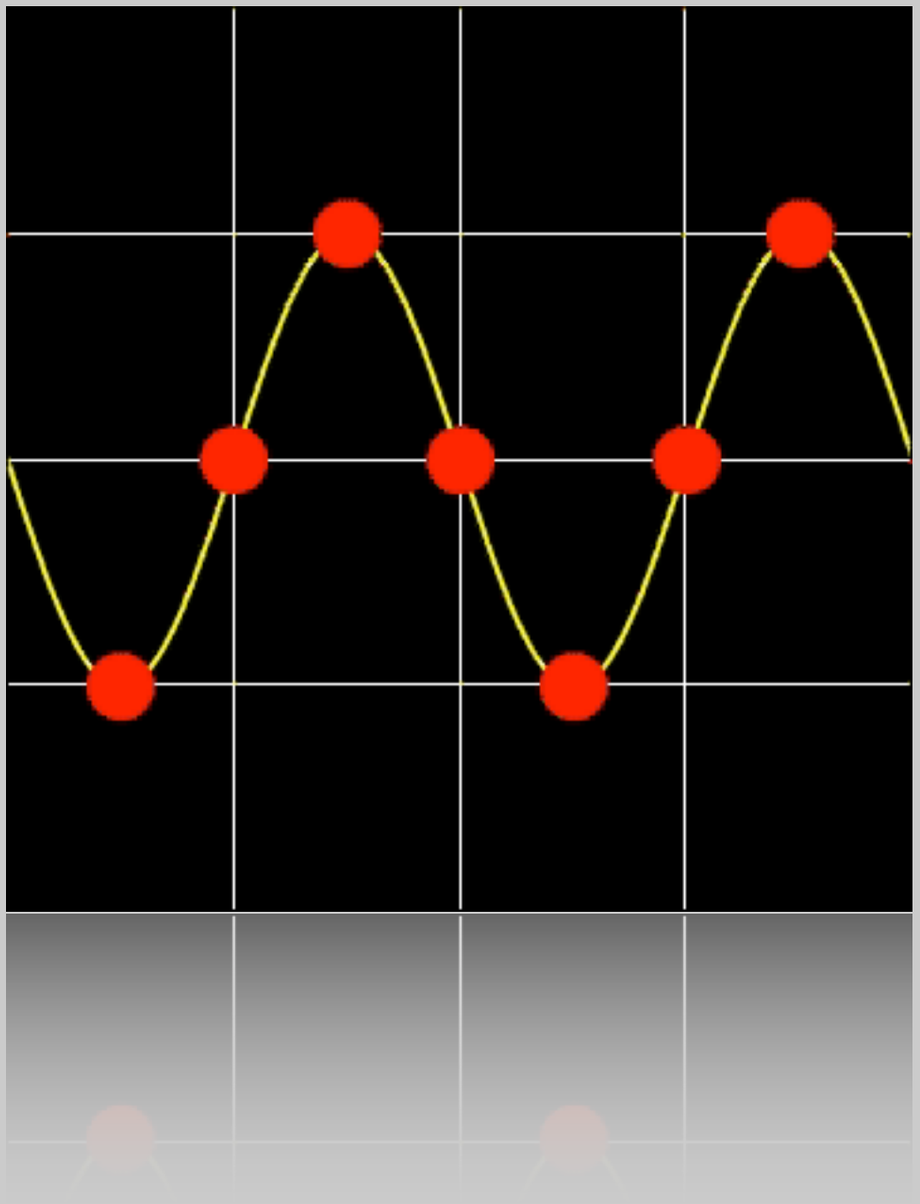
- Amplitude
- Wave length
- Frequency (or Period)
- Velocity

$$(\text{velocity}) = \frac{(\text{wave length})}{(\text{period})}$$

State of a Wave



State of a Wave



- Phase

Wave-Particle Correspondence

Particle-Like	Wave-Like
Energy	Frequency
Momentum	Wave length
Postion	Phase

Particle-Like	Wave-Like
Energy	Frequency
Momentum	Wave length
Postion	Phase

$$(\text{energy}) = h \times (\text{frequency})$$

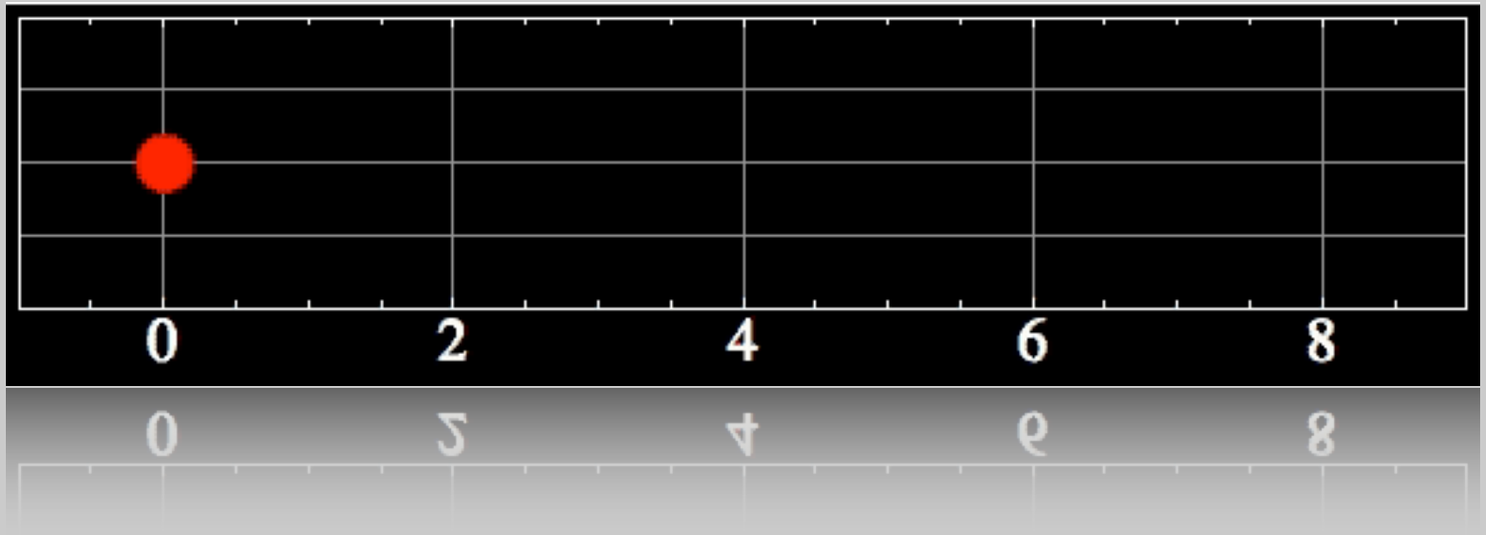
$$(\text{momentum}) = \frac{h}{(\text{wave length})}$$

$$(\text{mass}) = 1\,\text{kg}$$

$$(\text{velocity}) = 2\,\text{m/s}$$

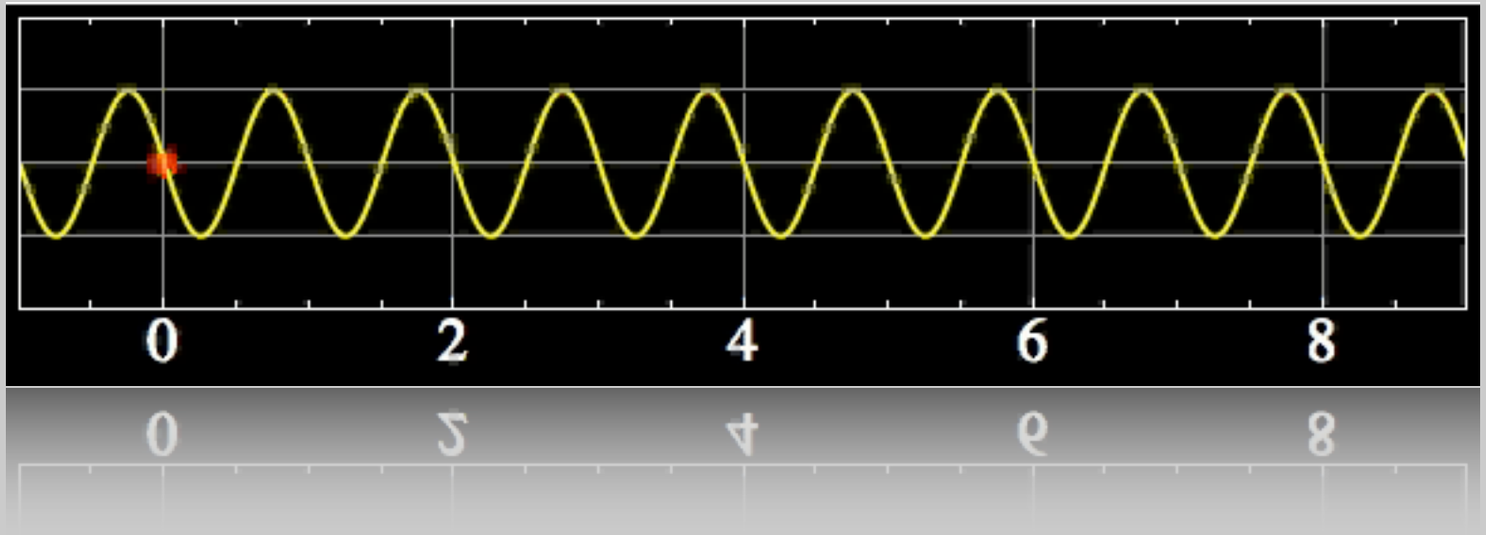
$$(\text{energy}) = 2\,\text{J}$$

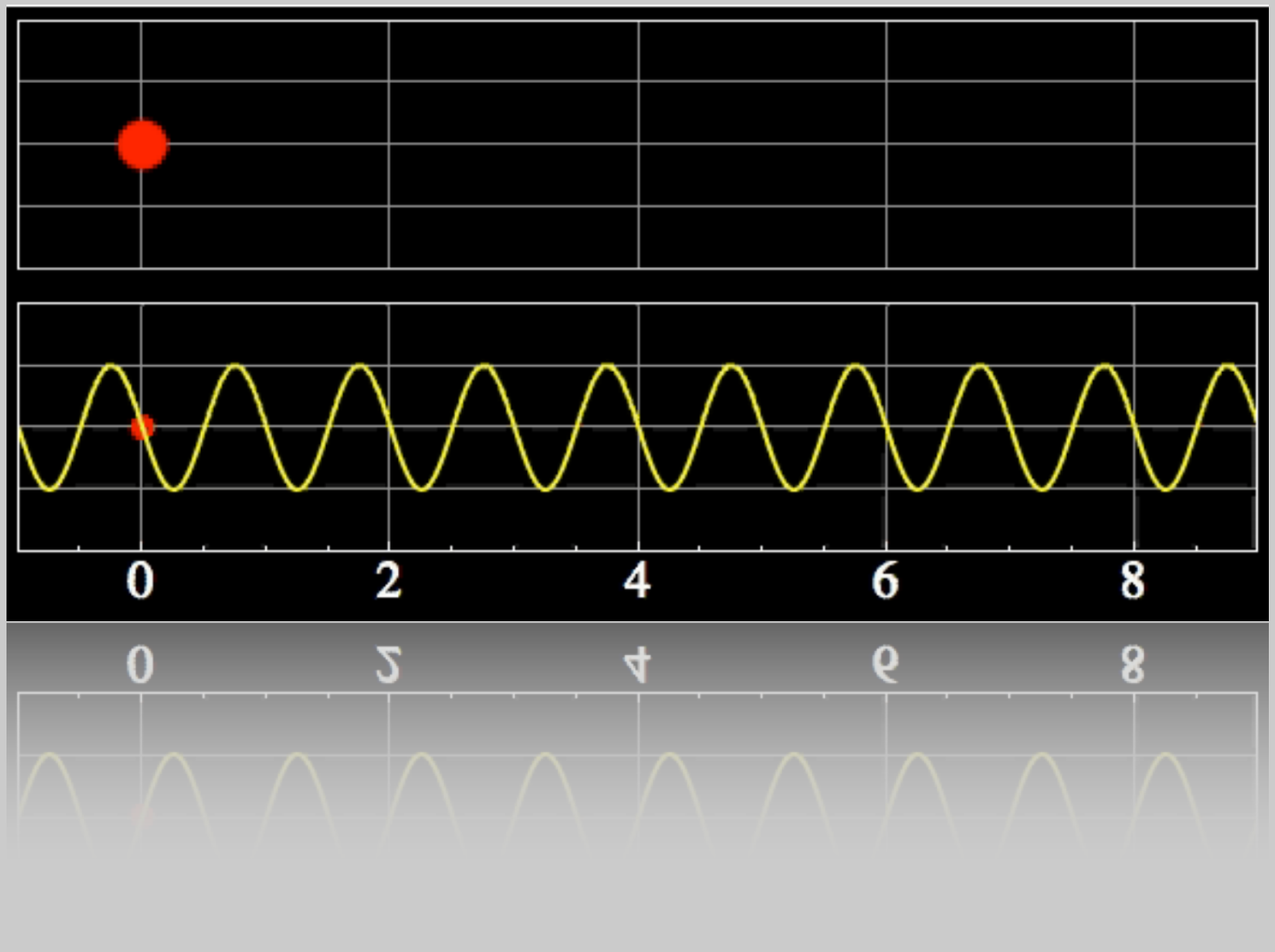
$$(\text{momentum}) = 2\,\text{kg·m/s}$$



$$h \times (\text{frequency}) = 2\,\text{J}$$

$$\frac{h}{(\text{wave length})} = 2\,\text{kg·m/s}$$

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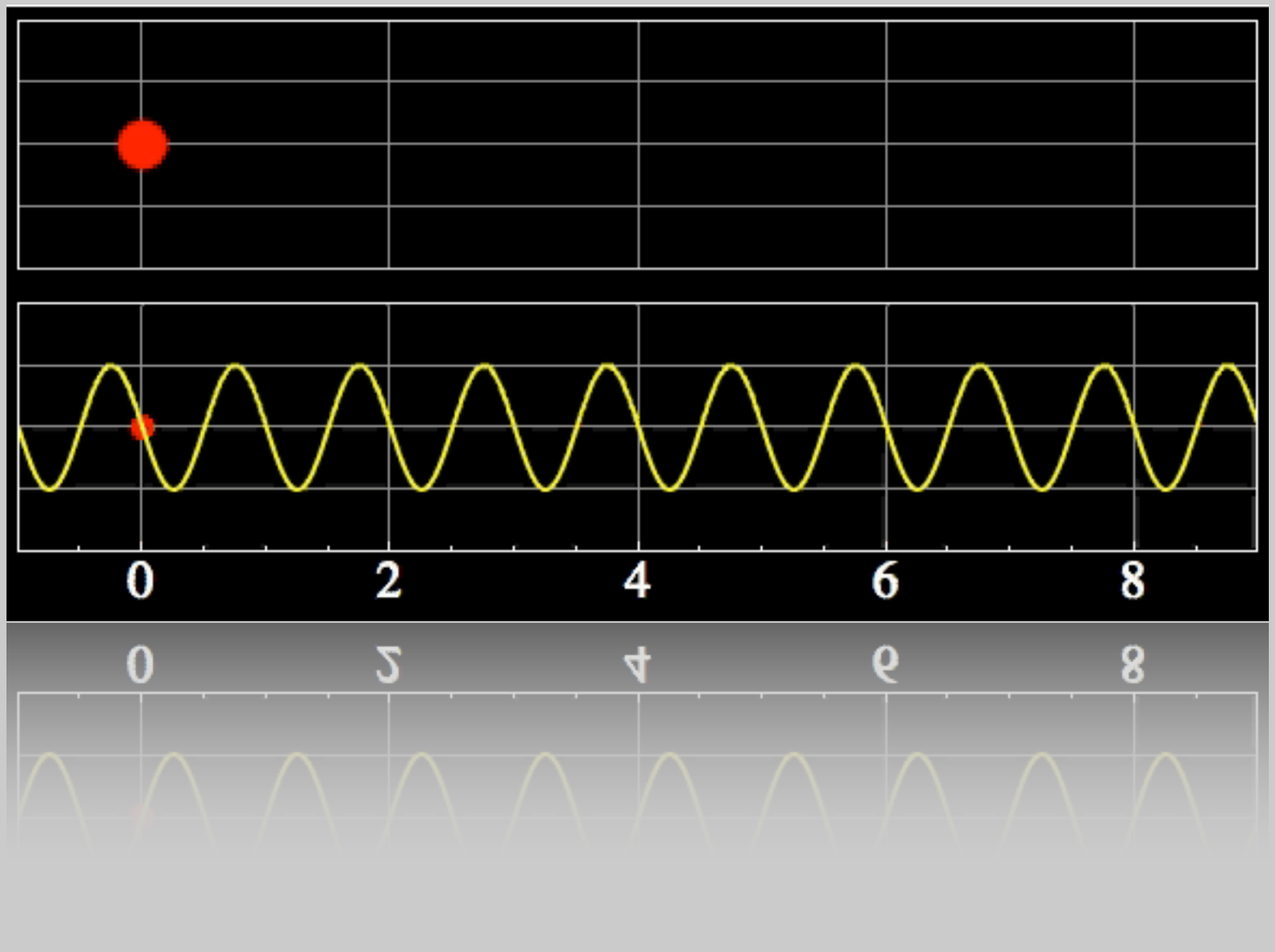
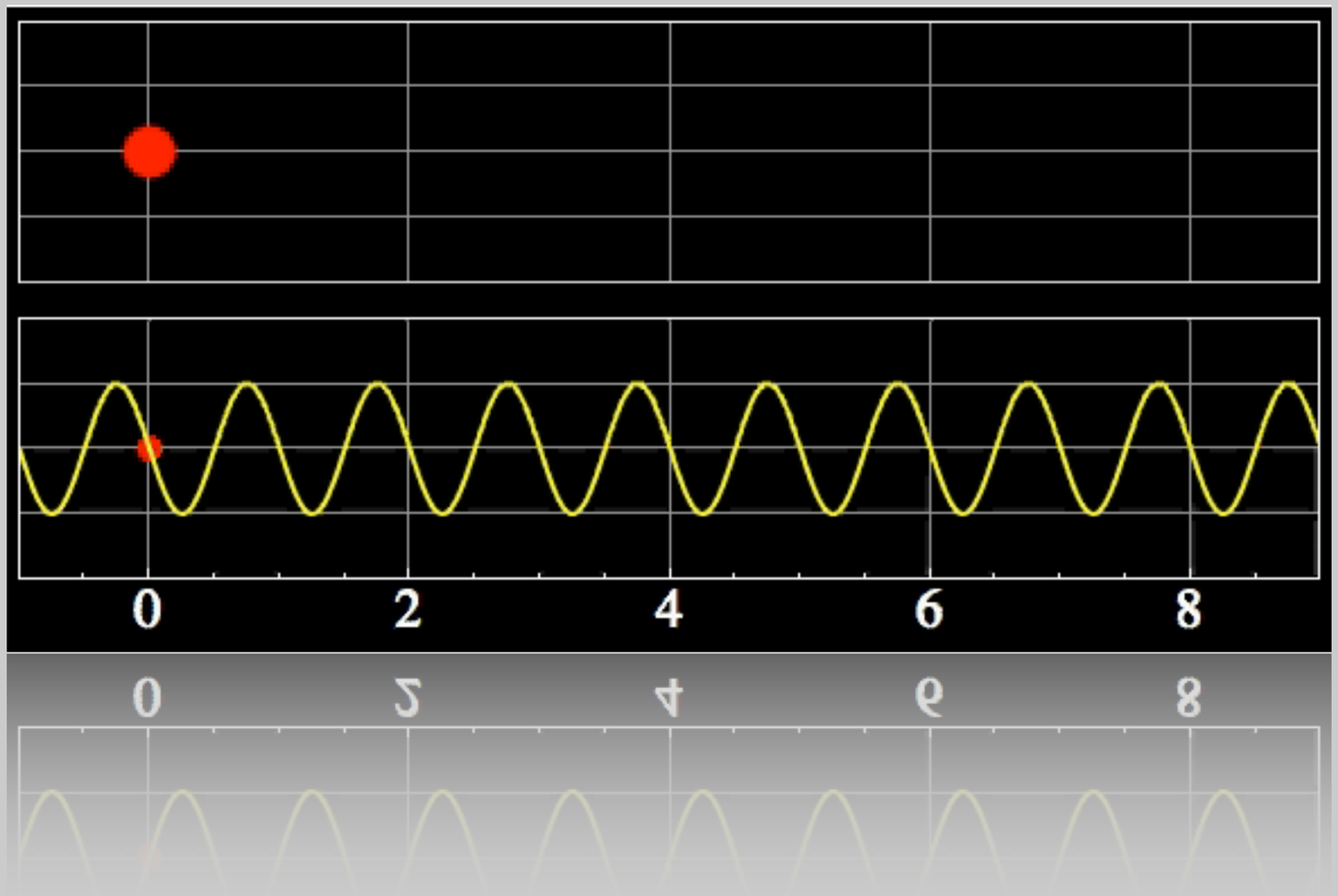
8

$$(\text{energy}) = h \times (\text{frequency})$$

$$(\text{momentum}) = \frac{h}{(\text{wave length})}$$



$$(\text{energy}) = h \times (\text{frequency})$$

$$(\text{momentum}) = \frac{h}{(\text{wave length})}$$