Lecture 6
Mon. 9.10.2018

Geometry of common power-law potentials

Geometric (Power) series

"Zig-Zag" exponential geometry

Projective or perspective geometry

Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

Coulomb geometry of $-1/r$-potential and $-1/r^2$-force fields

Compare mks units of Coulomb Electrostatic vs. Gravity

Geometry of idealized "Sophomore-physics Earth"

Coulomb field outside   *Isotropic Harmonic Oscillator (IHO) field inside*

Contact-geometry of potential curve(s)

"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

Earth matter vs nuclear matter:

*Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

Introducing 2D IHO orbits and phasor geometry

Phasor "clock" geometry

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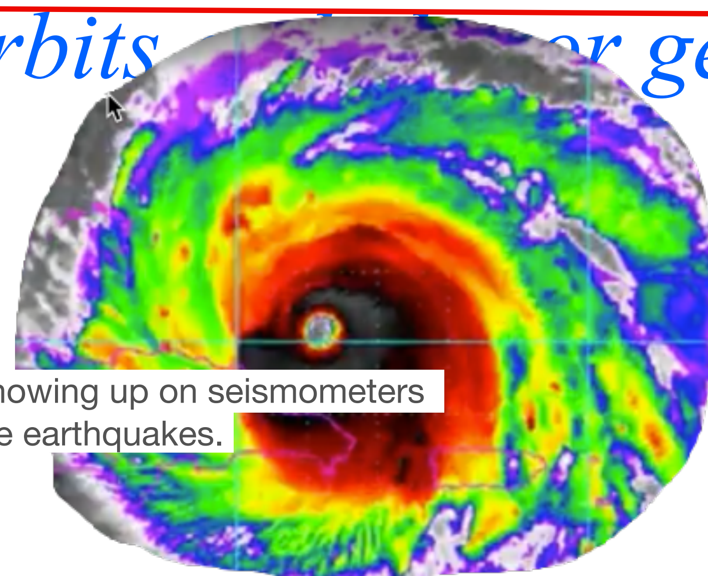
MONSTERS!

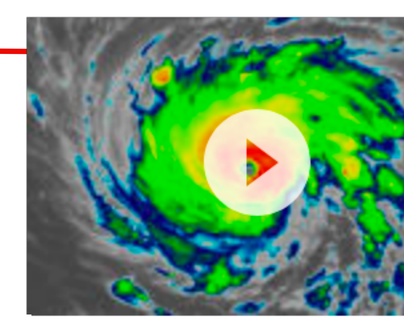
Introducing 2D IHO orbits … *r geometry*

Phasor "clock" geometry



Hurricane Irma is so strong it's showing up on seismometers — equipment designed to measure earthquakes.

This year it's **Hurricane Florence?**



Hurricane Florence strengthens to Category 3.

A running collection of links to course-relevant sites and articles

2018 CMwBang! site

Class YouTube Channel

You-Tube site displays related videos world-wide

AIP publications

AJP article on superball dynamics

AAPT summer reading

These *are* hot off the presses. Out in MISC for quick reference.
https://modphys.hosted.uark.edu//ETC/MISC/Sorting_ultracold_atoms_in_a_three-dimensional_optical_lattice_in_a_realization_of_Maxwell%e2%80%99s_demon_-_Kumar-n-2018.pdf
https://modphys.hosted.uark.edu//ETC/MISC/Synthetic_three-dimensional_atomic_structures_assembled_atom_by_atom_-_Barredo-n-2018.pdf

Older ones:
https://modphys.hosted.uark.edu/ETC/MISC/Wave-particle_duality_of_C60_molecules_-_arndt-ltn-1999.pdf
https://modphys.hosted.uark.edu/ETC/MISC/Optical_Vortex_Knots_-_One_Photon__At_A_Time_-_Tempone-Wiltshire-Sr-2018.pdf

Geometry of common power-law potentials

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→ *"Zig-Zag" exponential geometry*

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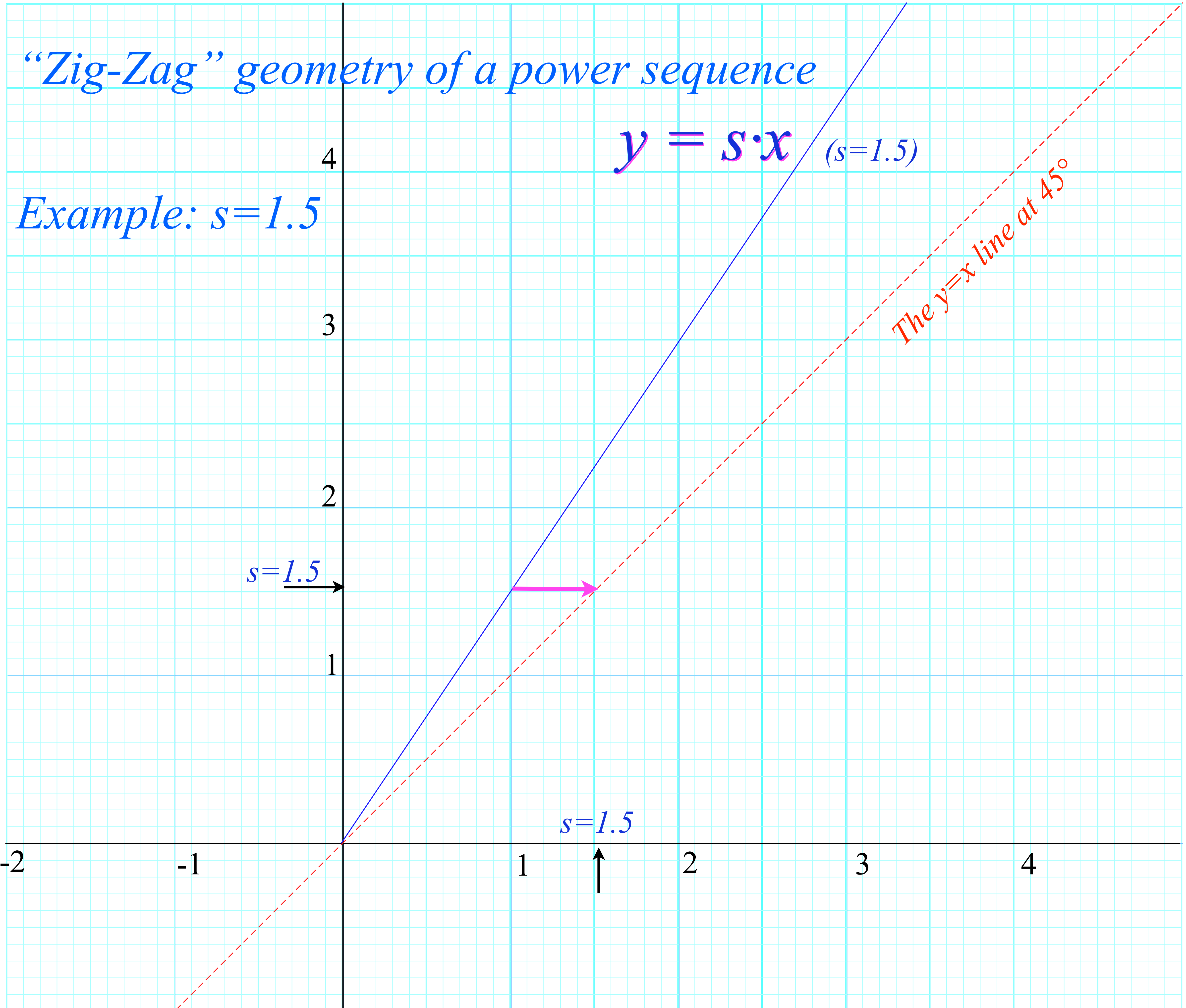
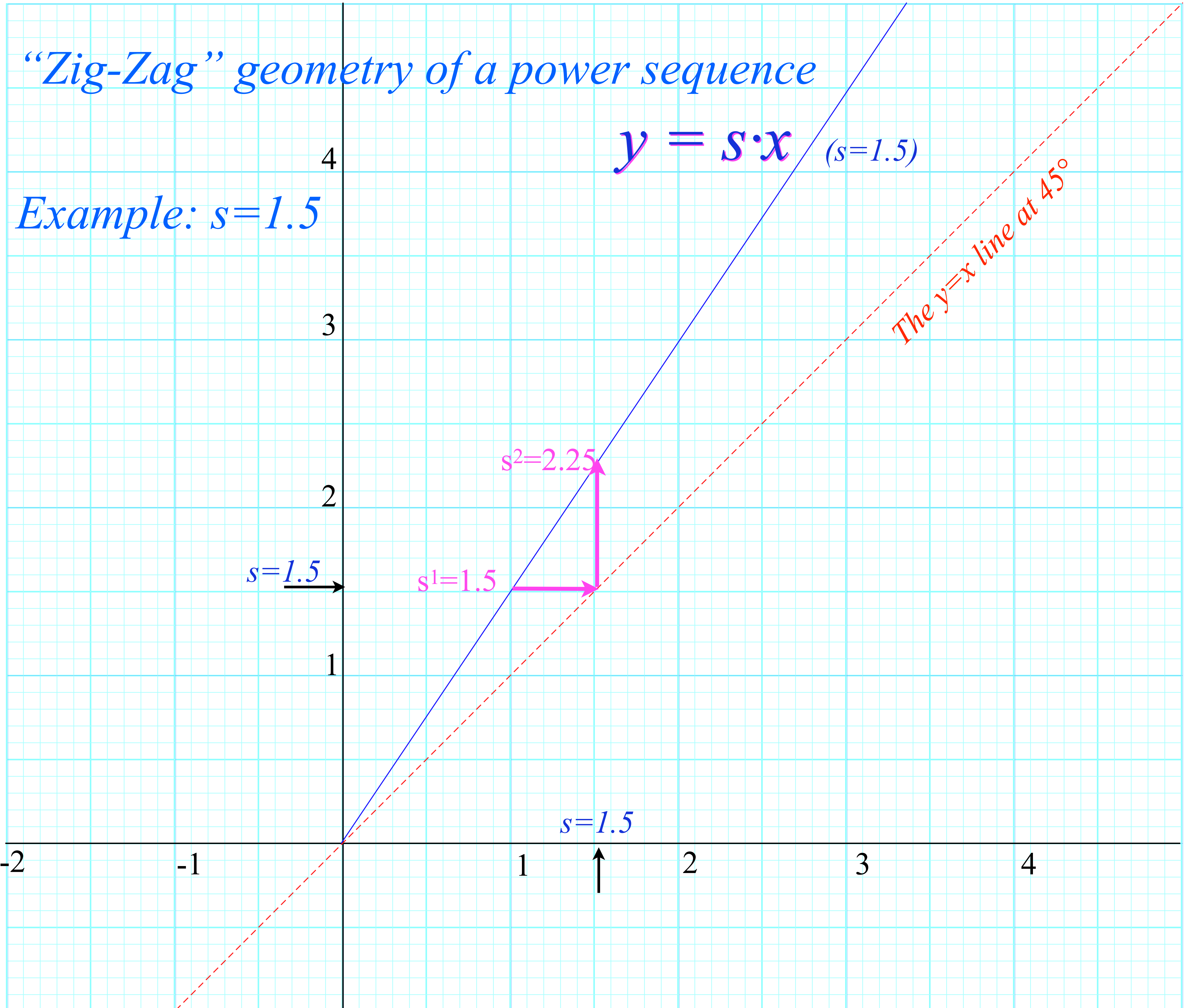


“Zig-Zag” geometry of a power sequence
y = s·x (s=1.5)
Example: s=1.5
The y=x line at 45°
s=1.5
s=1.5
4
3
2
1
-2
-1
1
2
3
4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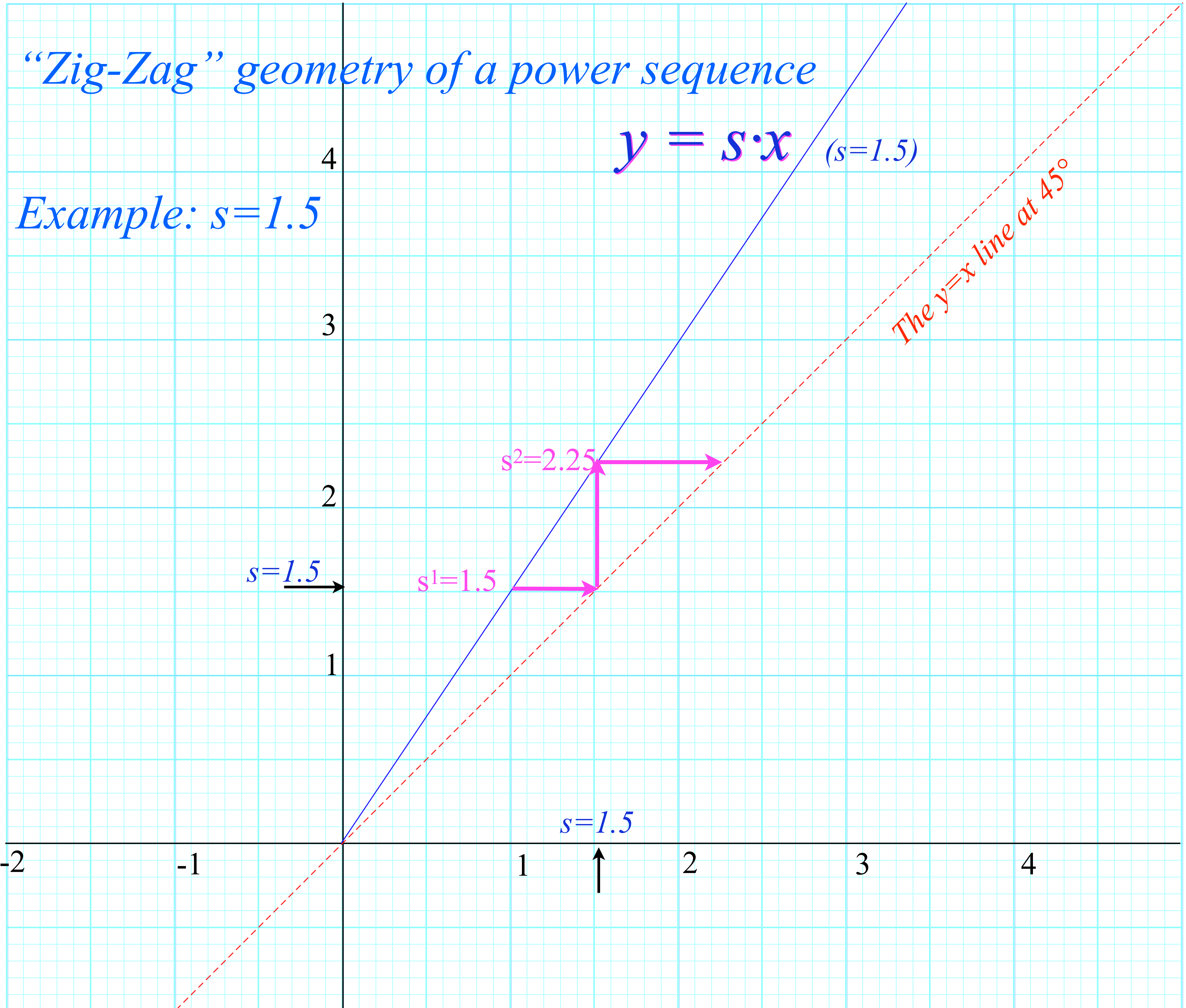
2
1
-2
-1
1
2
3
4
s²=2.25
s¹=1.5
s=1.5
s=1.5



"Zig-Zag" geometry of a power sequence
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Example: s=1.5
The y=x line at 45°
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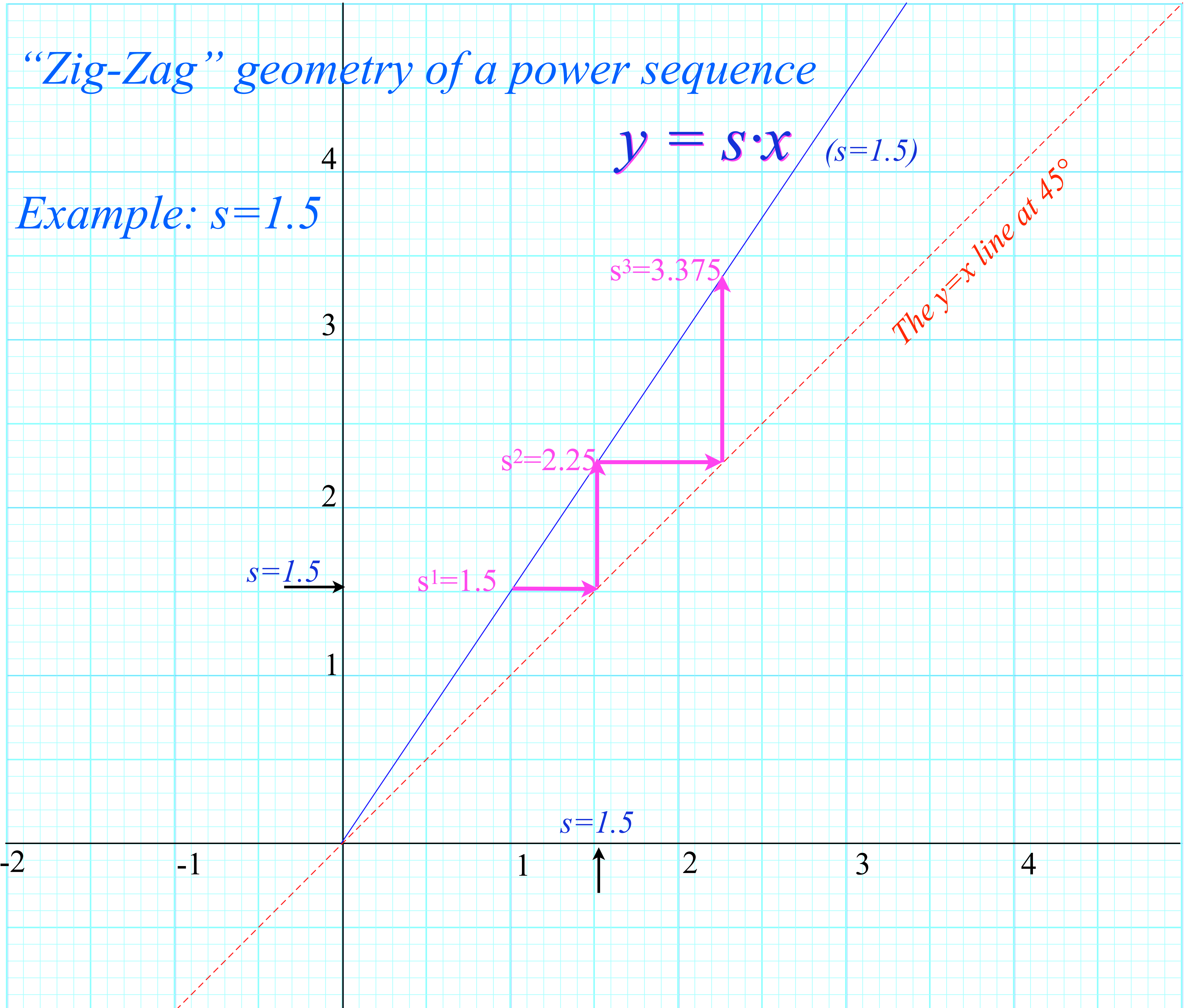
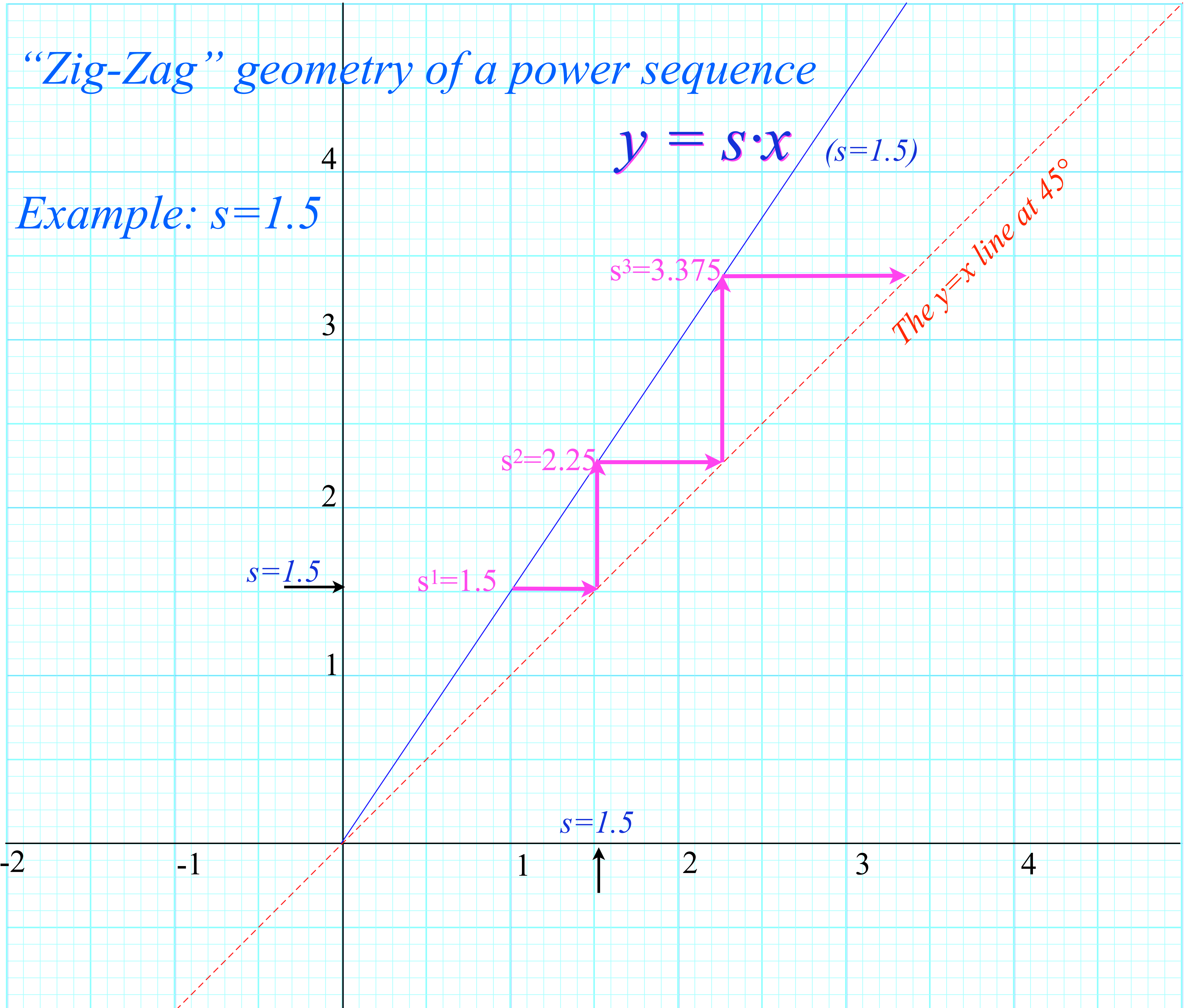
s¹=1.5
s=1.5
s=1.5
4
3
2
1
-2
-1
1
2
3
4



"Zig-Zag" geometry of a power sequence
y = s·x
(s=1.5)
Example: s=1.5
The y=x line at 45°
s³=3.375
s²=2.25
s¹=1.5
s=1.5
s=1.5
4
3
2
1
-2
-1
1
2
3
4



"Zig-Zag" geometry of a power sequence
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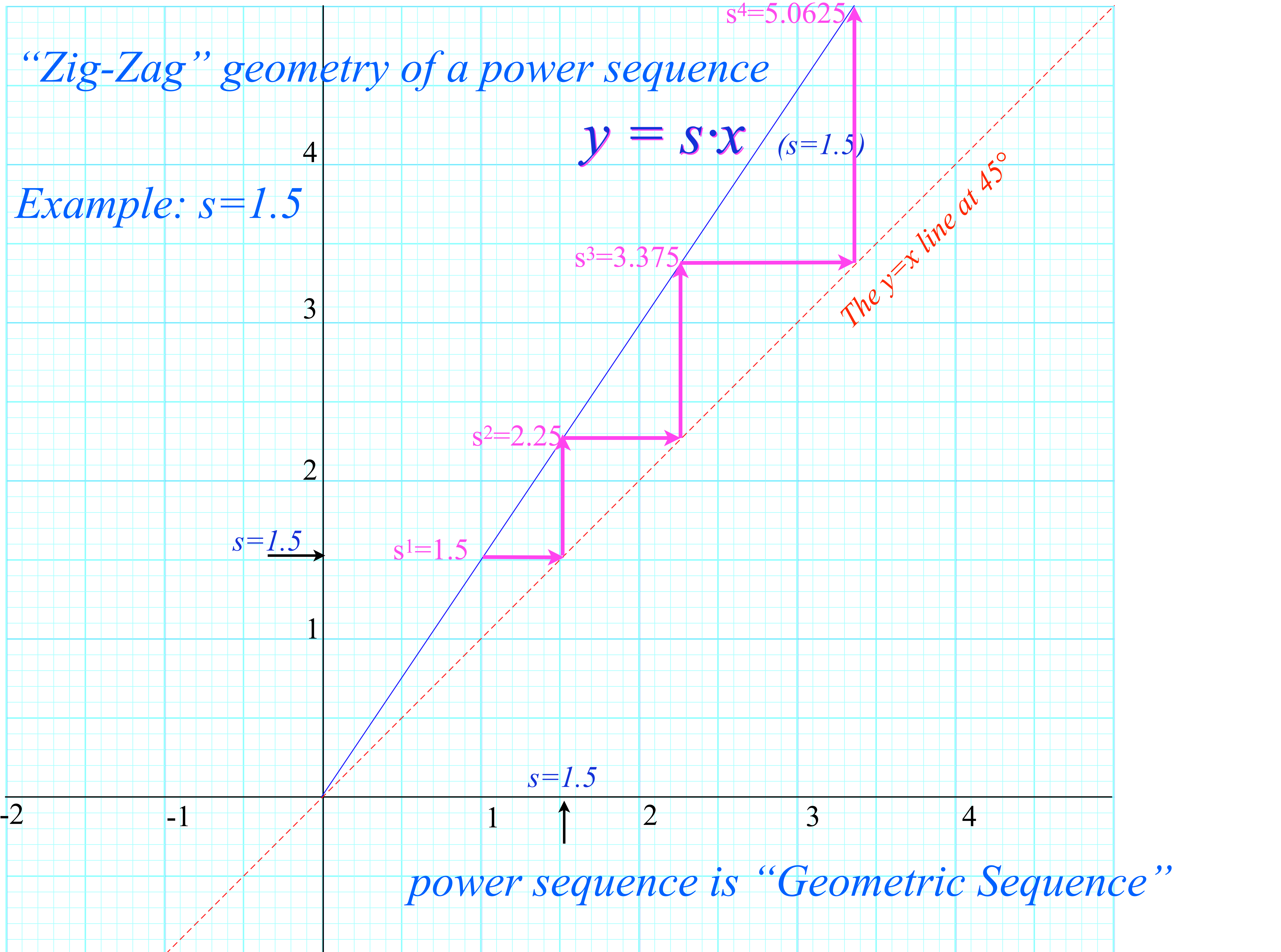
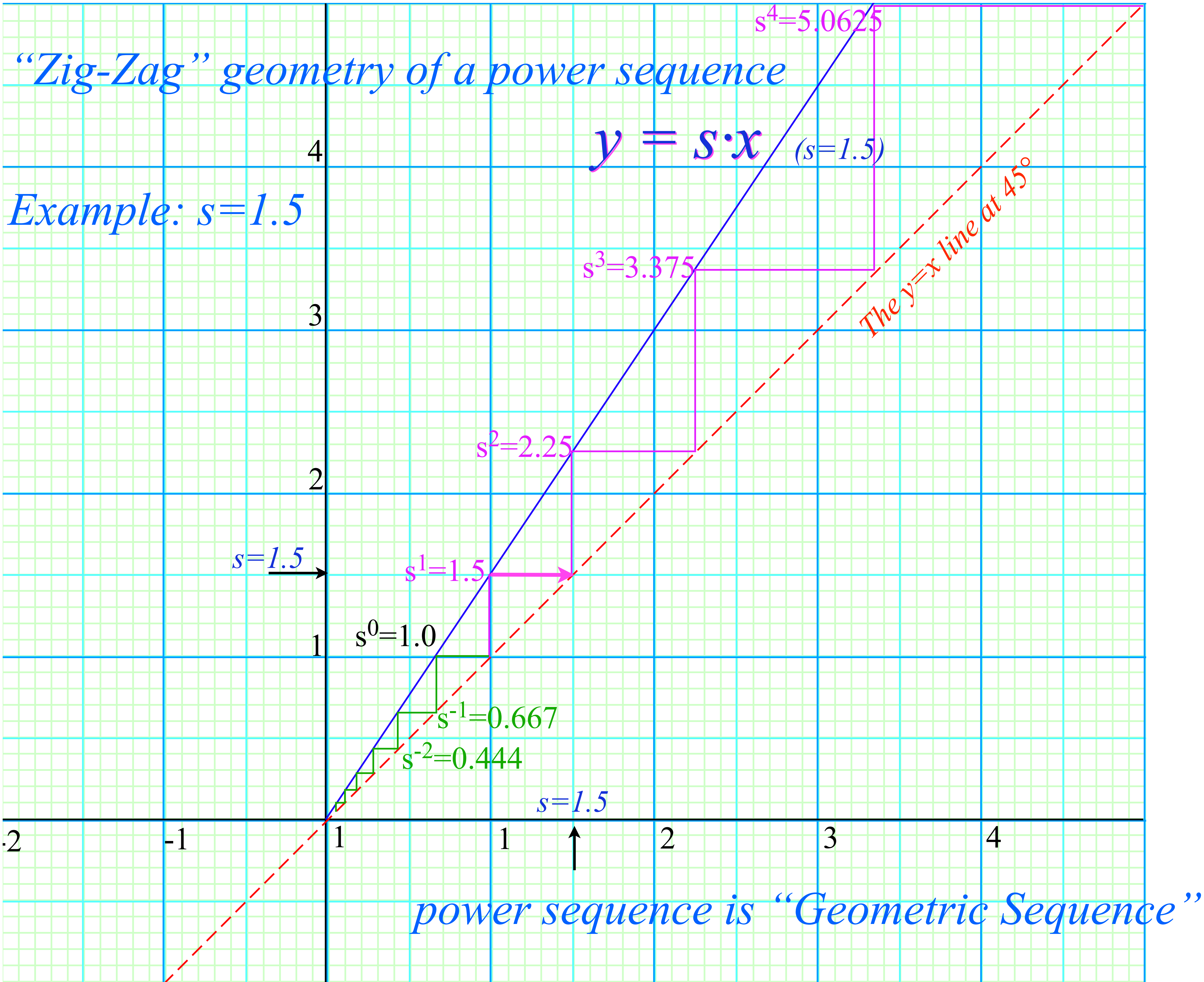
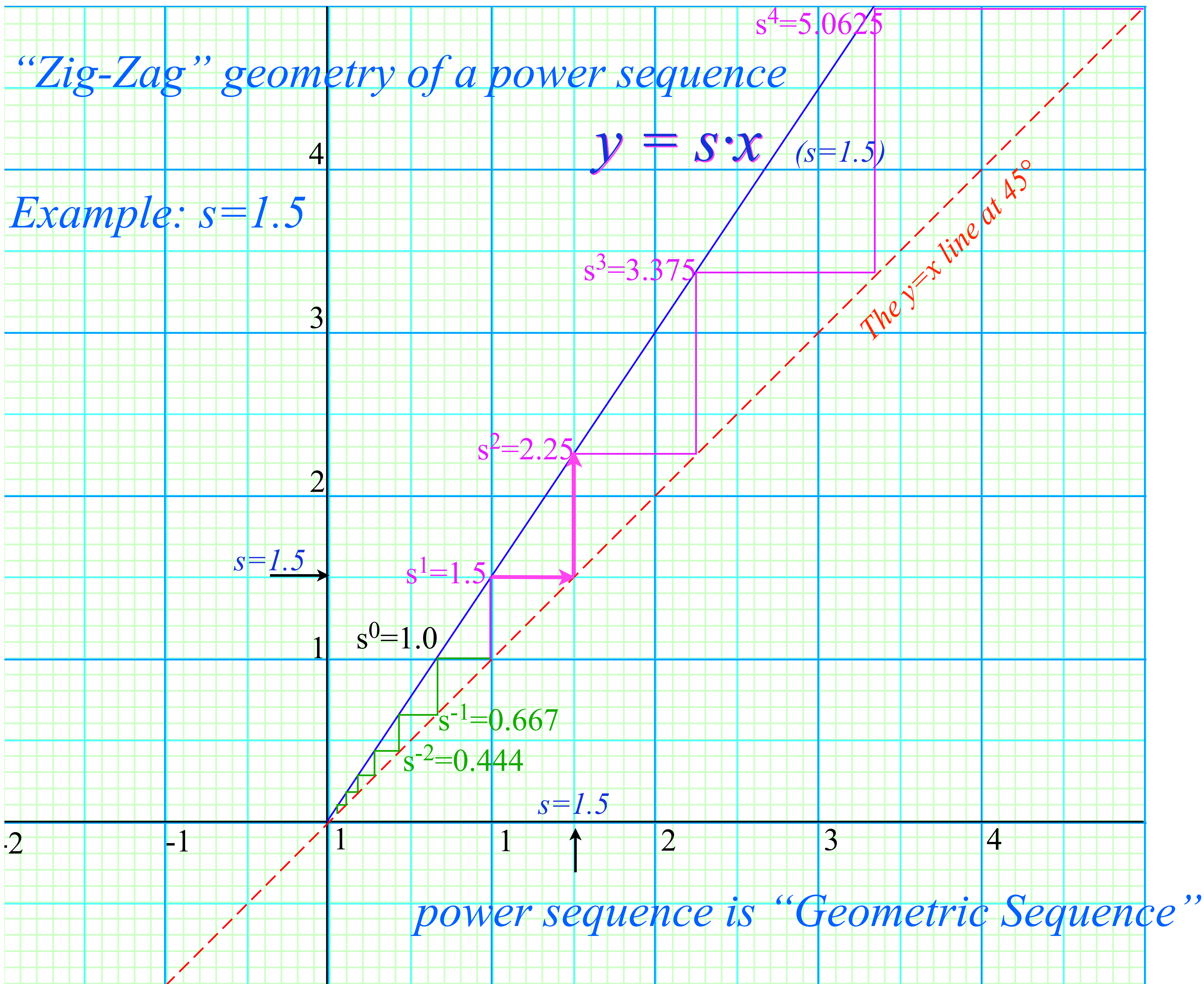
4
3
2
1
-2
-1
1
2
3
4



"Zig-Zag" geometry of a power sequence
$y = s \cdot x$
(s=1.5)
Example: s=1.5
$s^4=5.0625$
$s^3=3.375$
$s^2=2.25$
$s^1=1.5$
s=1.5
s=1.5
The y=x line at 45°
4
3
2
1
-2
-1
1
2
3
4
power sequence is "Geometric Sequence"



"Zig-Zag" geometry of a power sequence
y = s·x
(s=1.5)
Example: s=1.5
The y=x line at 45°
s⁴=5.0625
s³=3.375
s²=2.25
s¹=1.5
s⁰=1.0
s⁻¹=0.667
s⁻²=0.444
s=1.5
s=1.5
4
3
2
1
-2
-1
1
1
2
3
4
power sequence is "Geometric Sequence"



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4
3
2
1
-2
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1
1
2
3
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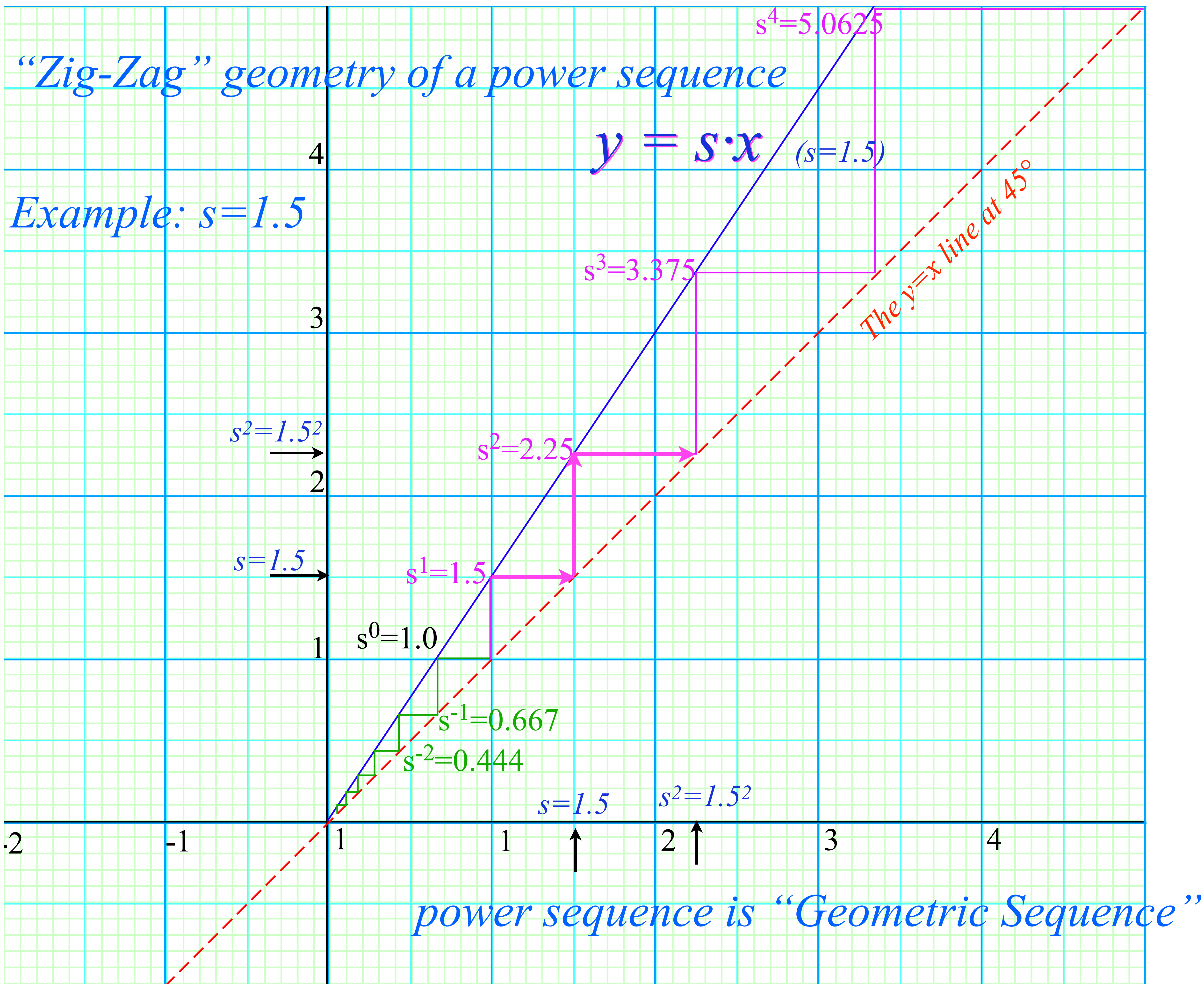

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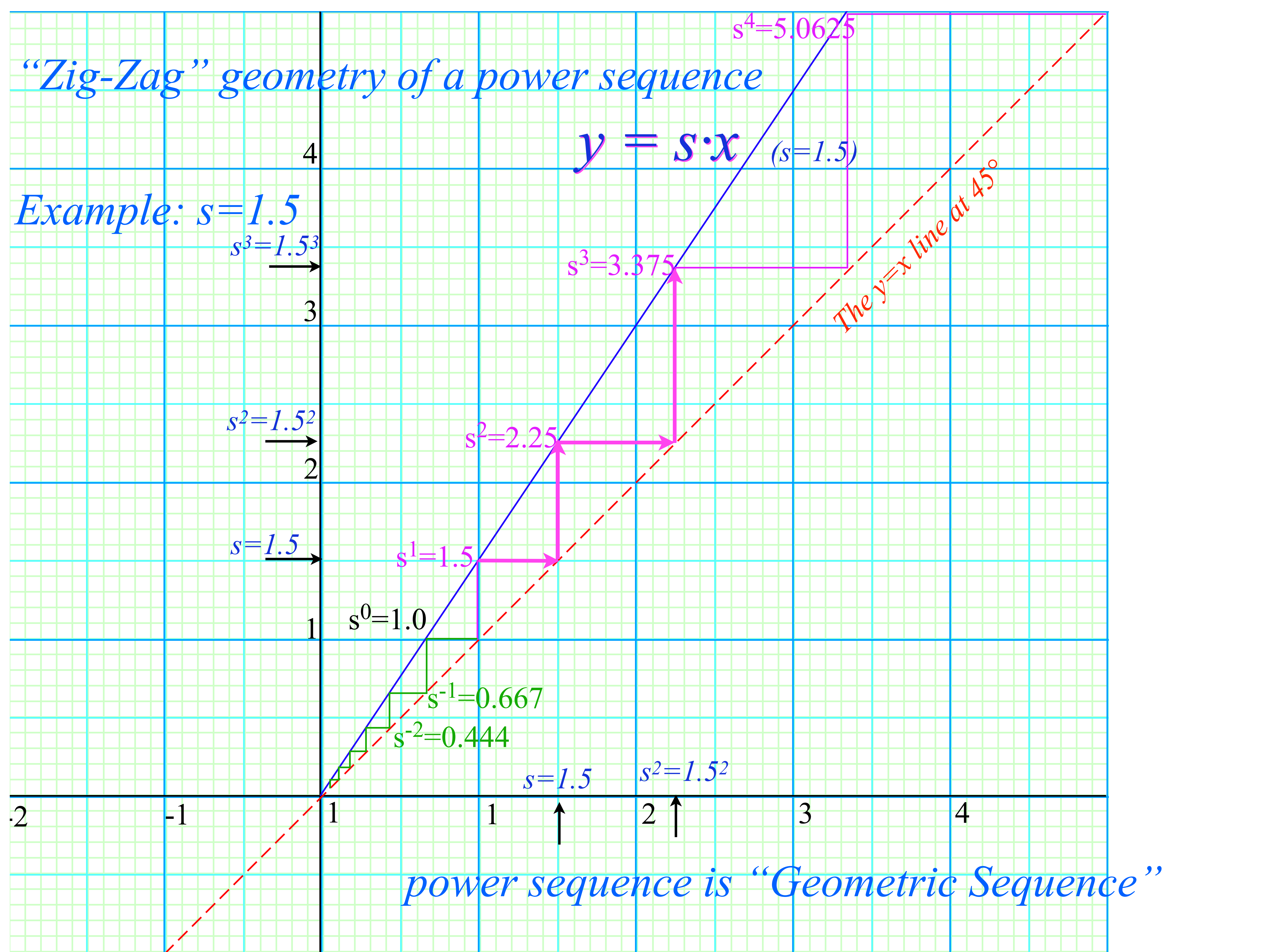
s²=1.5²
s=1.5
s=1.5
s²=1.5²
The y=x line at 45°
-2
-1
1
1
2
3
4
1
2
3
4
power sequence is “Geometric Sequence”



“Zig-Zag” geometry of a power sequence
Example: s=1.5
y = s·x
(s=1.5)
s⁴=5.0625
s³=1.5³
s³=3.375
s²=1.5²
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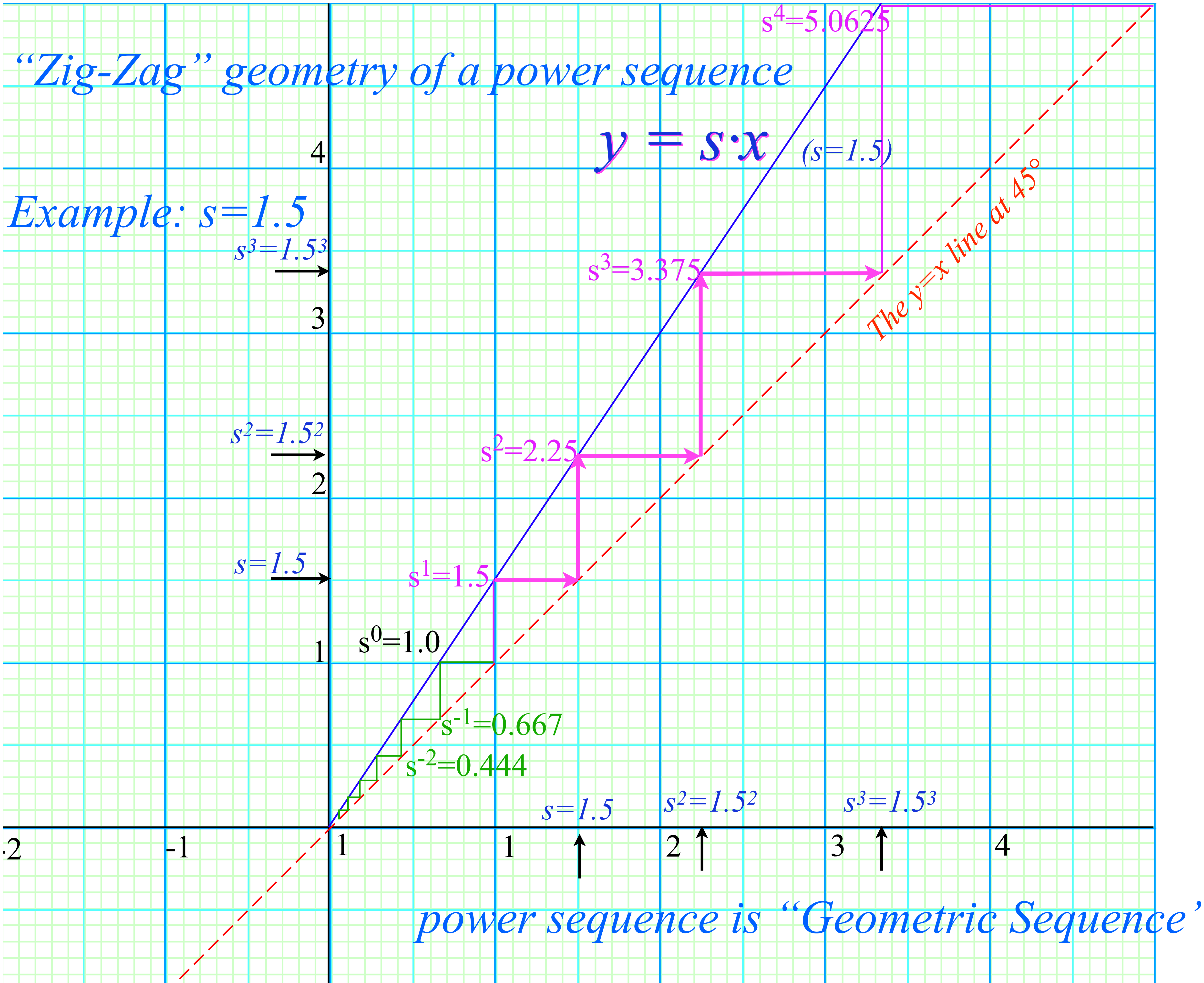
The y=x line at 45°
s=1.5
s²=1.5²
4
3
2
1
-2
-1
1
1
2
3
4
power sequence is “Geometric Sequence”



"Zig-Zag" geometry of a power sequence
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Example: s=1.5
s⁴=5.0625
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The y=x line at 45°
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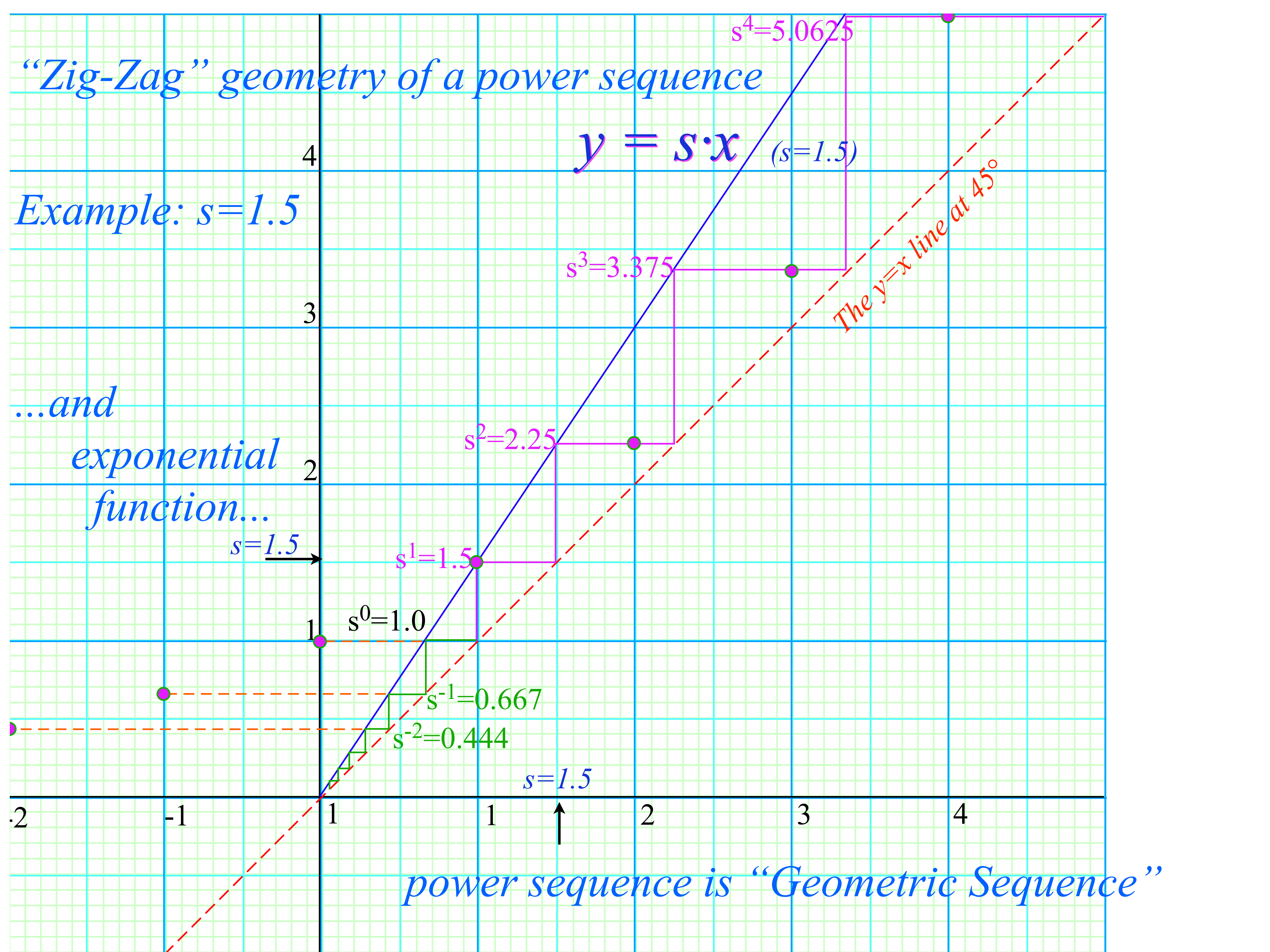
4
3
2
1
-2
-1
1
1
2
3
4
power sequence is "Geometric Sequence"



"Zig-Zag" geometry of a power sequence
y = s·x (s=1.5)
Example: s=1.5
...and
exponential
function...
s=1.5
s^4=5.0625
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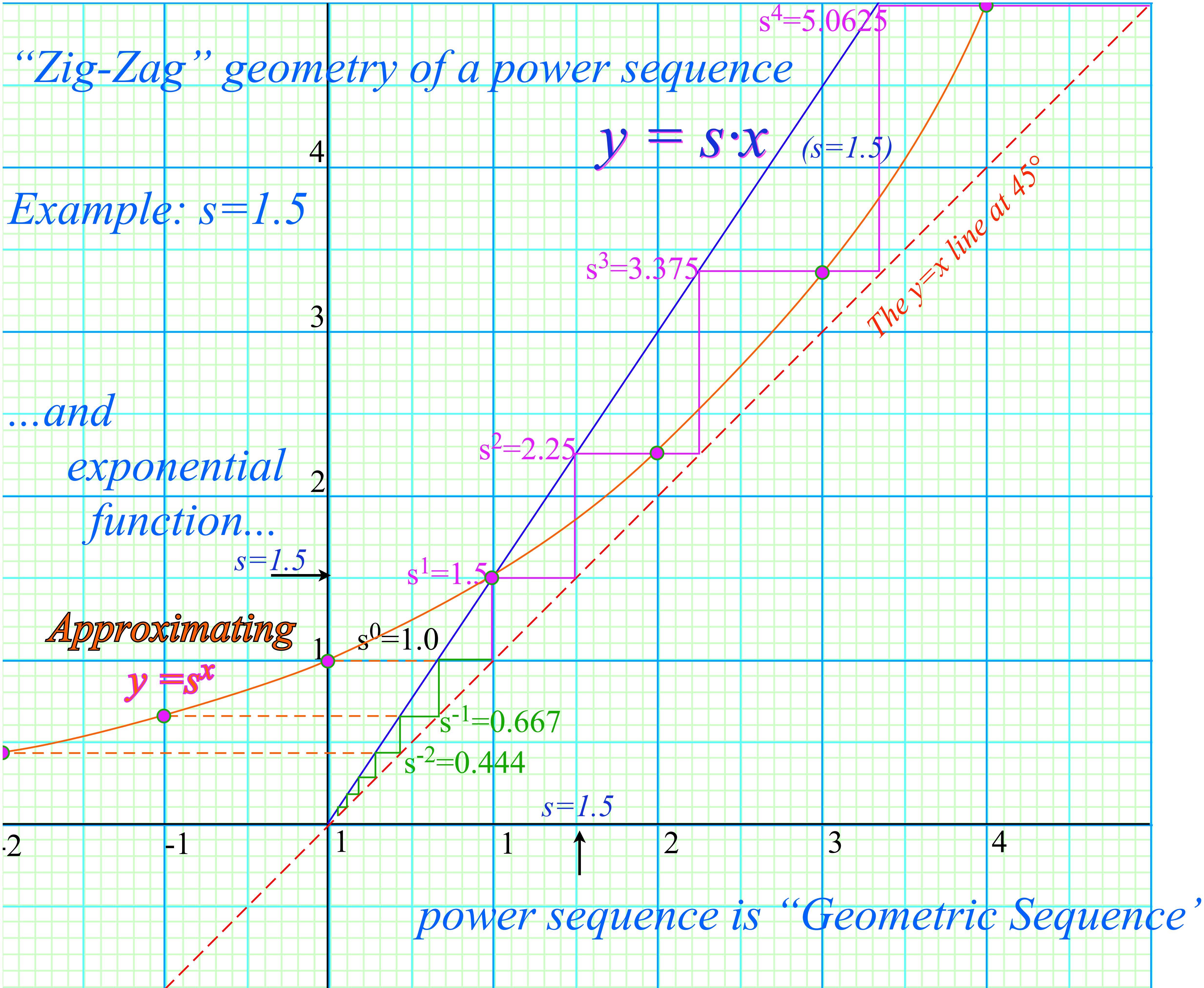
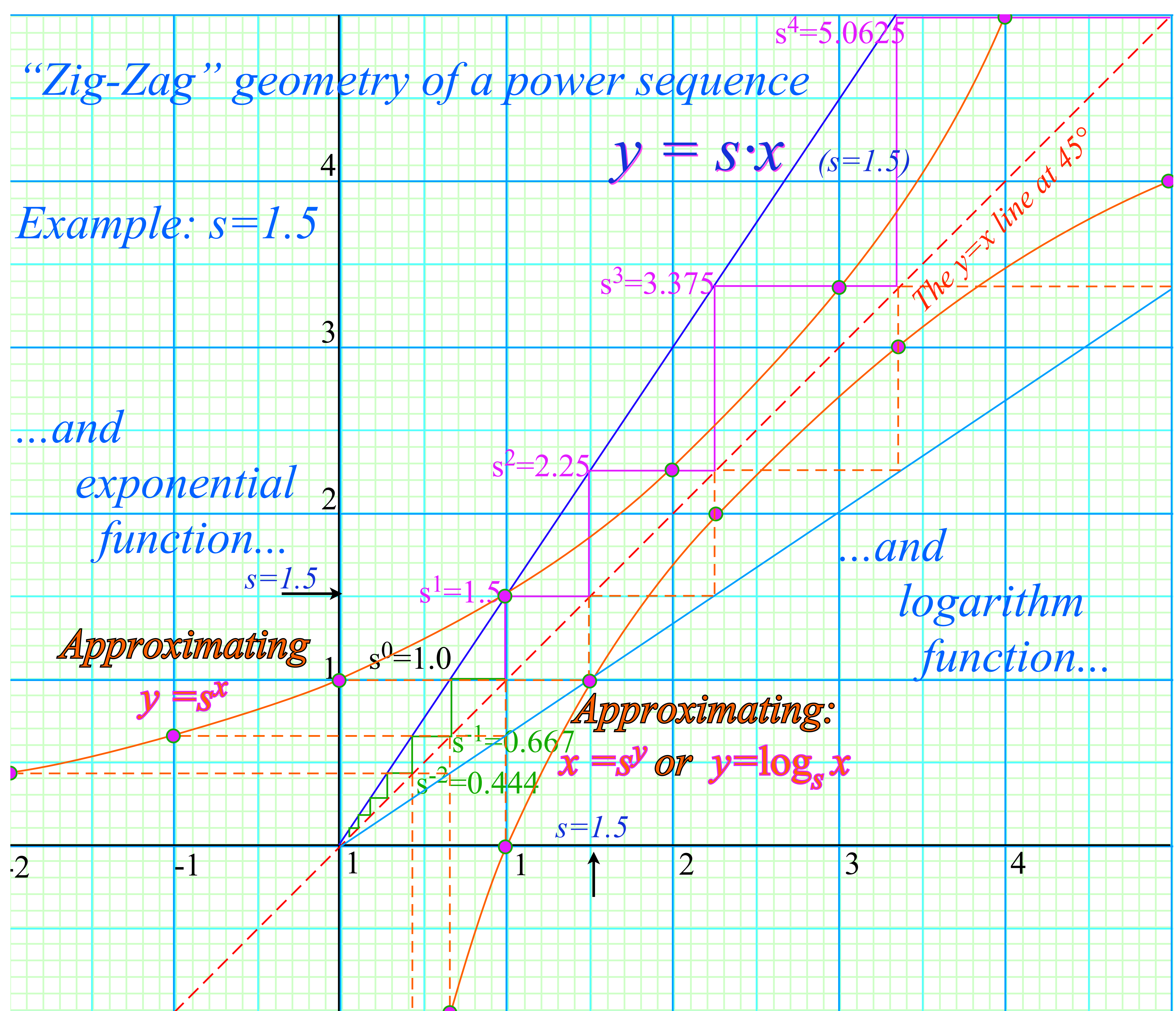
s^2=2.25
s^1=1.5
s^0=1.0
s^{-1}=0.667
s^{-2}=0.444
The y=x line at 45°
s=1.5
4
3
2
1
-2
-1
1
1
2
3
4
power sequence is "Geometric Sequence"



"Zig-Zag" geometry of a power sequence
Example: s=1.5
...and
exponential
function...
Approximating
y =s^x
y = s·x
(s=1.5)
s^4=5.0625
s^3=3.375
s^2=2.25
s^1=1.5
s^0=1.0
s^-1=0.667
s^-2=0.444
s=1.5
s=1.5
The y=x line at 45°
power sequence is "Geometric Sequence"
4
3
2
1
-2
-1
1
1
2
3
4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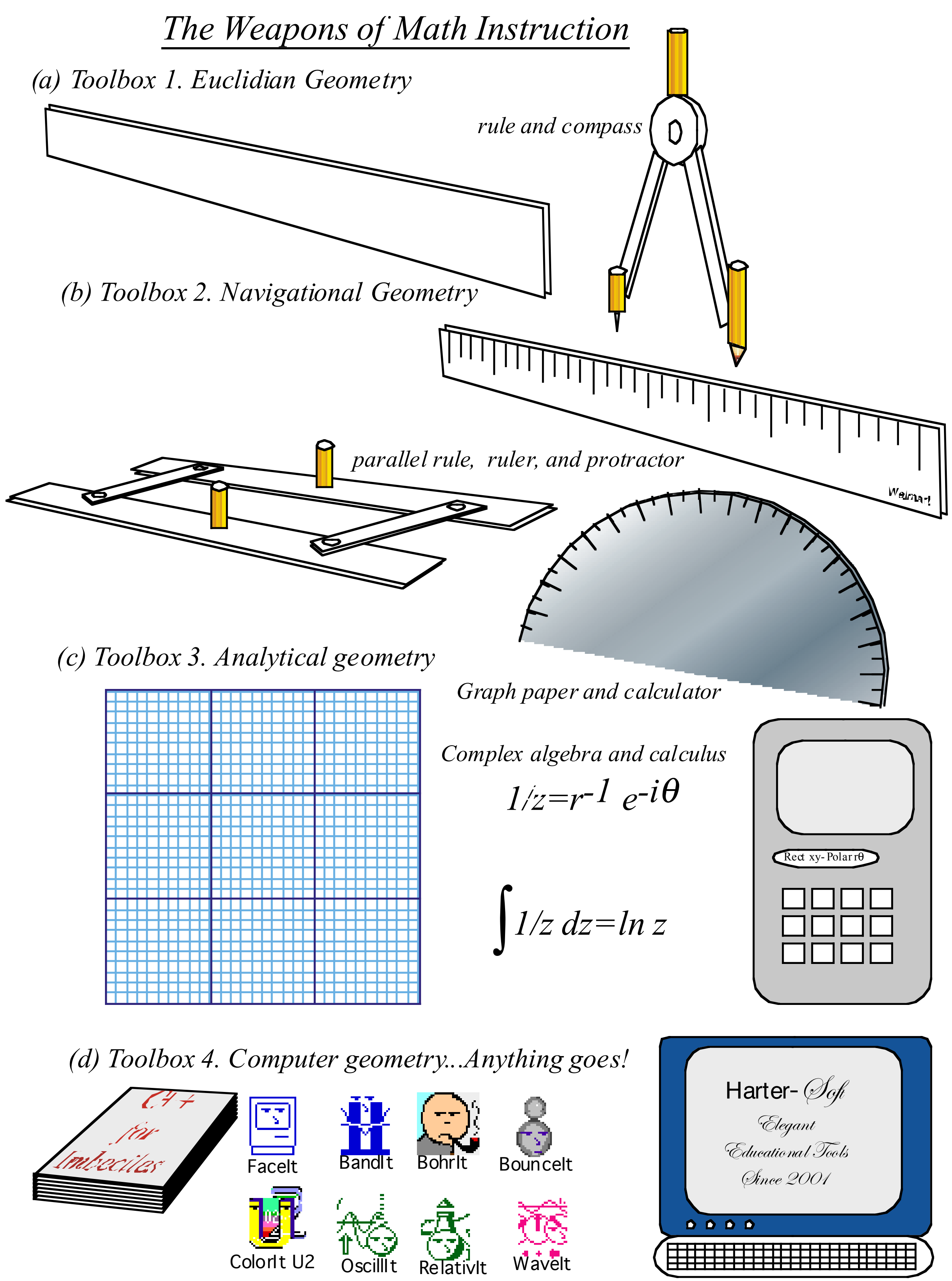
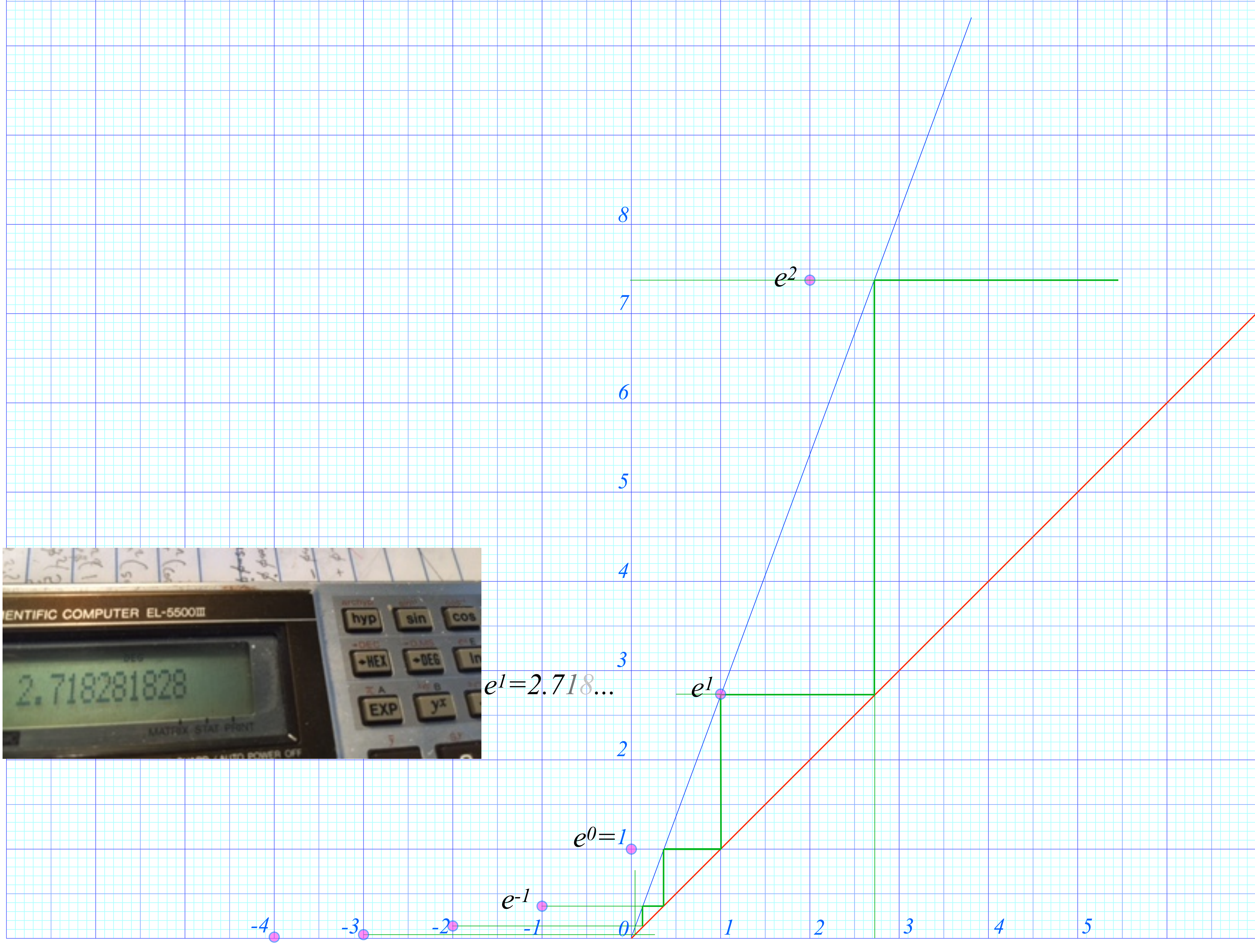
s^2=2.25
s^1=1.5
s^0=1.0
s^-1=0.667
s^-2=0.444
s=1.5
...and exponential function...
Approximating
y =s^x
...and logarithm function...
Approximating:
x =s^y or y=log_s x
s=1.5
-2
-1
1
1
2
3
4
1
2
3
4



So far we mostly use Toolbox (a-b)

What follows uses Toolbox (c) ...

...and Toolbox (d)



8
7
6
5
4
3
2
0
-4
-3
-2
-1
1
2
3
4
5
e^2
e^1
e^1=2.718...
e^0=1
e^-1
ENTIFIC COMPUTER EL-5500III
2.718281828
hyp
sin
cos
→HEX
→DEG
EXP
y^x
MATRIX STAT PRINT

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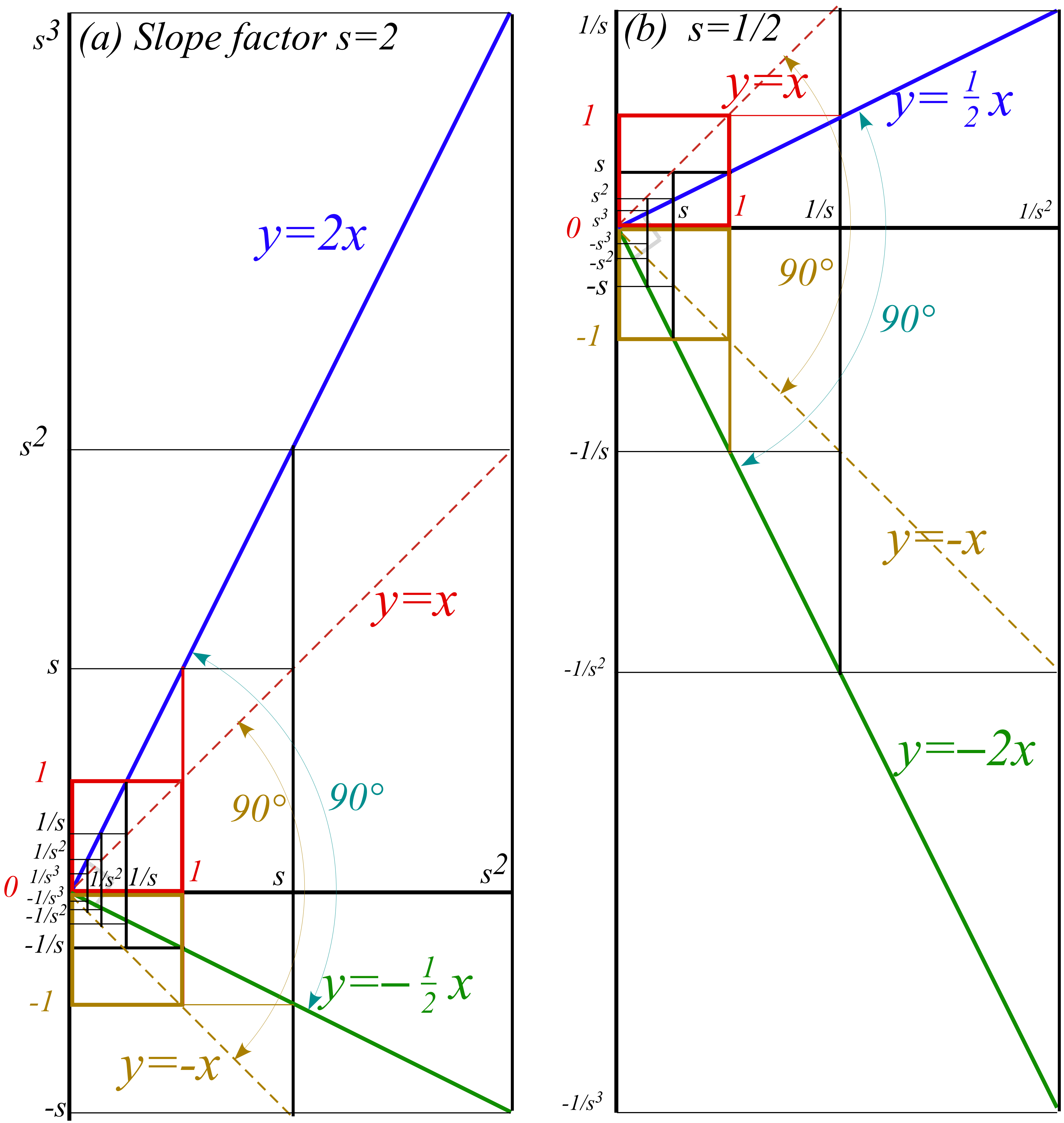
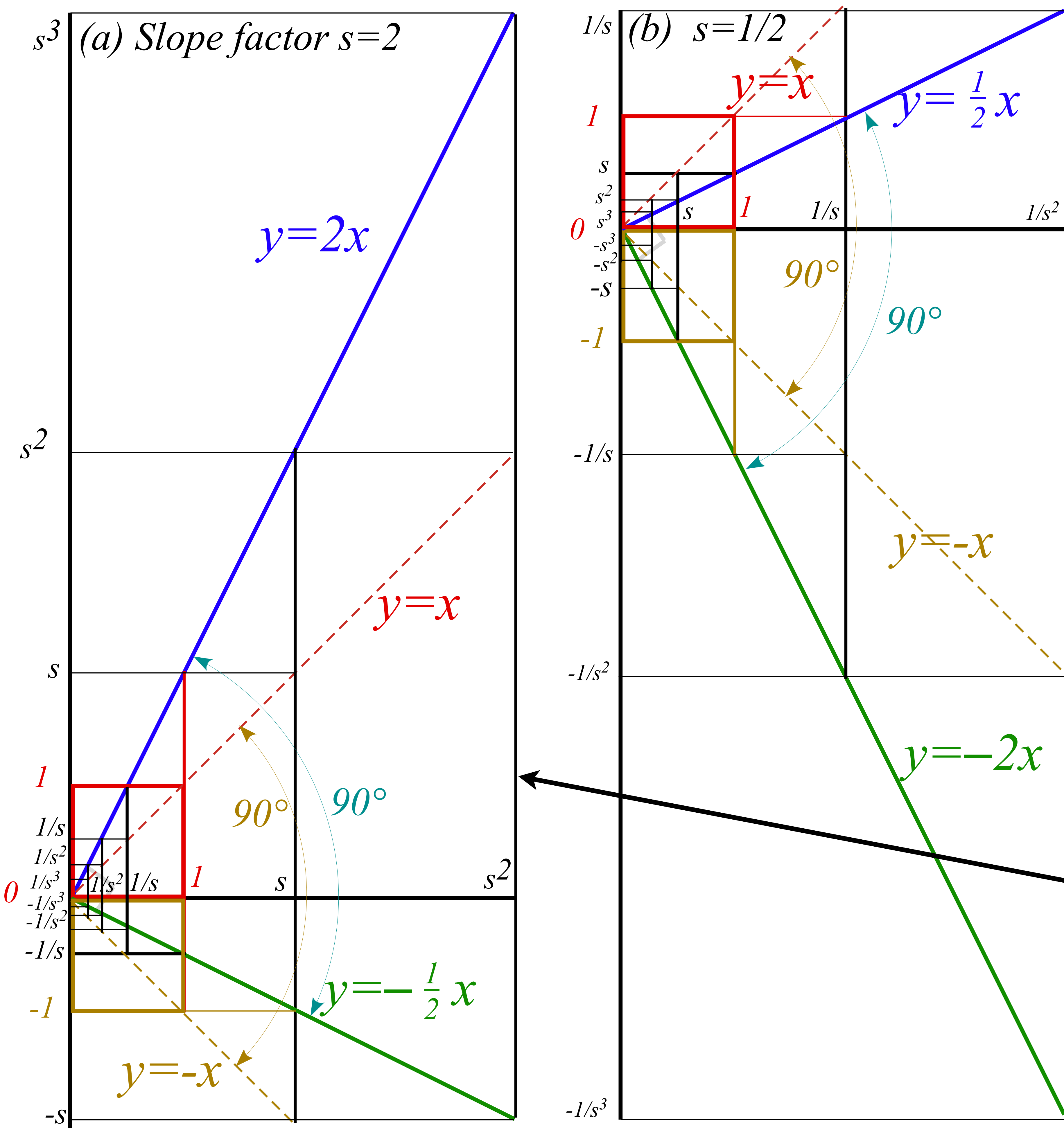


"Zig-Zags" give perspective geometry

(1D-vanishing point)

Unit 1
Fig. 9.2



“Zig-Zags” give perspective geometry

(1D-vanishing point)

Unit 1
Fig. 9.2

1st-day-of-school perspective of 12th-grader

1st-day-of-school perspective of 1st-grader

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"Zig-Zag" exponential geometry

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→ *Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields*

Coulomb geometry of $-1/r$-potential and $-1/r^2$-force fields

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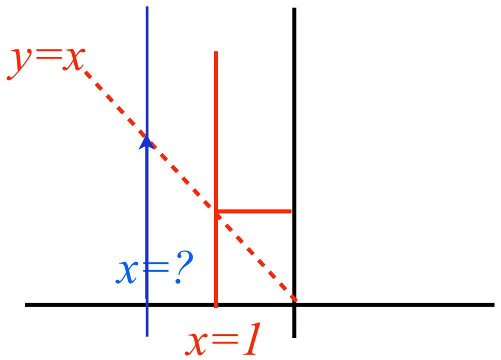
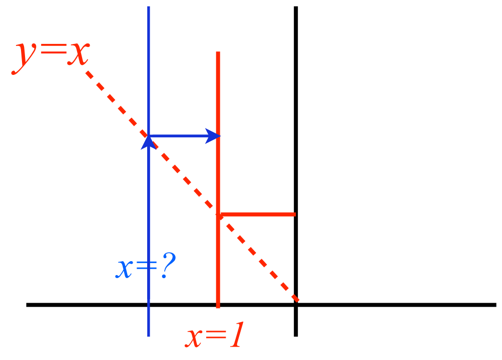
Each $y=x^2$ parabola point found by just one "Zig-Zag"

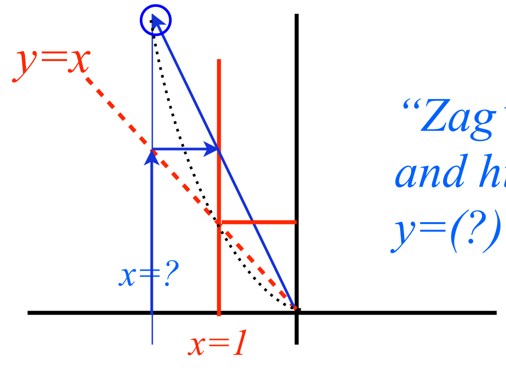
1. Pick an (x=?)-line

2. "Zig" from its y=x intersection to x=1 line

3. "Zag" from origin back to (x=?)-line







"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$

Each $y=x^2$ parabola point found by just one "Zig-Zag"

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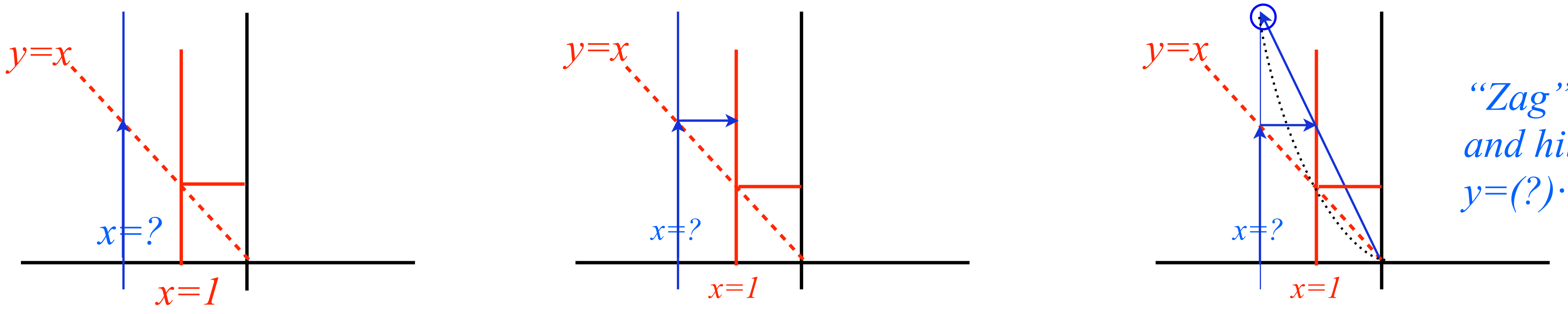

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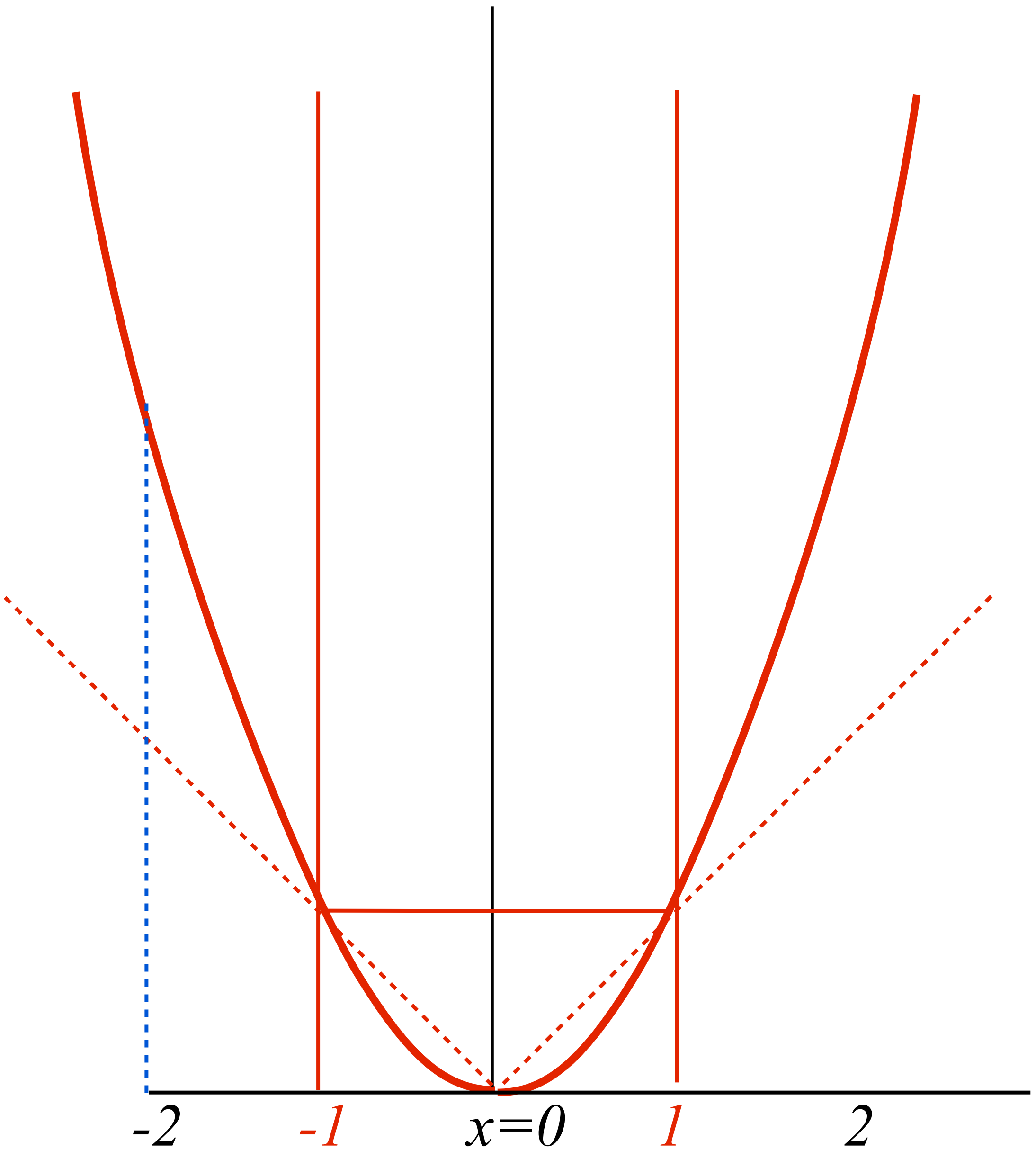

Unit 1
Fig. 9.1

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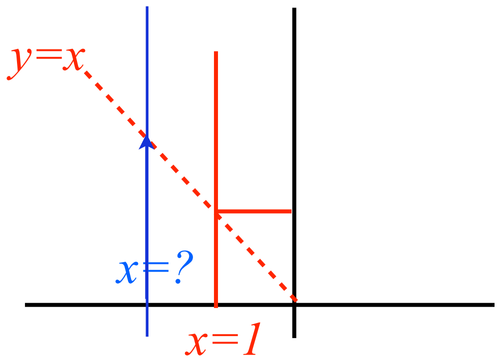
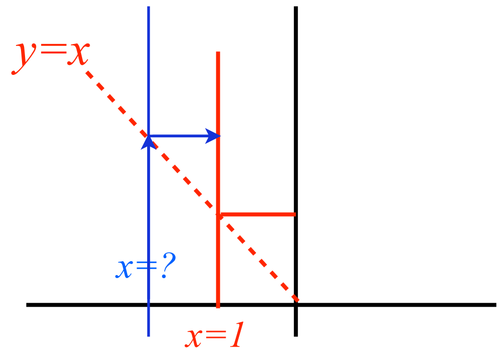


2. "Zig" from its y=x intersection to x=1 line



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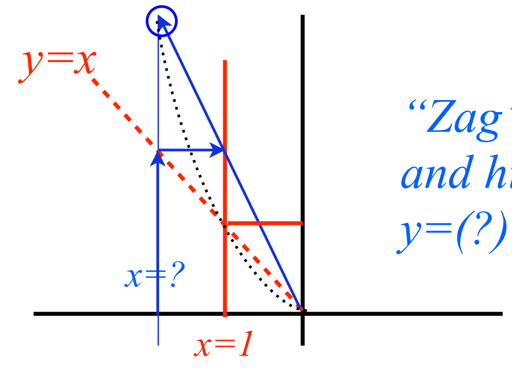
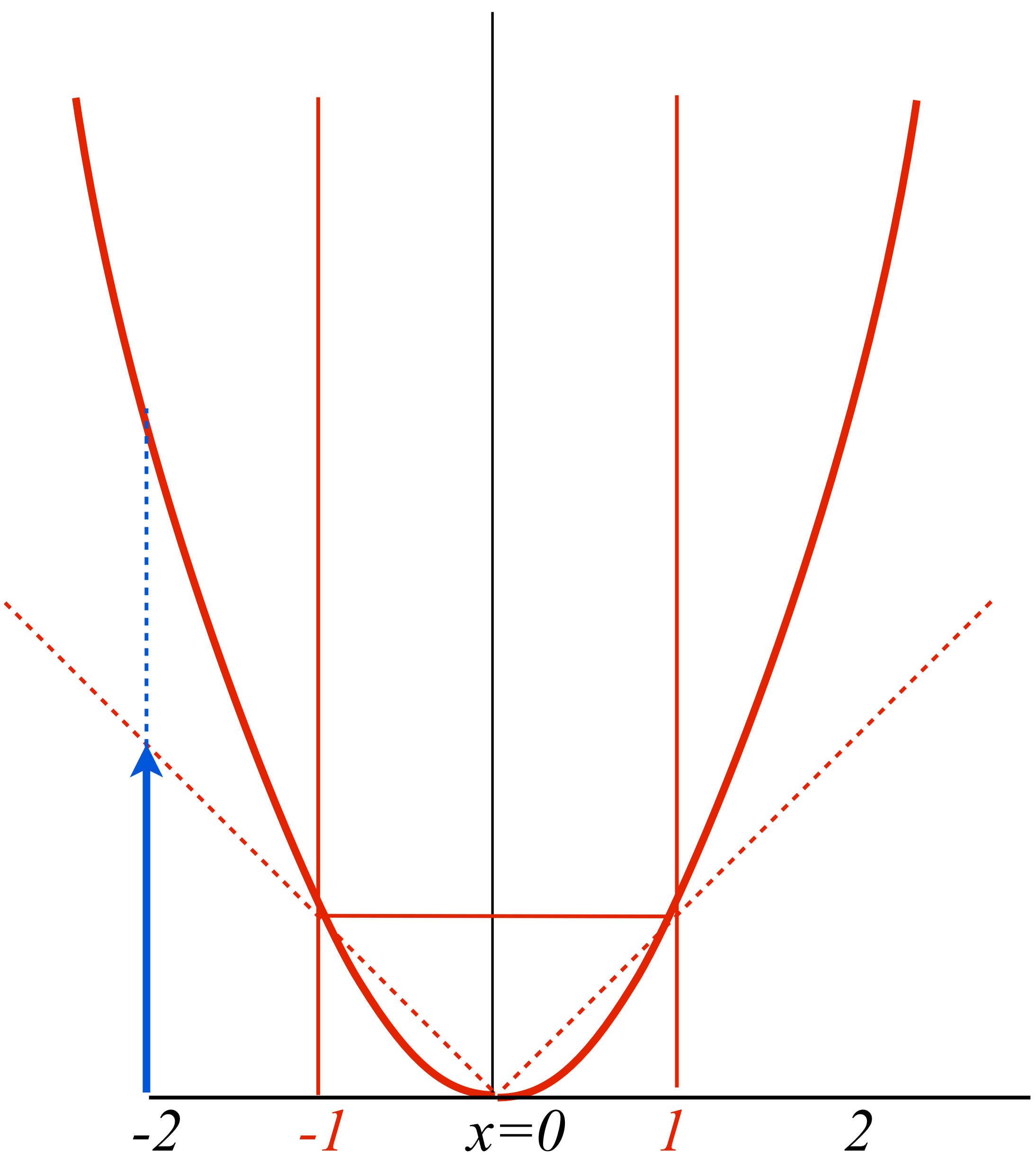


"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



Unit 1
Fig. 9.1

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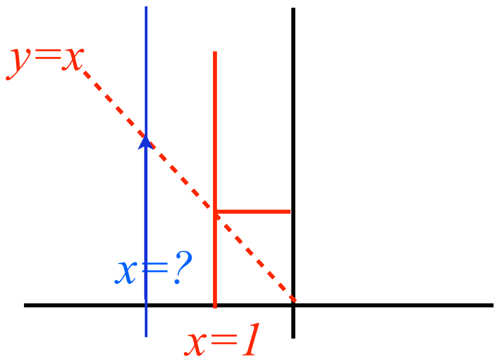

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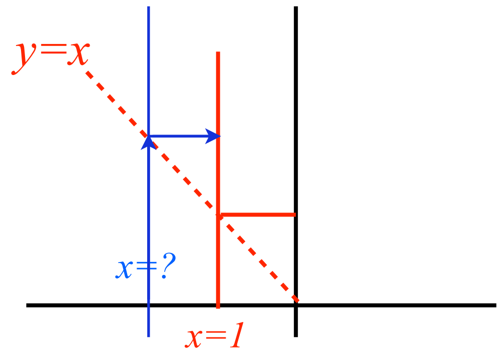

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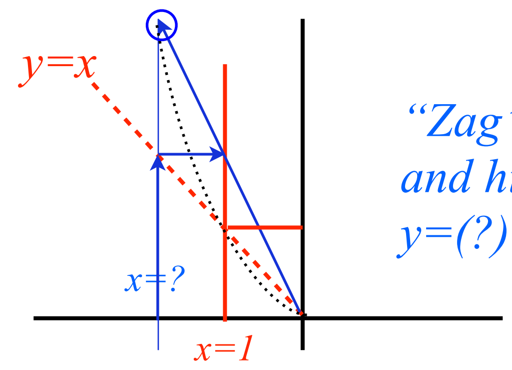

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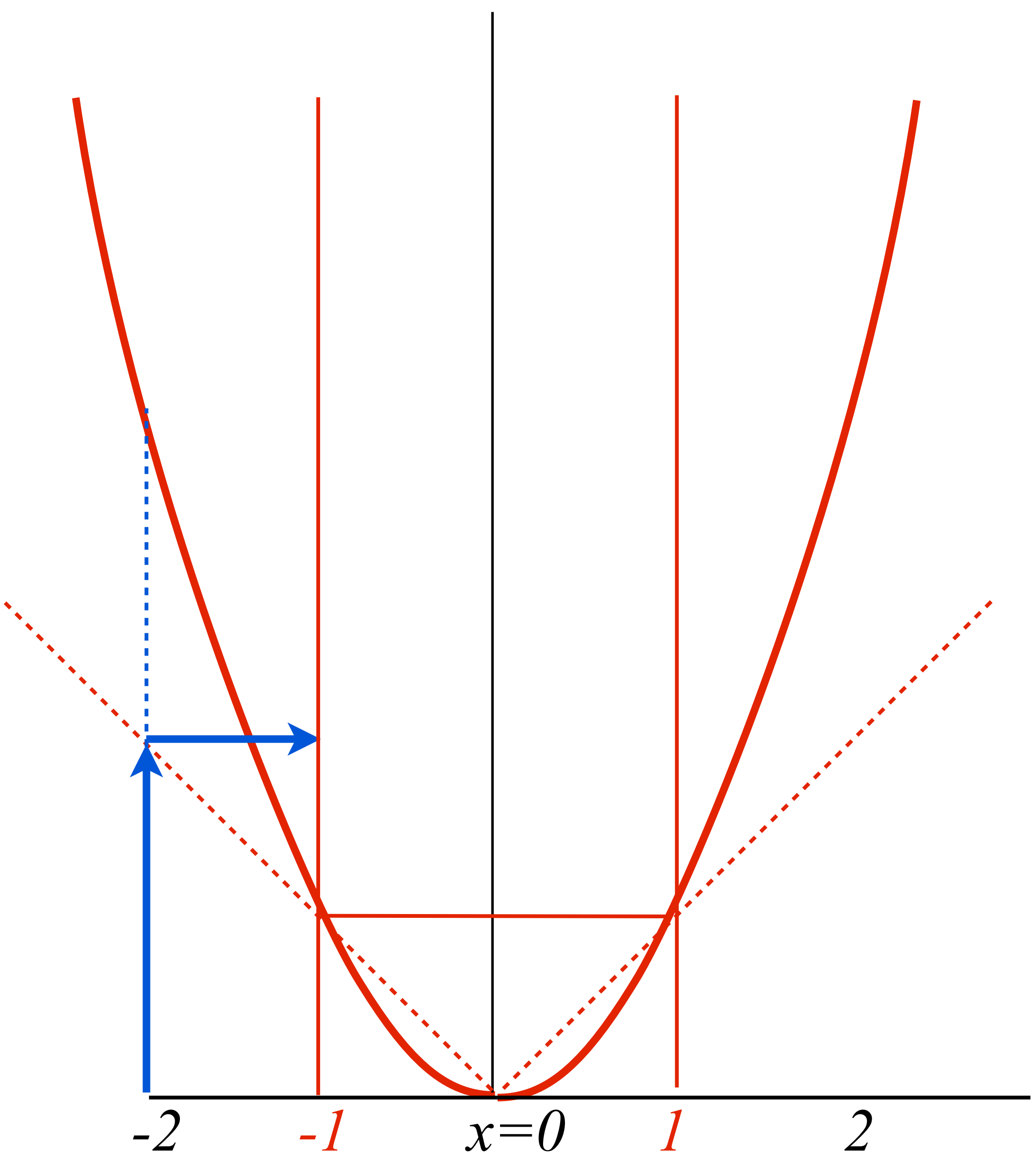

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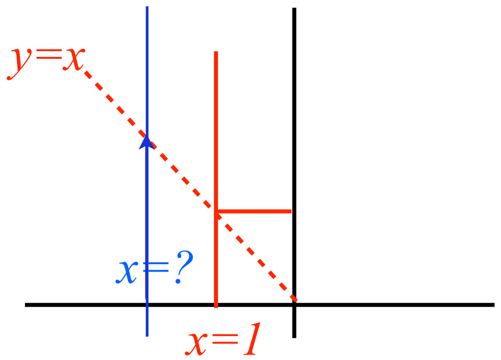

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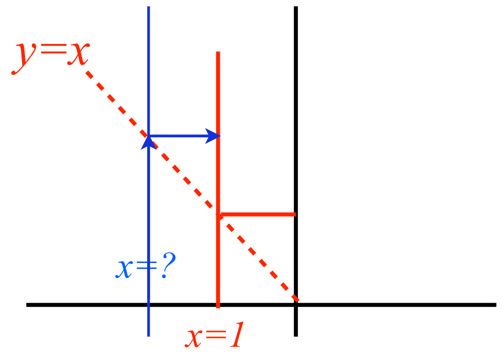
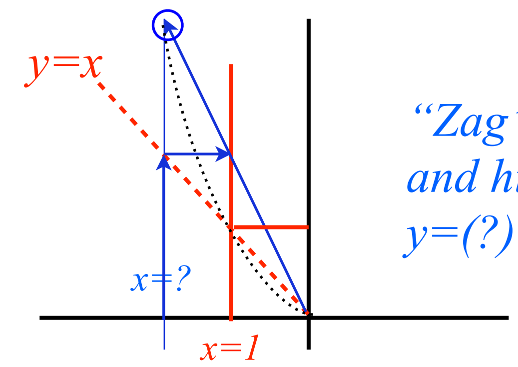
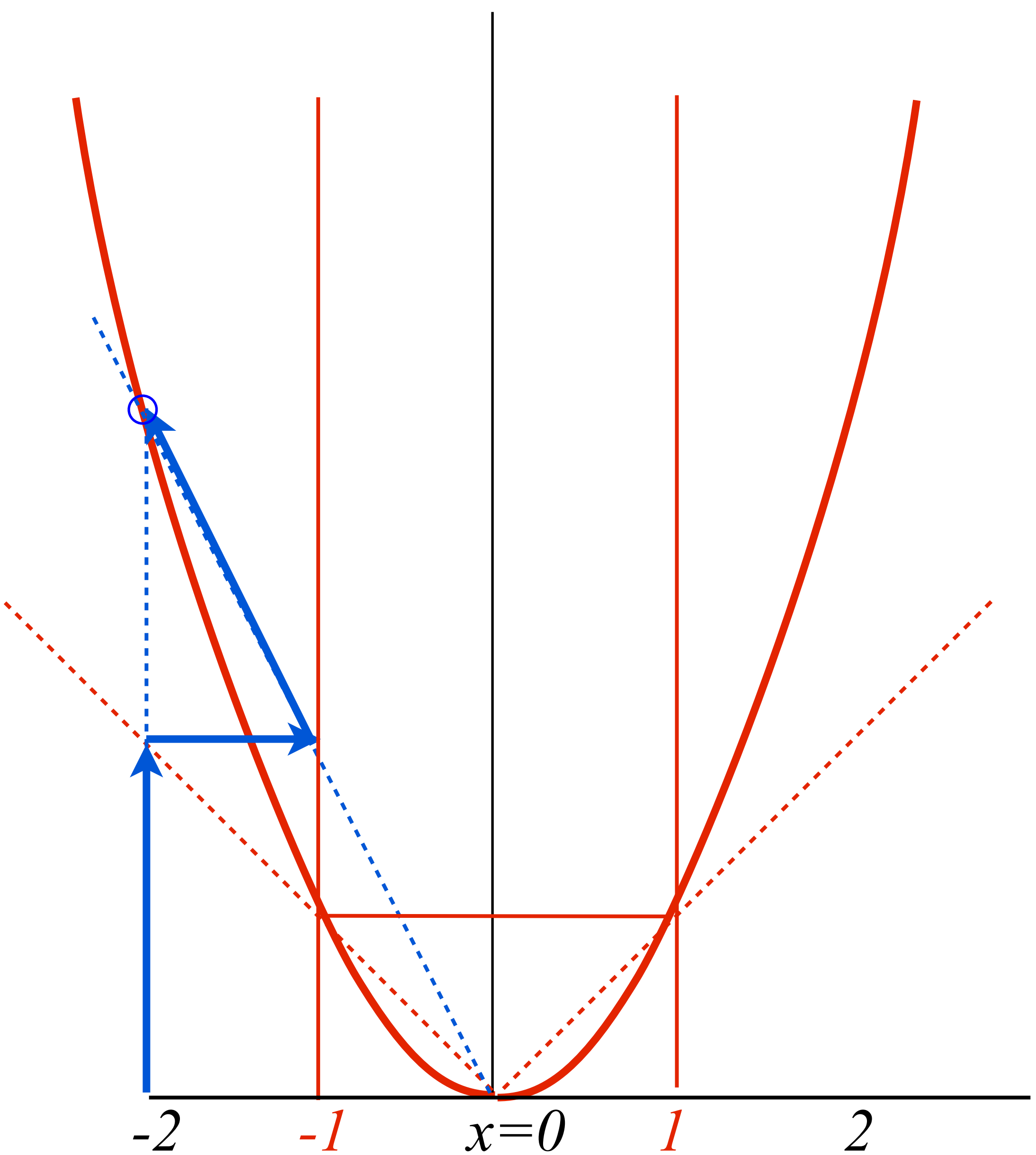


3. "Zag" from origin back to (x=?)-line



"Zag" line is y=(?)·x and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



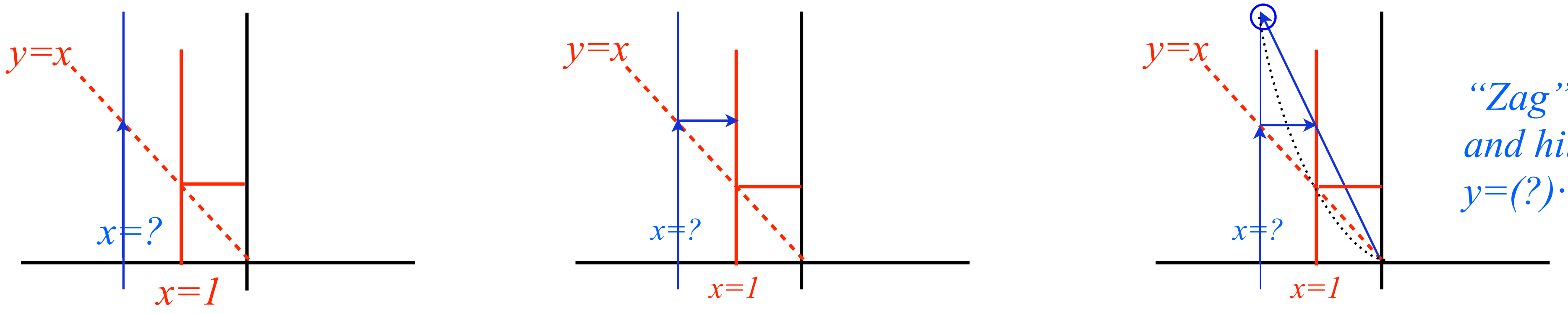
Unit 1
Fig. 9.1

Each $y=x^2$ parabola point found by just one "Zig-Zag"

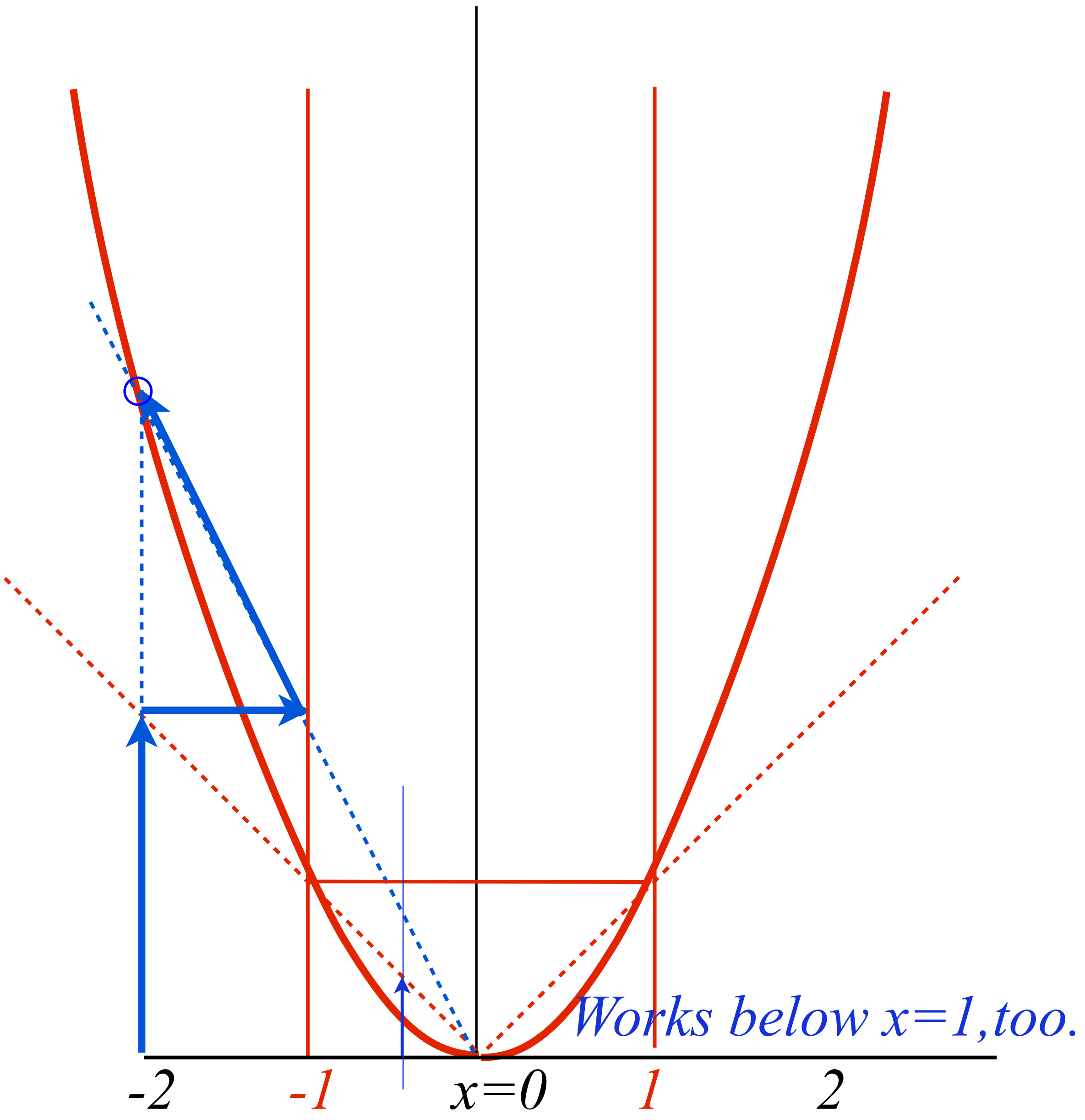
1. Pick an (x=?)-line

2. "Zig" from its y=x intersection to x=1 line

3. "Zag" from origin back to (x=?)-line

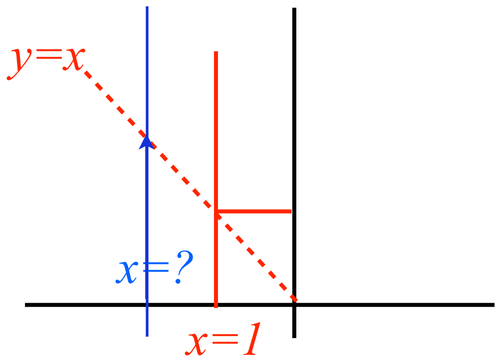


"Zag" line is y=(?)·x and hits (x=?)-line at y=(?)·(?)=(?)²

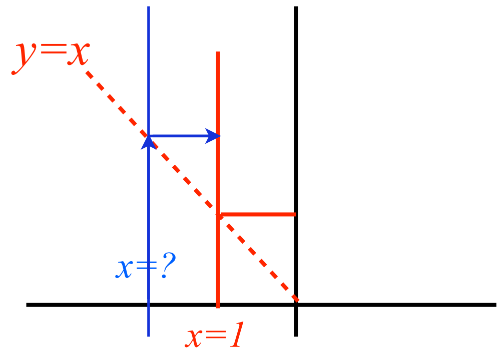


Each $y=x^2$ parabola point found by just one "Zig-Zag"

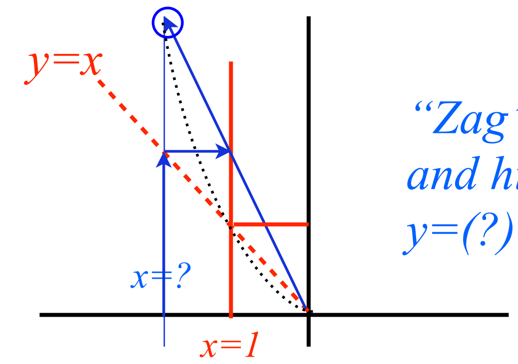
1. Pick an (x=?)-line



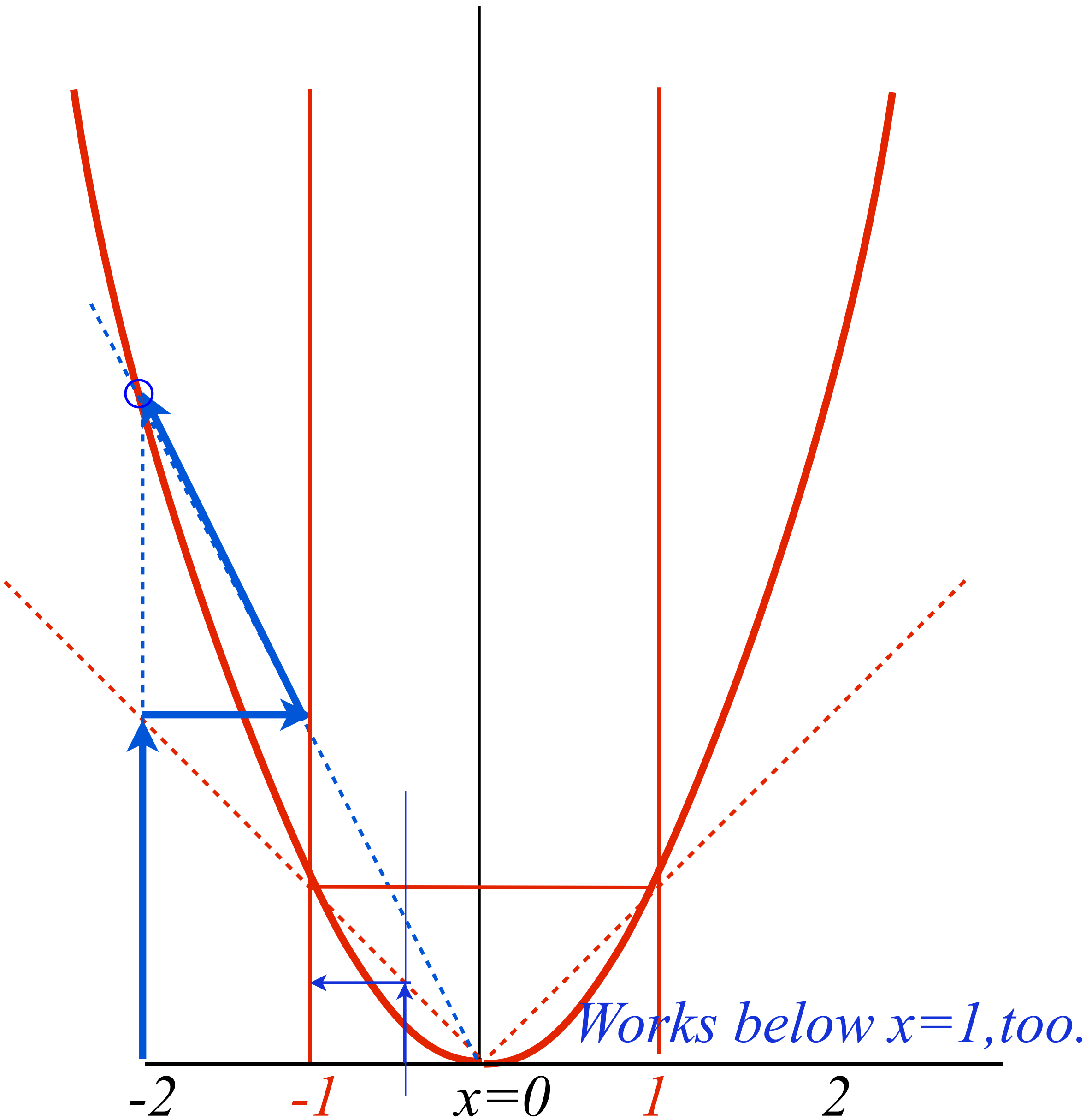
2. "Zig" from its y=x intersection to x=1 line



3. "Zag" from origin back to (x=?)-line

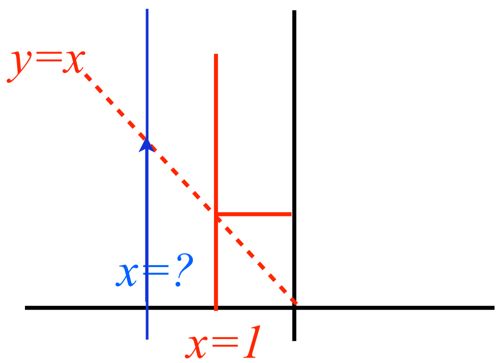


"Zag" line is y=(?)·x and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$

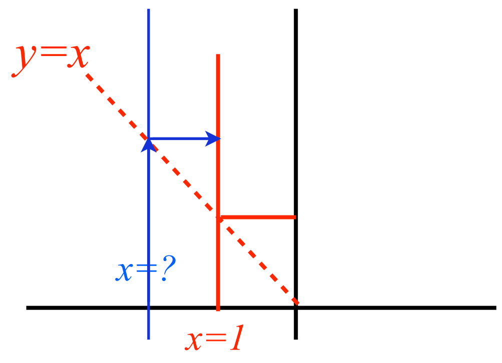


Each $y=x^2$ parabola point found by just one "Zig-Zag"

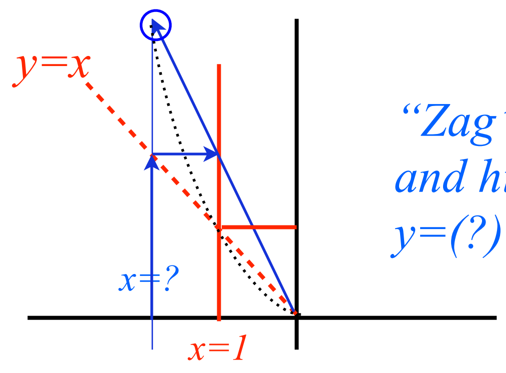
1. Pick an (x=?)-line



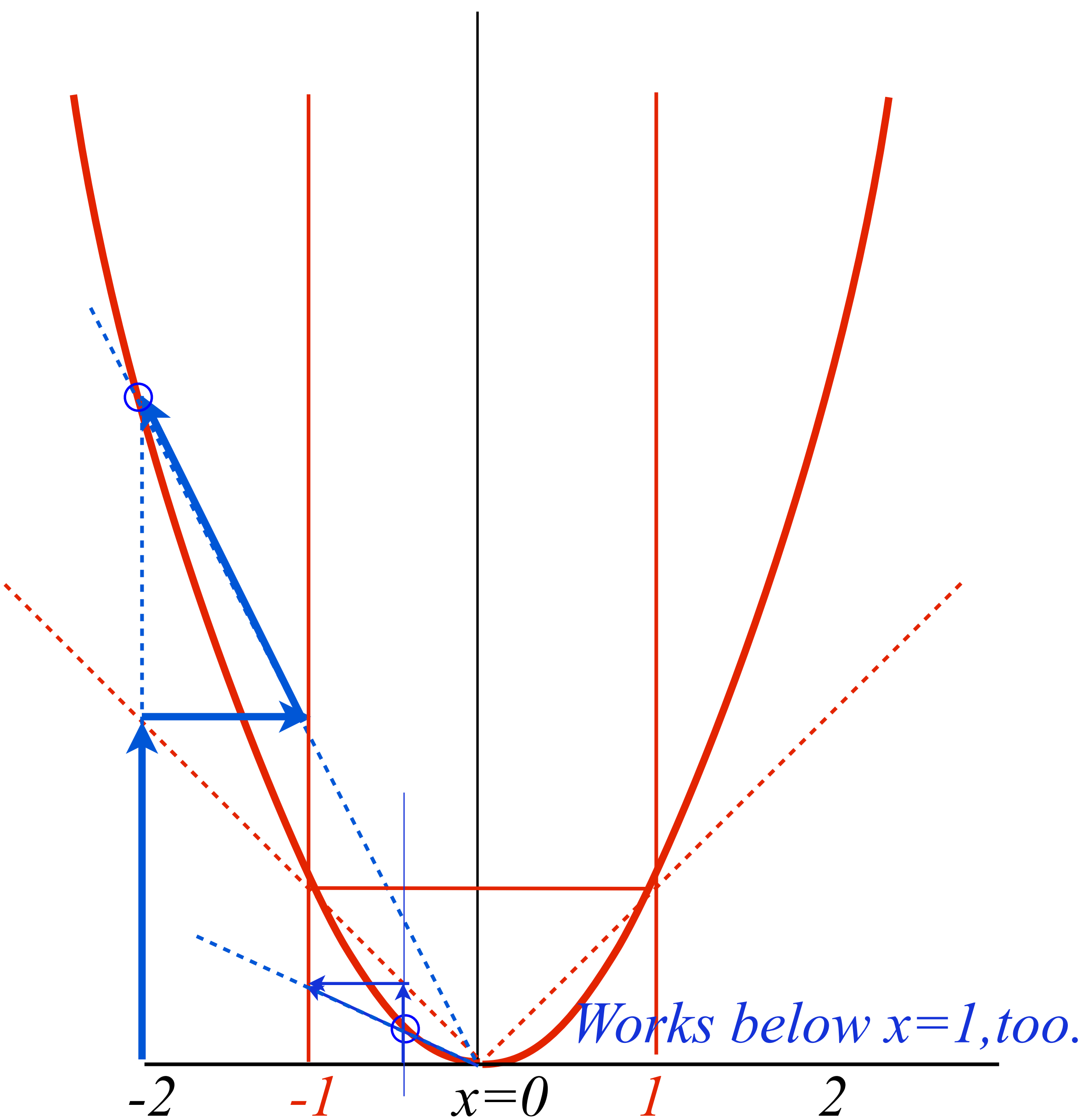
2. "Zig" from its y=x intersection to x=1 line



3. "Zag" from origin back to (x=?)-line



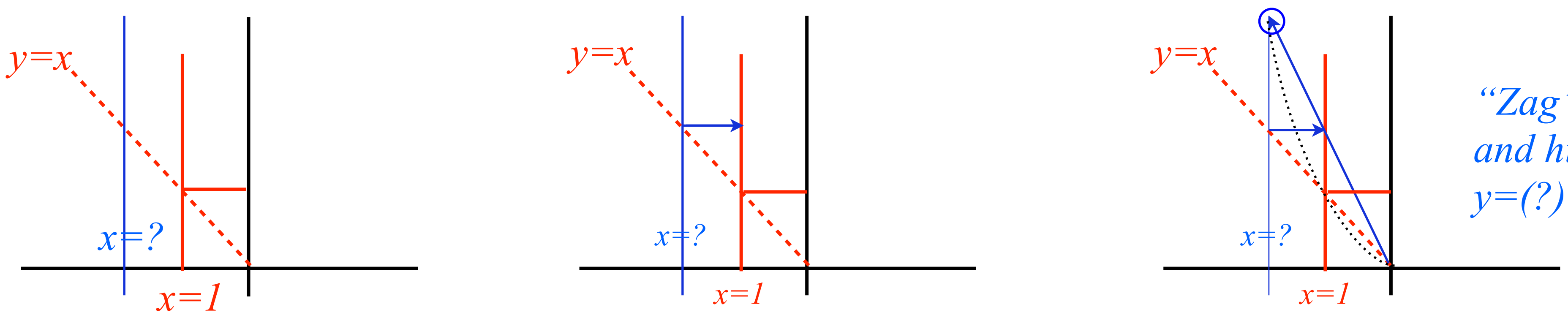
"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



Unit 1
Fig. 9.1

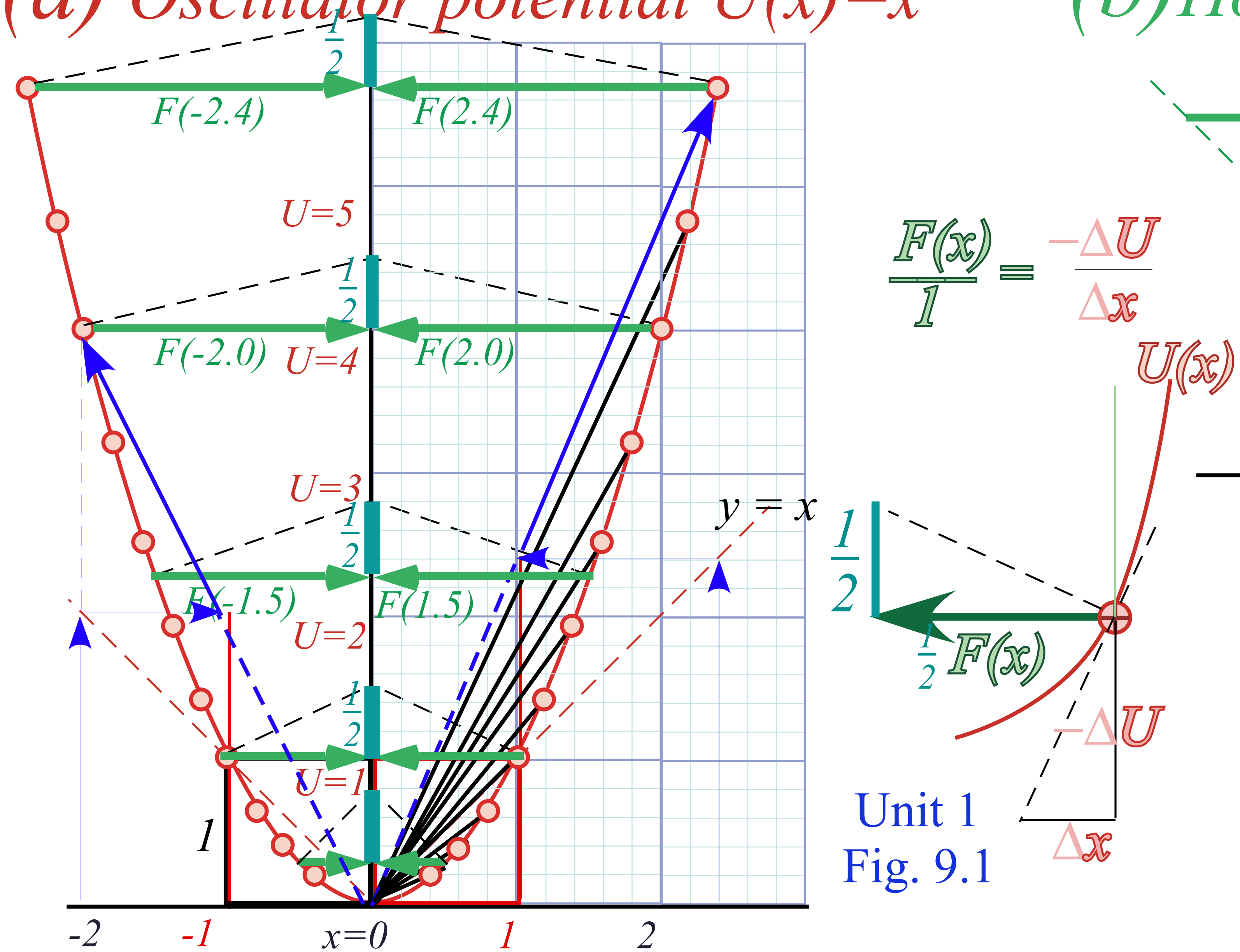
Each $y=x^2$ parabola point found by just one "Zig-Zag"

1. Pick an $(x=?)$-line
2. "Zig" from its $y=x$ intersection to $x=1$ line
3. "Zag" from origin back to $(x=?)$-line

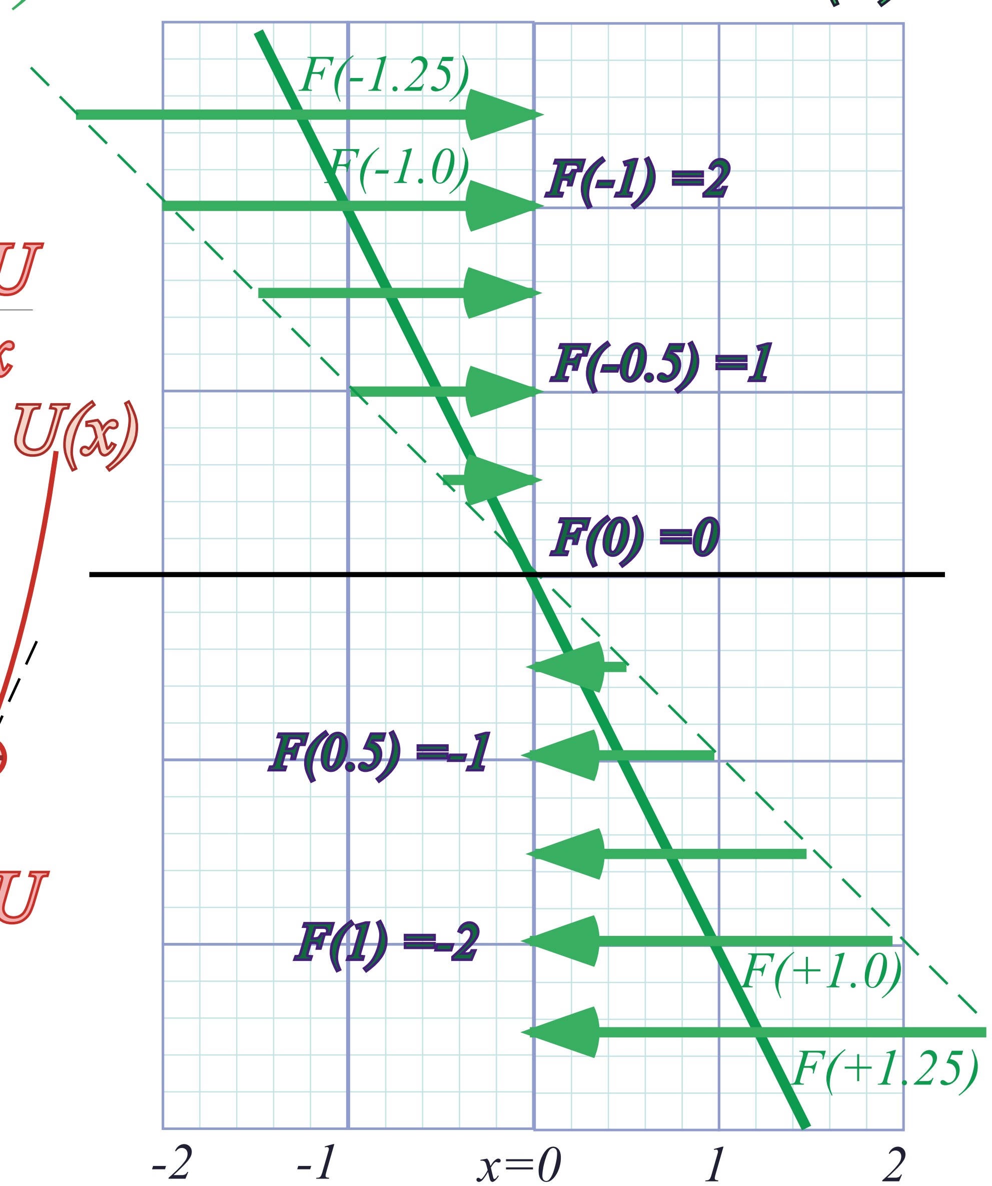


"Zag" line is $y=(?)\cdot x$ and hits $(x=?)$-line at $y=(?)\cdot(?)=(?)^2$

(a) Oscillator potential $U(x)=x^2$

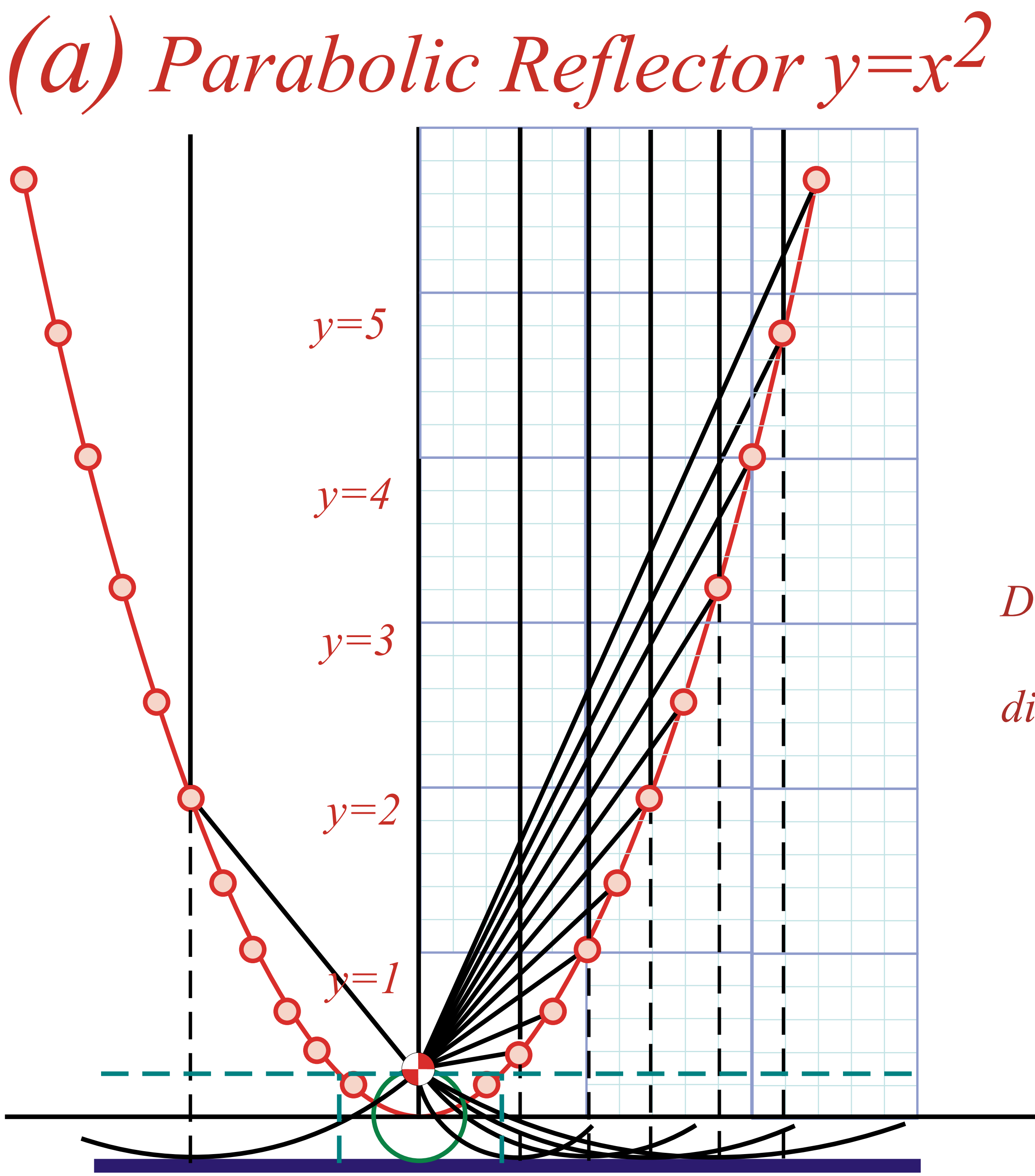


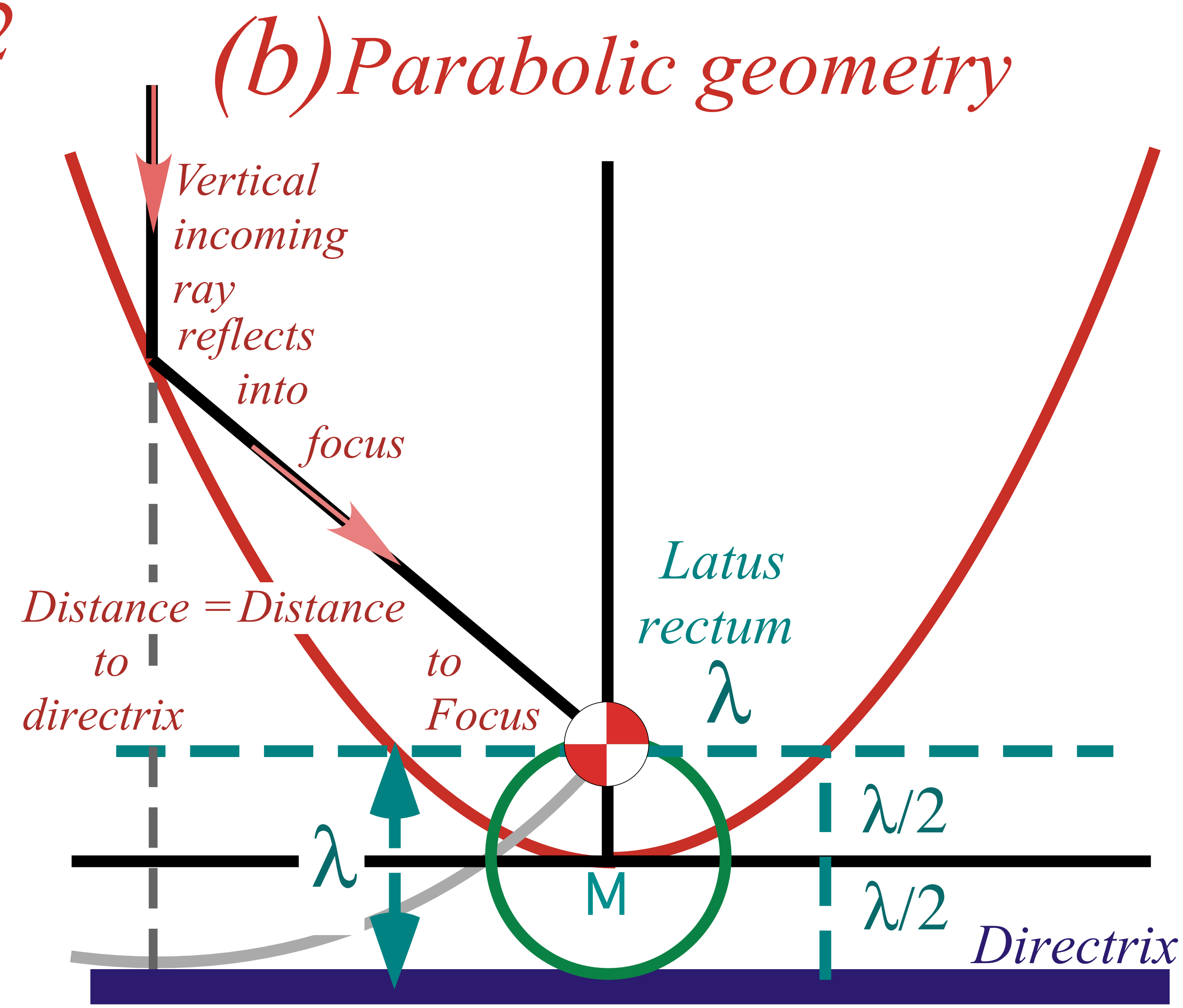
(b) Hooke-Law Force $F(x)=-2x$



Unit 1
Fig. 9.1

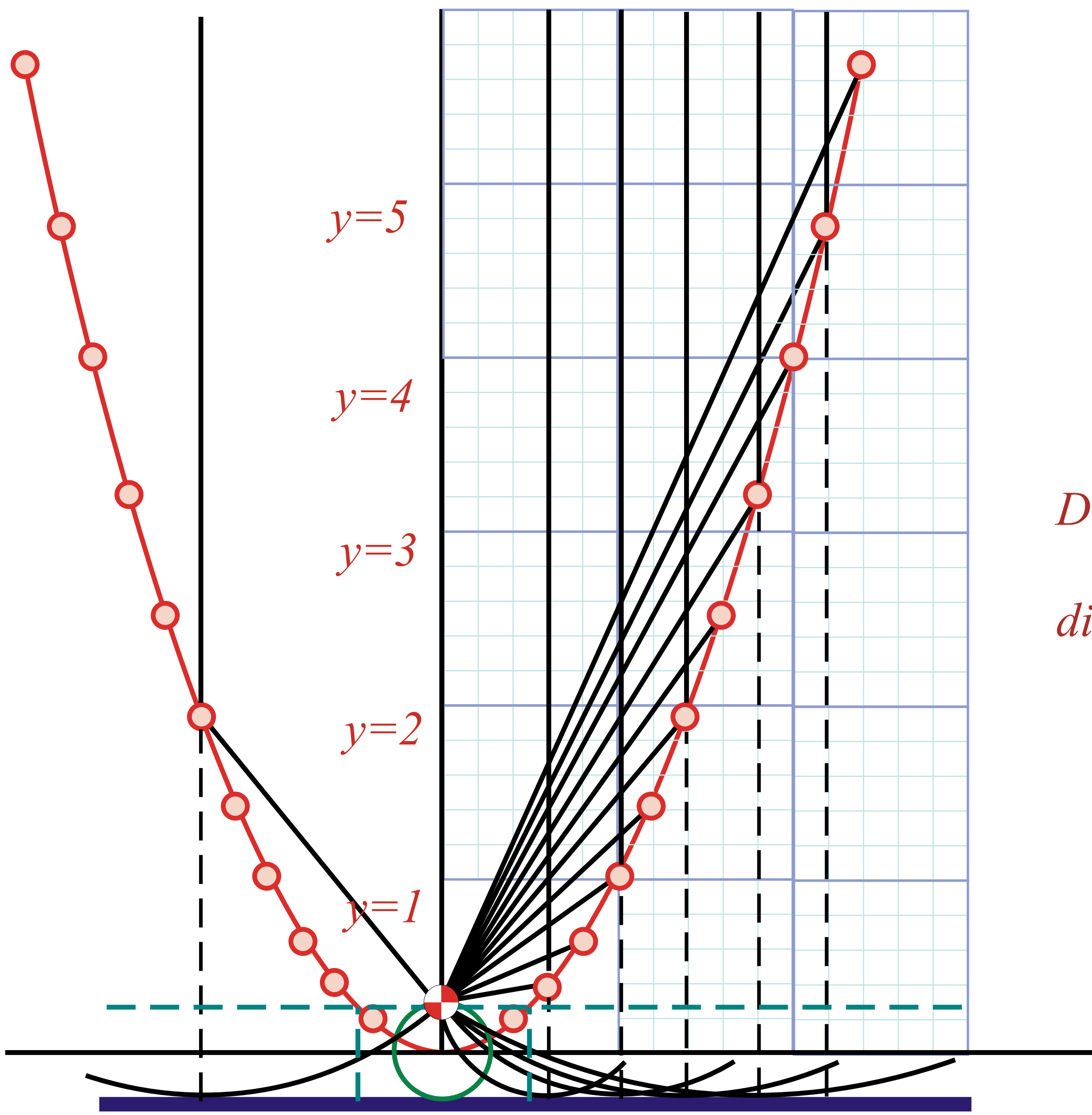
A more conventional parabolic geometry…(uses focal point)

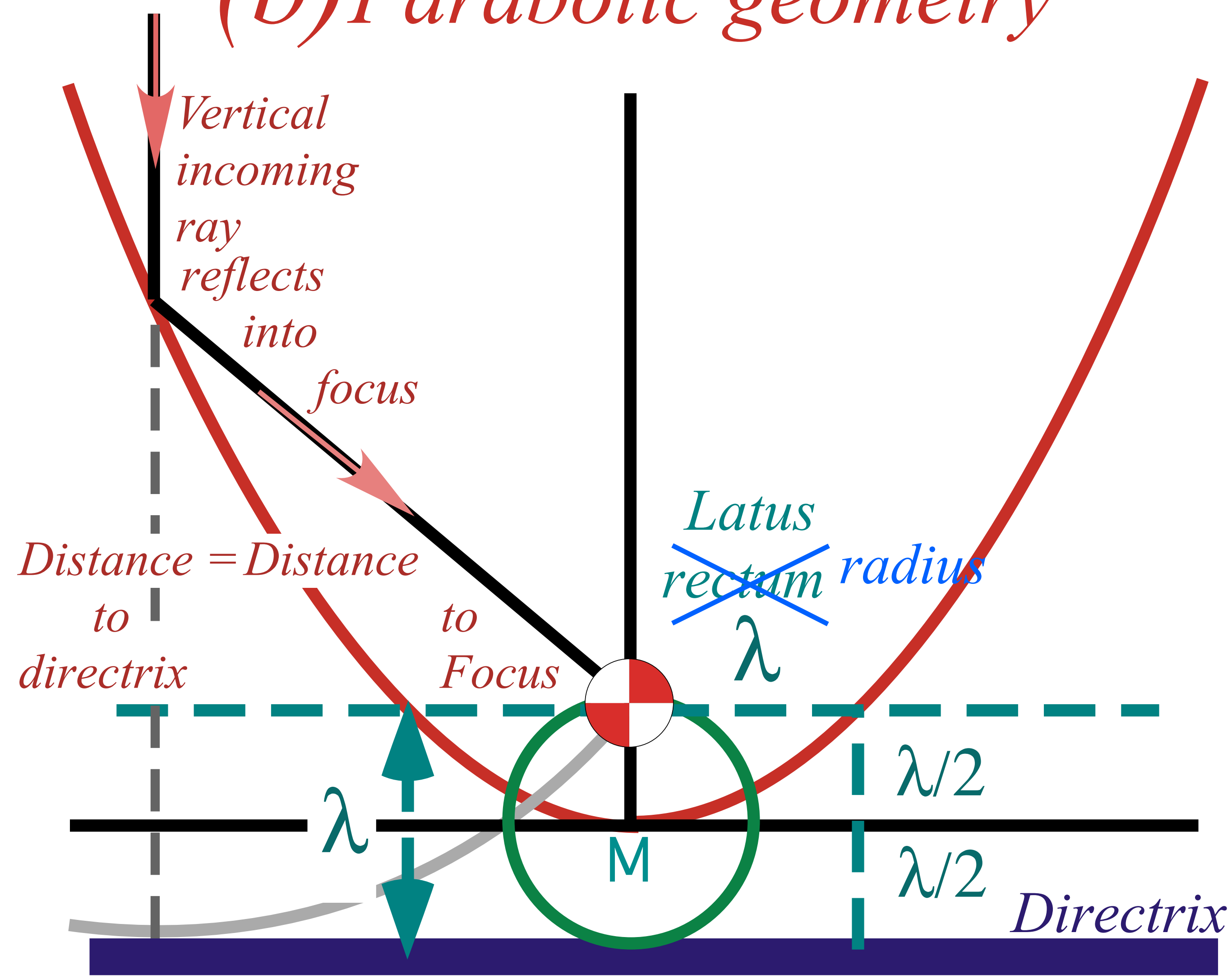




Unit 1
Fig. 9.3

A more conventional parabolic geometry...



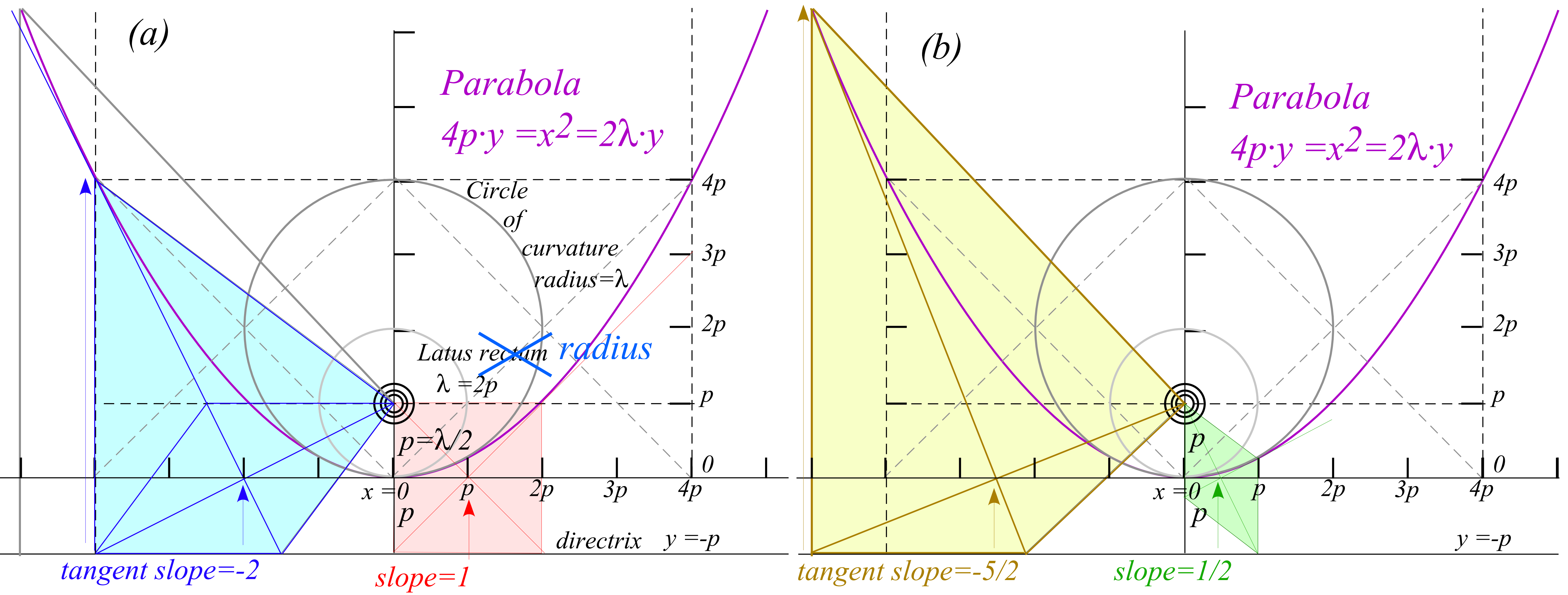


Better name† for λ : *latus radius*

†Old term *latus rectum* is exclusive copyright of
X-Treme Roidrage Gyms
Venice Beach, CA 90017

Unit 1
Fig. 9.3

...conventional parabolic geometry...carried to extremes...



Unit 1
Fig. 9.4

Geometry of common power-law potentials

Geometric (Power) series

"Zig-Zag" exponential geometry

Projective or perspective geometry

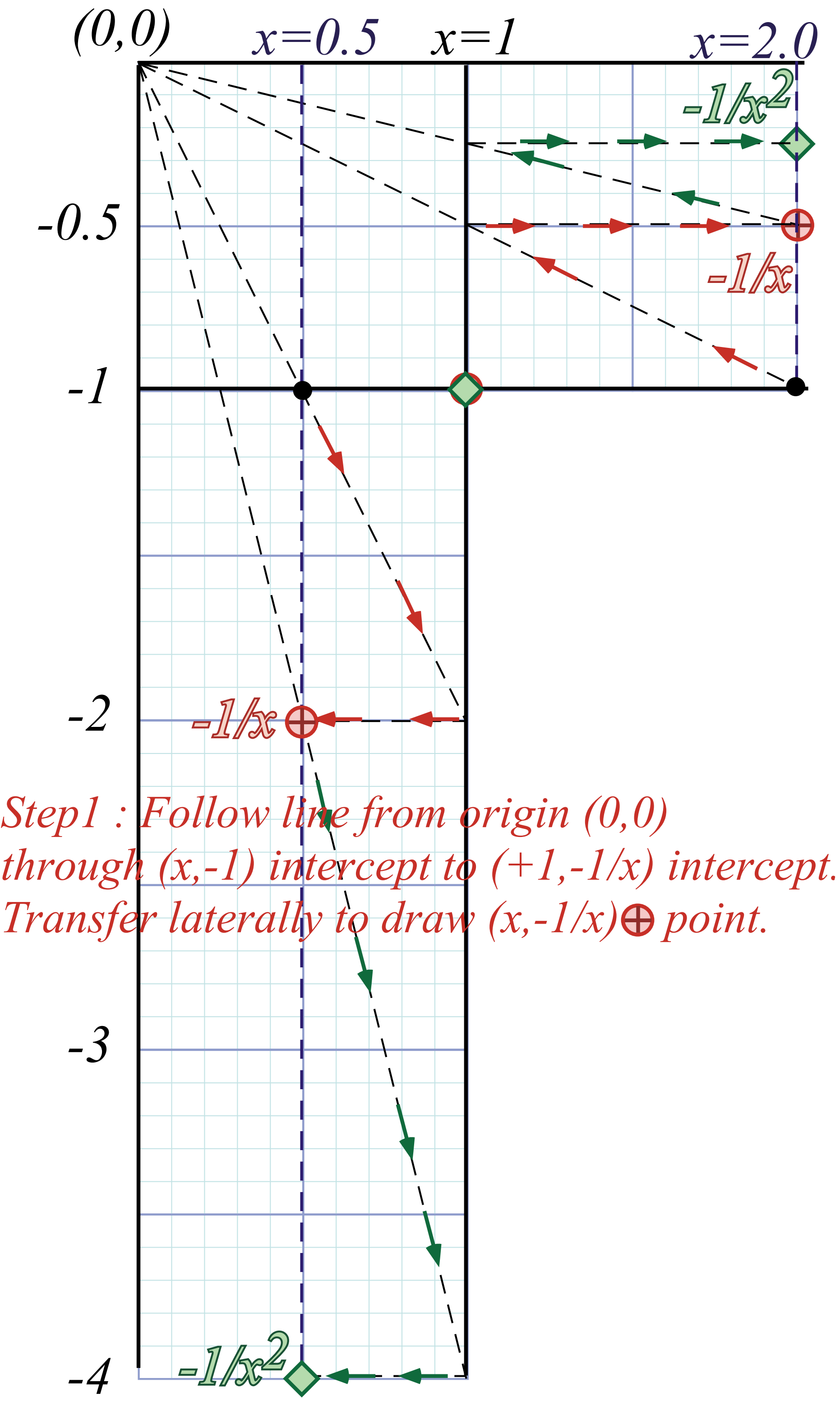
Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

→ *Coulomb geometry of $-1/r$-potential and $-1/r^2$-force fields*

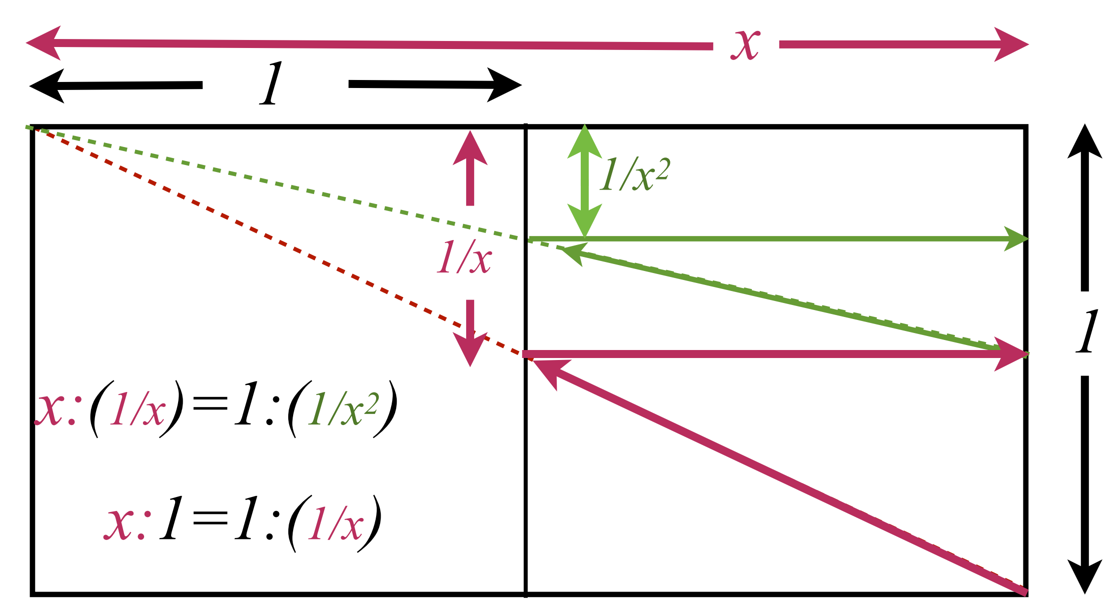
Compare mks units of Coulomb Electrostatic vs. Gravity

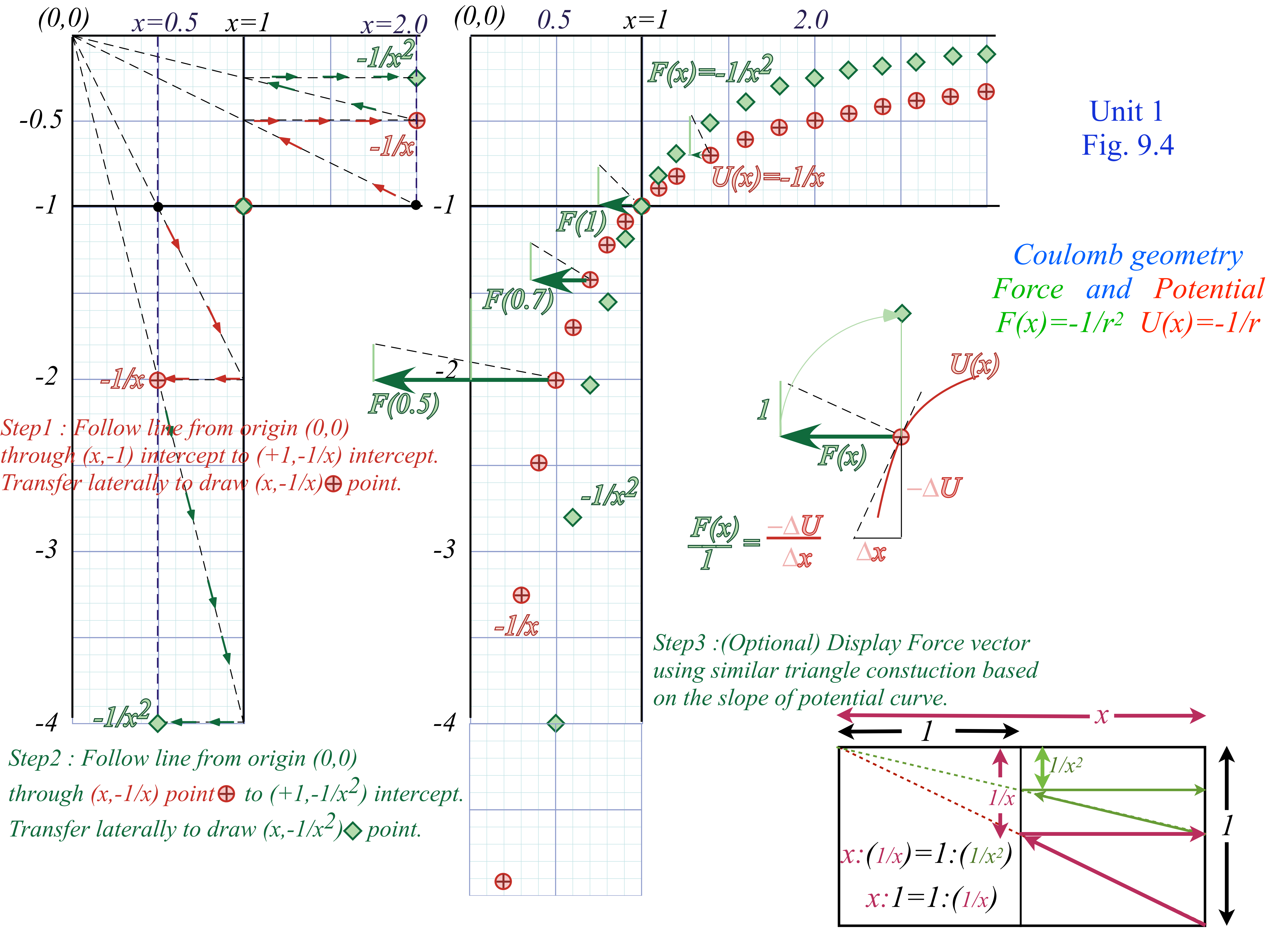
Unit 1
Fig. 9.4

Coulomb geometry
Force and Potential
$F(x)=-1/r^2$ $U(x)=-1/r$



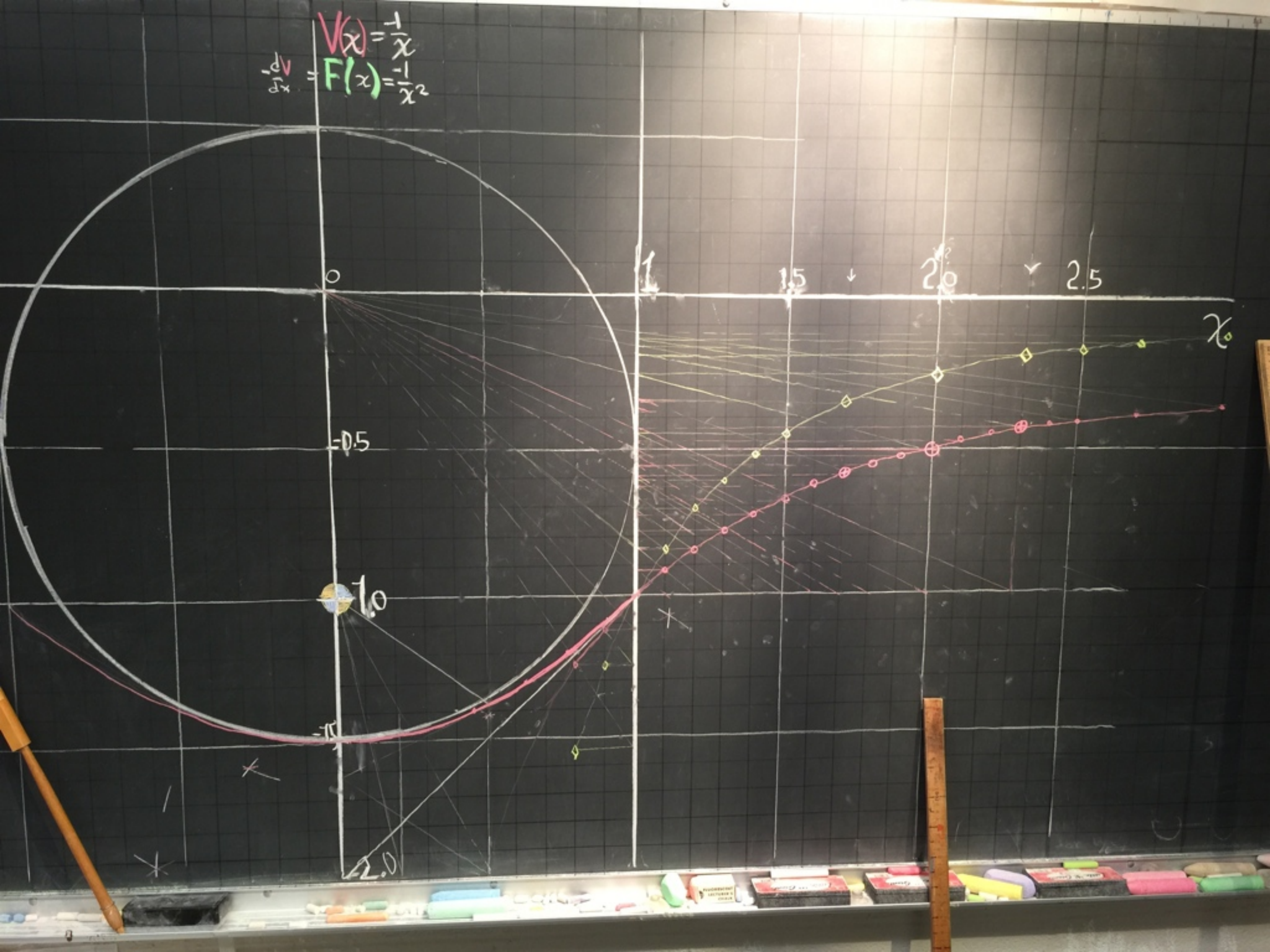
Step2 : Follow line from origin (0,0) through (x,-1/x) point⊕ to (+1,-1/x²) intercept. Transfer laterally to draw (x,-1/x²)◇ point.





(0,0)
x=0.5
x=1
x=2.0
-1/x²
-1/x
-0.5
-1
-2
-3
-4
-1/x
-1/x²
(0,0)
0.5
x=1
2.0
F(x)=-1/x²
U(x)=-1/x
F(1)
F(0.7)
F(0.5)
-1/x²
-1/x
Coulomb geometry
Force and Potential
F(x)=-1/r² U(x)=-1/r
U(x)
1
F(x)
−ΔU
F(x)/1 = −ΔU/Δx
Δx
Step1 : Follow line from origin (0,0) through (x,-1) intercept to (+1,-1/x) intercept. Transfer laterally to draw (x,-1/x)⊕ point.
Step2 : Follow line from origin (0,0) through (x,-1/x) point⊕ to (+1,-1/x²) intercept. Transfer laterally to draw (x,-1/x²)◇ point.
Step3 :(Optional) Display Force vector using similar triangle constuction based on the slope of potential curve.
x
1
1/x²
1/x
1
x:(1/x)=1:(1/x²)
x:1=1:(1/x)

Unit 1
Fig. 9.4



$V(x) = \frac{-1}{x}$
$-\frac{dV}{dx} = F(x) = \frac{-1}{x^2}$
0
1
1.5
2.0
2.5
x
-0.5
-1.0
-1.5
-2.0

Geometry of common power-law potentials

Geometric (Power) series

"Zig-Zag" exponential geometry

Projective or perspective geometry

Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

Coulomb geometry of $-1/r$-potential and $-1/r^2$-force fields

→ *Compare mks units of Coulomb Electrostatic vs. Gravity*

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong \boxed{?.?\cdot 10^{?}} \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)   !!!!

~9E9~10^10

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.) !!!!

$\sim 9E9 \sim 10^{10}$

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2$ $\sim 9 \cdot 10^9 \sim 10^{10}$

quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ Coulomb

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

...but 1 Ampere = 1 Coulomb/sec.

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)   !!!!

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

~9E9~10^{10}

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2$ ~$9\cdot10^9$~10^{10}

quantum of charge: $|e| = 1.6022\cdot10^{-19}$ Coulomb

↑
Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

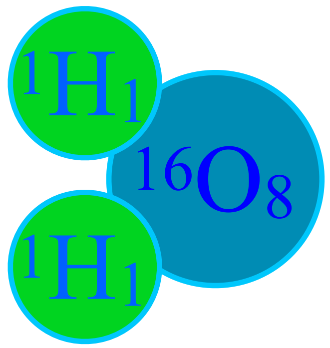
...but 1 Ampere = 1 Coulomb/sec.

"Fingertip Physics" of Ch. 8 notes that 1 $(cm)^3$ =1gm of water (1/18 Mole) has (1/18) $6\cdot10^{23}$ molecules

Avogodro's Number

~$0.3\cdot10^{23}$

H_2O Molecular weight~18



Compare mks units for Coulomb fields
1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2 \sim 9 \cdot 10^9 \sim 10^{10}$

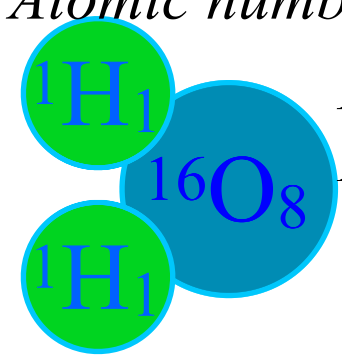
quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ *Coulomb*

↑
Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

...but 1 Ampere = 1 Coulomb/sec.

"Fingertip Physics" of Ch. 9 notes that 1 $(cm)^3$ *=1gm of water (1/18 Mole) has (1/18)* $6 \cdot 10^{23}$ *molecules or ~* $3 \cdot 10^{23}$ *electrons*
$\sim 0.3 \cdot 10^{23}$ *and ~* $3 \cdot 10^{23}$ *protrons.*

H_2O *Molecular weight~18*
Atomic number = 10



10 electrons
10 protons

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2 \sim 9 \cdot 10^9 \sim 10^{10}$

quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ Coulomb

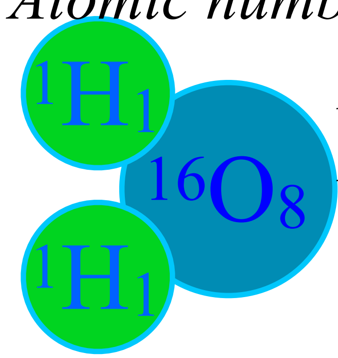
↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

...but 1 Ampere = 1 Coulomb/sec.

"Fingertip Physics" of Ch. 9 notes that 1 $(cm)^3$ =1gm of water (1/18 Mole) has (1/18) $6 \cdot 10^{23}$ molecules or ~ $3 \cdot 10^{23}$ electrons
~$0.3 \cdot 10^{23}$ and ~ $3 \cdot 10^{23}$ protrons.

H_2O Molecular weight~18
Atomic number = 10



10 electrons *That is ~ $-3 \cdot 10^{23} \, 1.6022 \cdot 10^{-19}$ Coulomb or about $-0.5 \cdot 10^{+5}$ C or − 50,000 Coulomb*

10 protons *plus ~ $+3 \cdot 10^{23} \, 1.6022 \cdot 10^{-19}$ Coulomb or about $+0.5 \cdot 10^{+5}$ C or +50,000 Coulomb*

Equals zero total charge

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)   !!!!

~9E9~10^{10}

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2$ ~$9\cdot10^9$~10^{10}

quantum of charge: $|e| = 1.6022\cdot10^{-19}$ Coulomb

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)
vs
Always Attractive (so far)

↓

↕ COMPARE! ↕

BIG
vs
small

2. Gravitational force between m(kilograms) and M(kg.)

$$F^{grav.}(r) = -G\frac{mM}{r^2} \quad where: G = \boxed{?.?\cdot10^{?}} \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.) !!!!

~9E9~10^{10}

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9,000,000,000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for electrostatic constant : $1/4\pi\varepsilon_0 = 8.987,551 \cdot 10^9 Nm^2/C^2$ ~$9\cdot 10^9$~10^{10}

quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ Coulomb

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)
vs
Always Attractive (so far)

↓

↕ COMPARE! ↕

BIG
vs
small

2. Gravitational force between m(kilograms) and M(kg.) !!!!

~ $^2/_3 10^{-10}$~10^{-10}

$$F^{grav.}(r) = -G\frac{mM}{r^2} \quad where: G = 0.000,000,000,067 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

More precise value for gravitational constant : $G = 6.67384(80) \cdot 10^{-11} Nm^2/C^2$ ~$(2/3)10^{-10}$

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

quantum of charge: $|e|=1.6022\cdot 10^{-19}$ Coulomb

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

Discussion of repulsive force and PE in Ch. 9...

1(a). Electrostatic potential energy between q(Coulombs) and Q(C.)

~9E9~10^{10} !!!!

$$U(r) = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Joule}{per\ square\ Coulomb}$$

Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

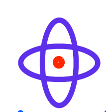
quantum of charge: $|e|=1.6022\cdot10^{-19}$ Coulomb

Discussion of repulsive force and PE in Ch. 9...

1(a). Electrostatic potential energy between q(Coulombs) and Q(C.)

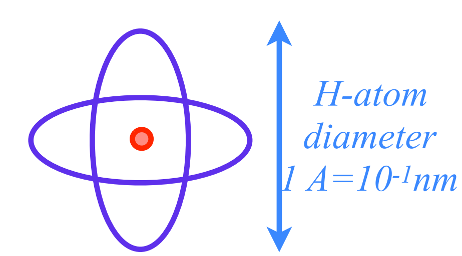
~9E9~10^{10} *!!!!*

$$U(r) = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Joule}{per\ square\ Coulomb}$$



Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

Atomic size ~ 1 Angstrom = 10^{-10} m



Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm\frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000\,\frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

↑

Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

quantum of charge: $|e|=1.6022\cdot 10^{-19}$ Coulomb

Discussion of repulsive force and PE in Ch. 9...

1(a). Electrostatic potential energy between q(Coulombs) and Q(C.)

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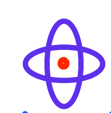
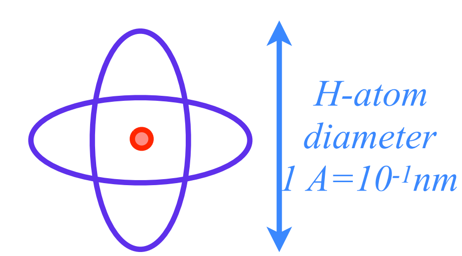


Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

Atomic size ~ 1 Angstrom = 10^{-10} m

Big molecule ~ 10 Angstrom = 10^{-9} m = 1nanometer=1nm



Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

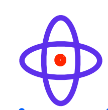
quantum of charge: |e|=1.6022·10^-19 Coulomb ($|e| = 1.6022 \cdot 10^{-19}$ Coulomb)

↑
Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

Discussion of repulsive force and PE in Ch. 9...

1(a). Electrostatic potential energy between q(Coulombs) and Q(C.)

$$U(r) = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Joule}{per\ square\ Coulomb}$$

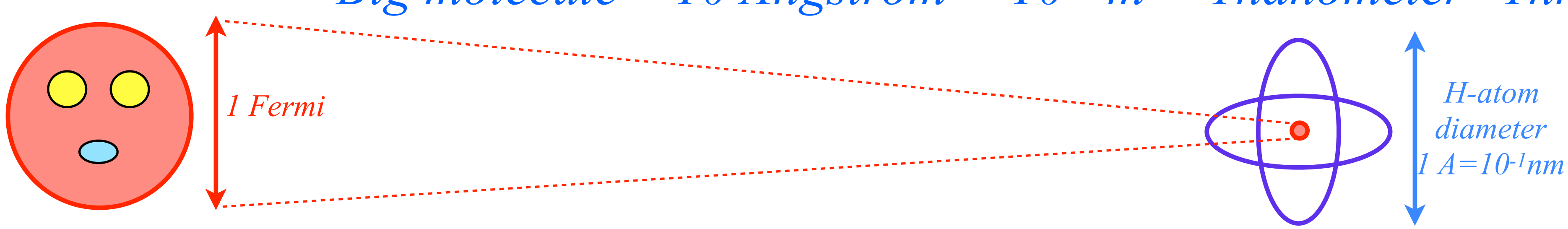


Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

Atomic size ~ 1 Angstrom = 10^{-10} m

Big molecule ~ 10 Angstrom = 10^{-9} m = 1nanometer=1nm

also: 1fm = 10^{-13} cm =1Fermi
=1Fm



Compare mks units for Coulomb fields

1. Electrostatic force between q(Coulombs) and Q(C.)

$$F^{elec.}(r) = \pm \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

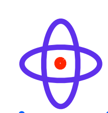
quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ Coulomb

↑
Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

Discussion of repulsive force and PE in Ch. 9...

1(a). Electrostatic potential energy between q(Coulombs) and Q(C.)

$$U(r) = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{r} \quad where: \frac{1}{4\pi\varepsilon_0} \cong 9{,}000{,}000{,}000 \frac{Joule}{per\ square\ Coulomb}$$



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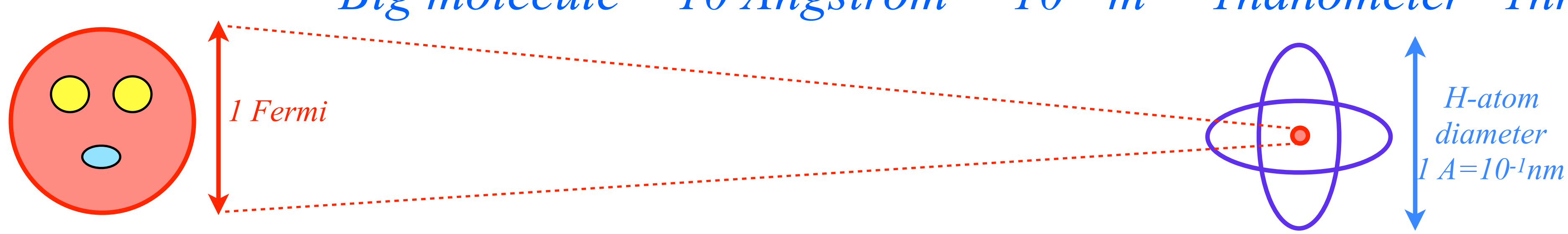


nuclear radii are 100,000 to 1,000,000 times smaller than atomic/chemical radii

...so nuclear qQ/r energy 100,000 to 1,000,000 times **larger** than that of atomic/chemical...

Geometry of idealized "Sophomore-physics Earth"

Coulomb field outside *Isotropic Harmonic Oscillator (IHO) field inside*

Contact-geometry of potential curve(s)

"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

Earth matter vs nuclear matter:

*Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

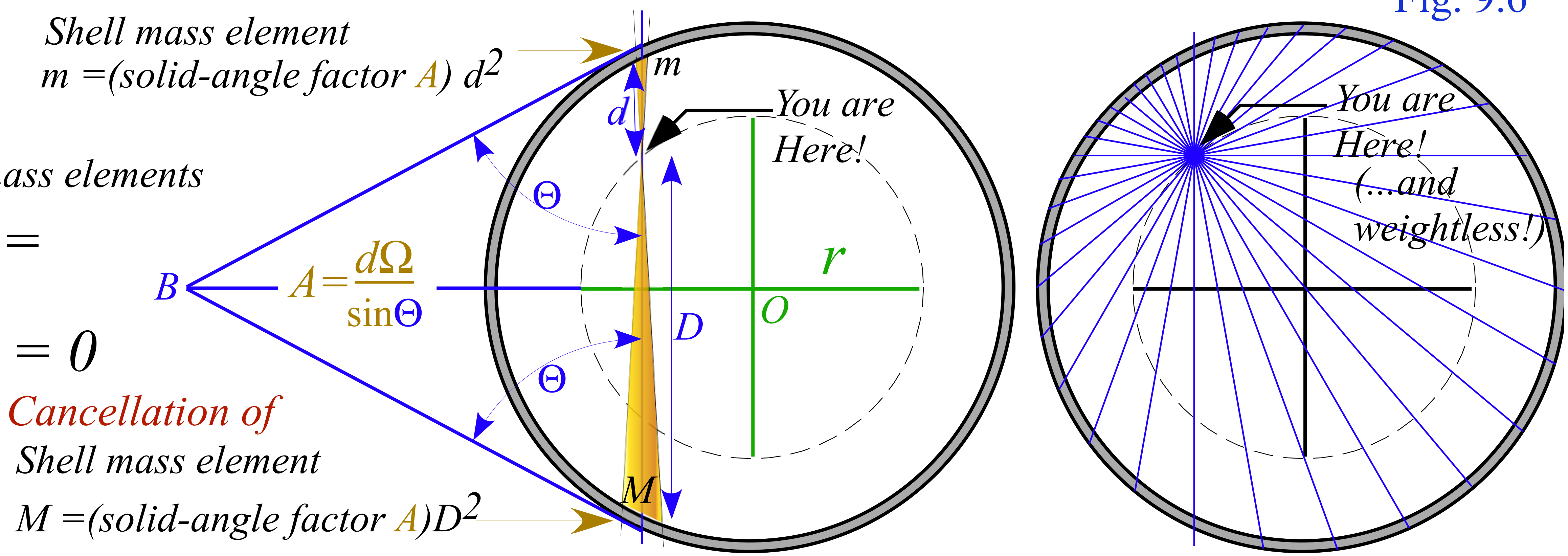
Coulomb force vanishes inside-spherical shell (Gauss-law)

Unit 1
Fig. 9.6

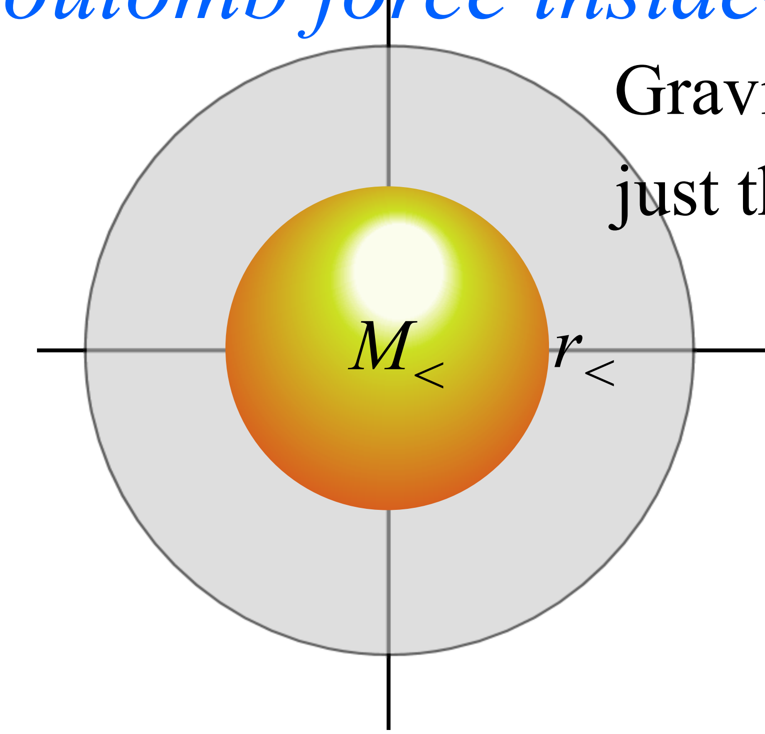
Gravity at r
due to shell mass elements

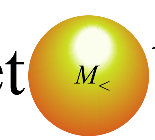
$$\frac{G\,M}{D^2} - \frac{G\,m}{d^2} =$$

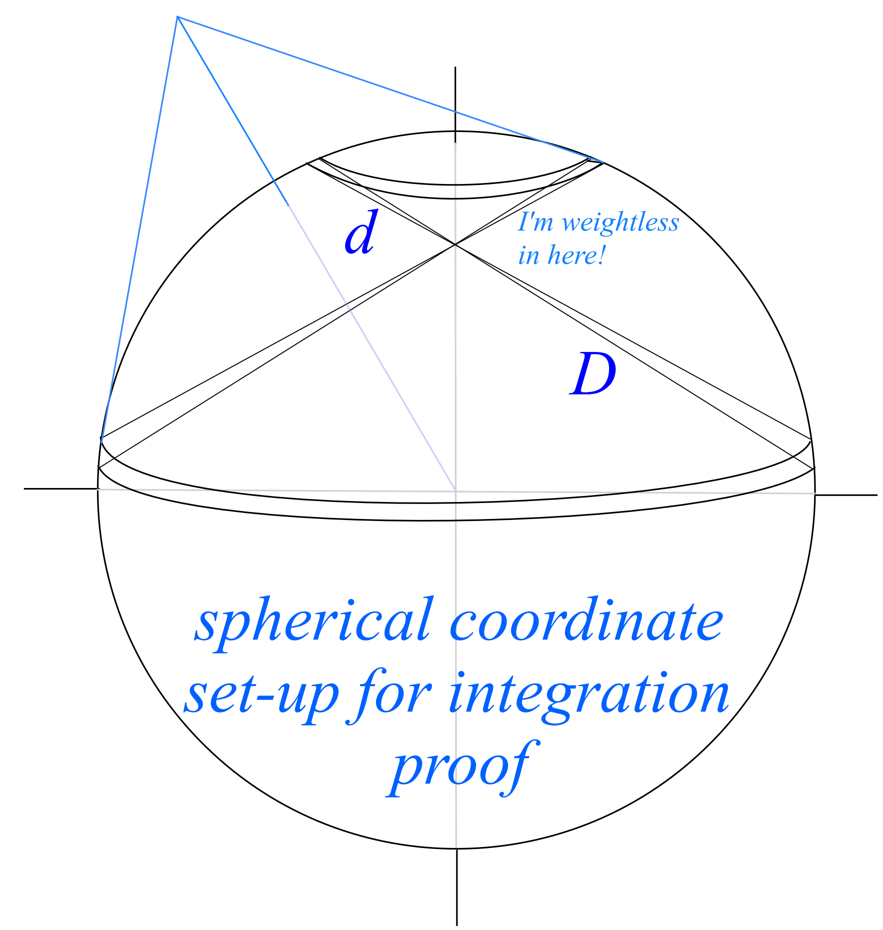
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$



Coulomb force inside-spherical body due to stuff below you, only.

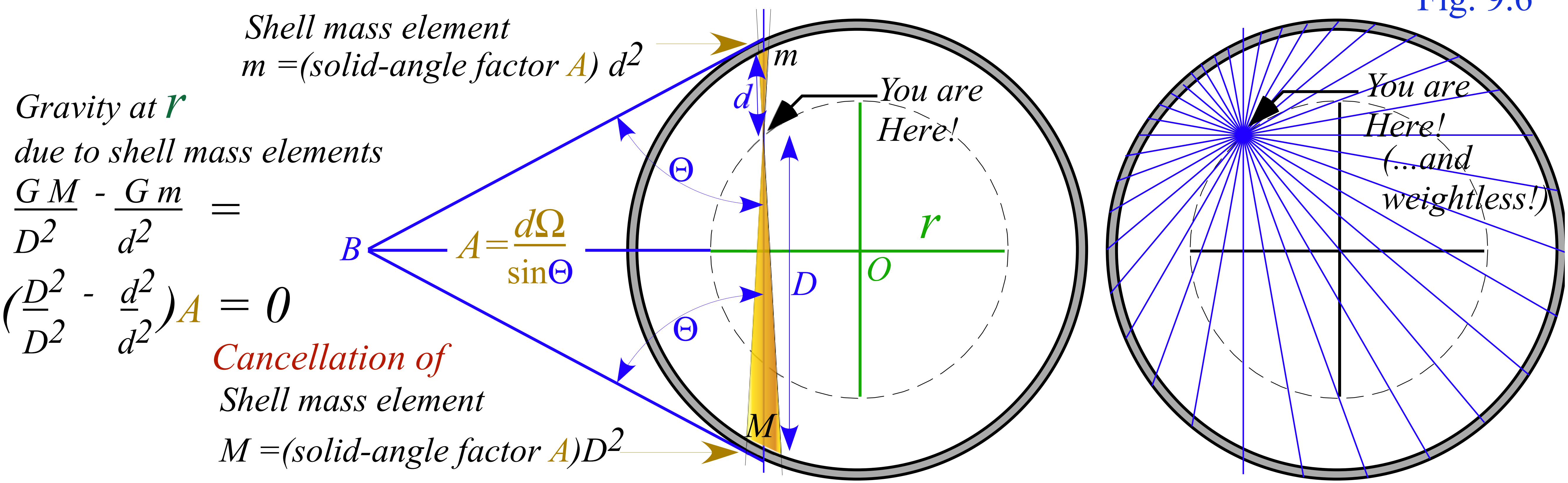


Gravitational force at $r_<$ is just that of planet  below $r_<$

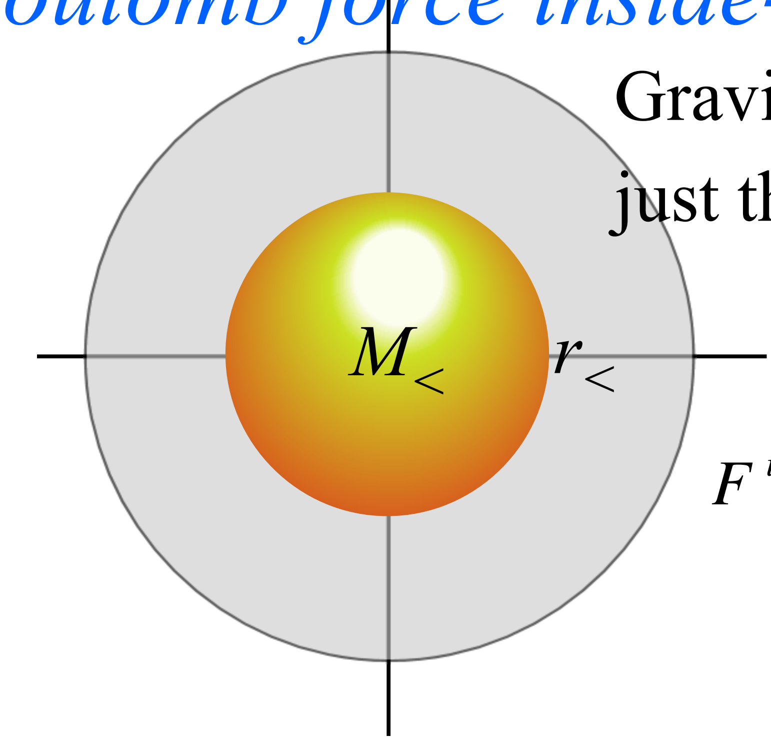


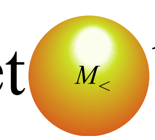
Coulomb force vanishes inside-spherical shell (Gauss-law)

Unit 1
Fig. 9.6



Coulomb force inside-spherical body due to stuff below you, only.



Gravitational force at $r_<$ is just that of planet  below $r_<$

Note: Hooke's (linear) force law for $r_<$ inside uniform body

$$F^{\,inside}(r_<) = G\frac{mM_<}{r_<^{\,2}} = Gm\frac{4\pi}{3}\frac{M_<}{\frac{4\pi}{3}r_<^{\,3}}r_< = Gm\frac{4\pi}{3}\rho_\oplus r_< = mg\frac{r_<}{R_\oplus} \equiv mg\cdot x$$

Coulomb force vanishes inside-spherical shell *(Gauss-law)*

Unit 1
Fig. 9.6

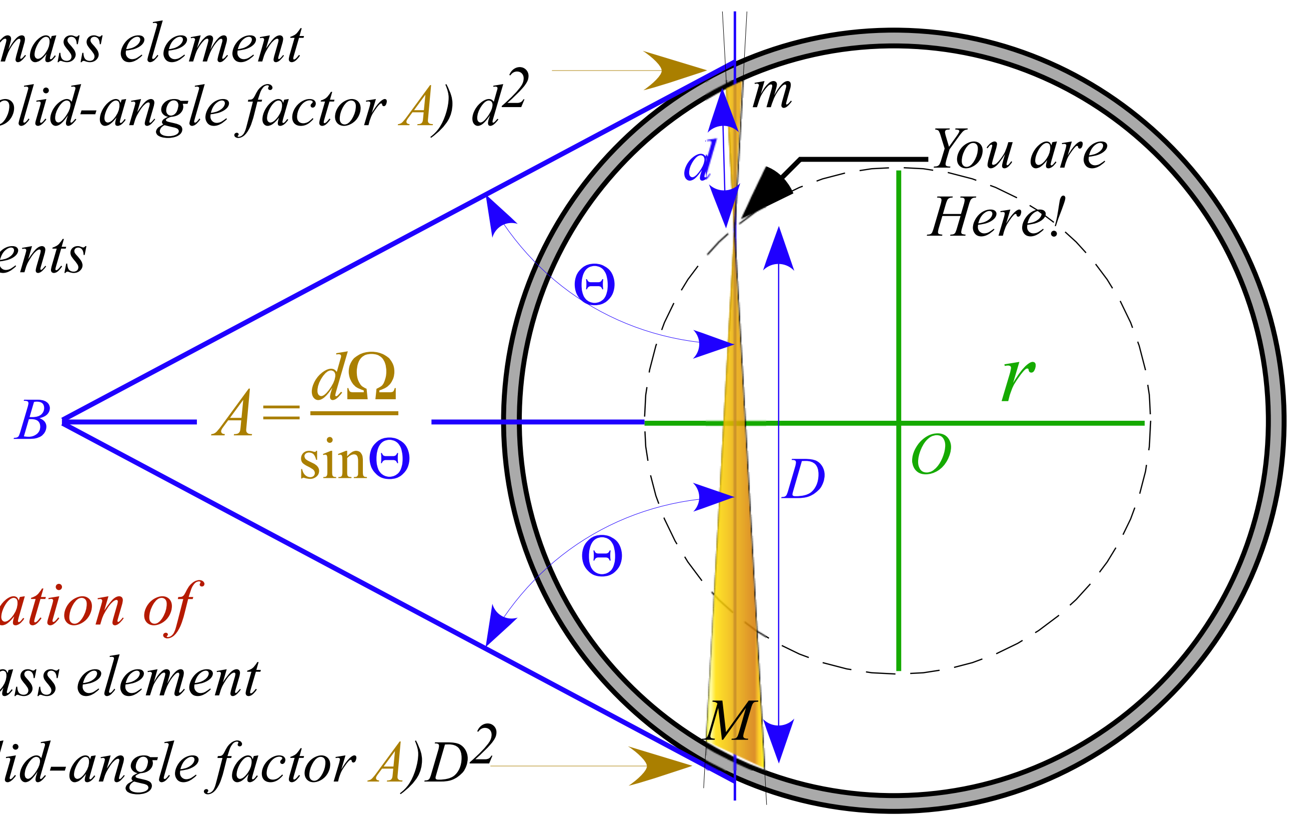
Shell mass element
m =(solid-angle factor A) d^2

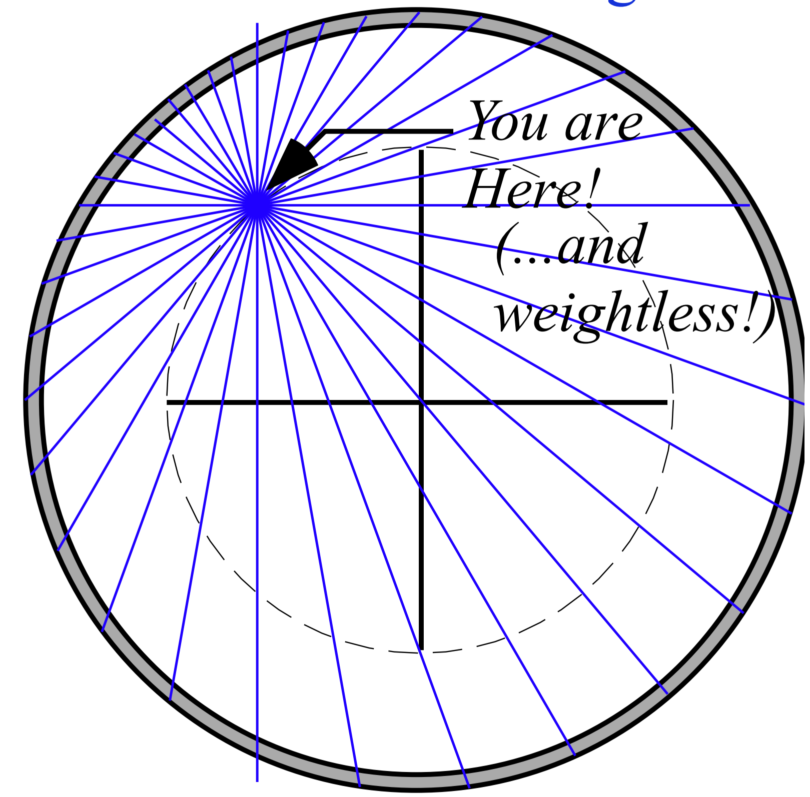
Gravity at r
due to shell mass elements

$$\frac{G\,M}{D^2} - \frac{G\,m}{d^2} =$$

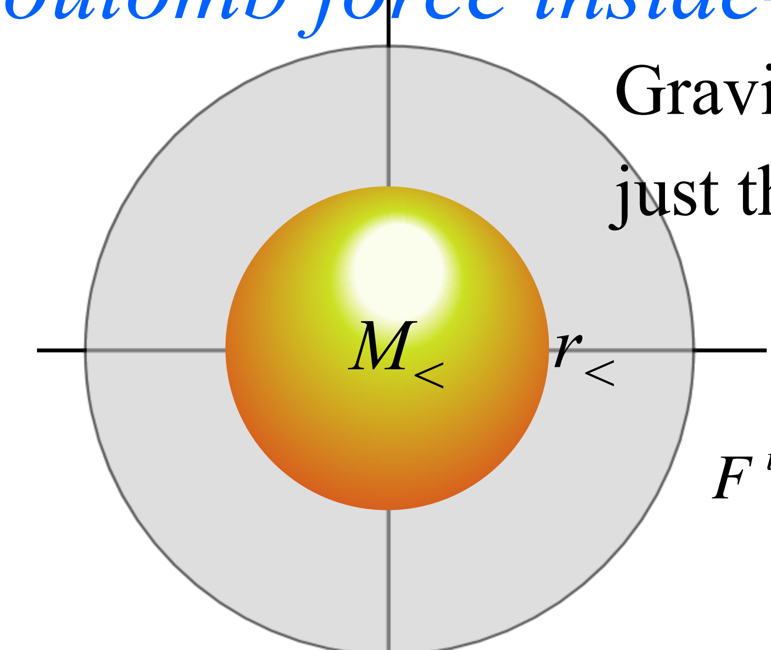
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$

Cancellation of
Shell mass element
M =(solid-angle factor A)D^2





Coulomb force inside-spherical body due to stuff <u>below</u> you, <u>only</u>.



Gravitational force at $r_<$ is
just that of planet $M_<$ below $r_<$

Note:
Hooke's (linear) force law
for $r_<$ inside uniform body

$$F^{inside}(r_<) = G\frac{mM_<}{r_<^2} = Gm\frac{4\pi}{3}\frac{M_<}{\frac{4\pi}{3}r_<^3}r_< = Gm\frac{4\pi}{3}\rho_\oplus r_< = mg\frac{r_<}{R_\oplus} \equiv mg\cdot x$$

Earth surface gravity acceleration: $g = G\frac{M_\oplus}{R_\oplus^2} = G\frac{M_\oplus}{R_\oplus^3}R_\oplus = G\frac{4\pi}{3}\frac{M_\oplus}{\frac{4\pi}{3}R_\oplus^3}R_\oplus = G\frac{4\pi}{3}\rho_\oplus R_\oplus = 9.8m/s$

$G=6.67384(80)\cdot 10^{-11}Nm^2/C^2 \sim (2/3)10^{-10}$

Coulomb force vanishes inside-spherical shell *(Gauss-law)*

Unit 1
Fig. 9.6

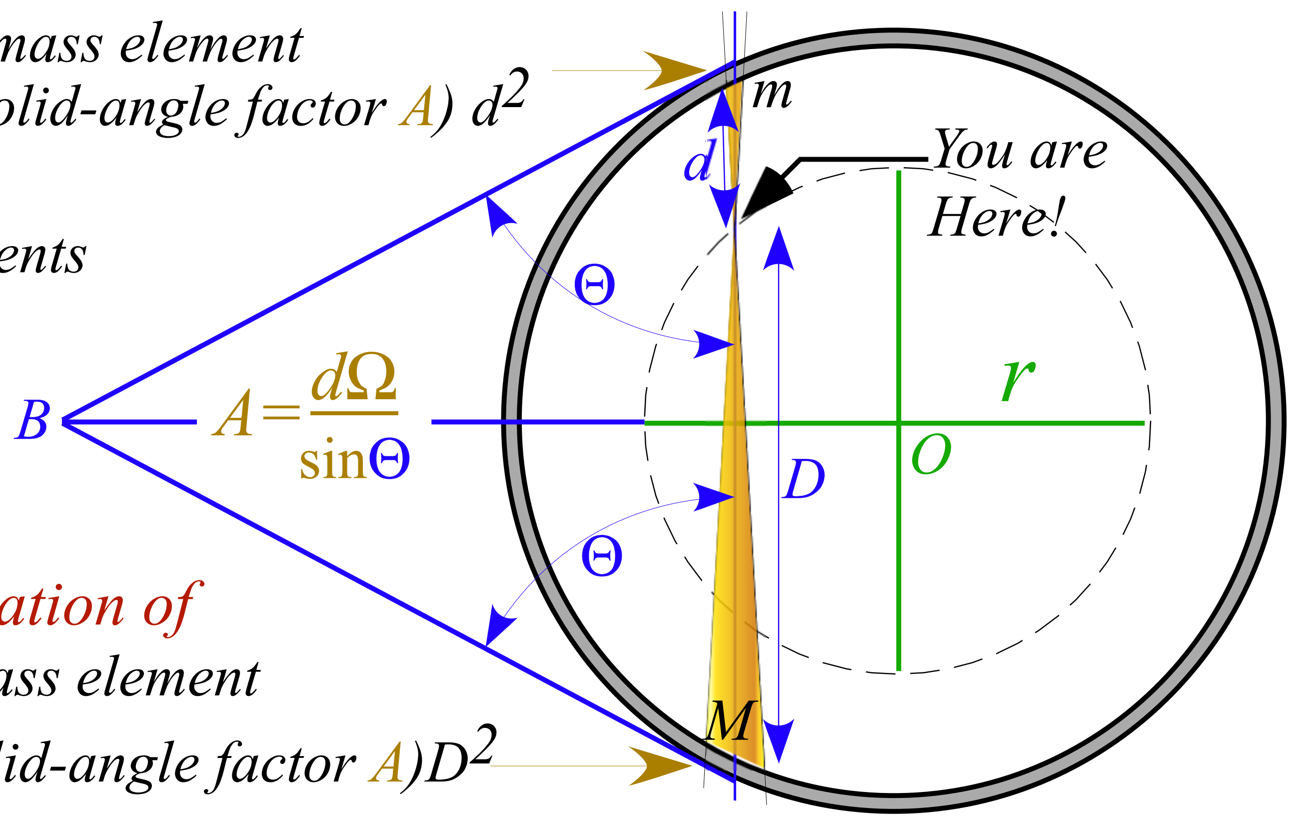
Shell mass element
m =(solid-angle factor A) d^2

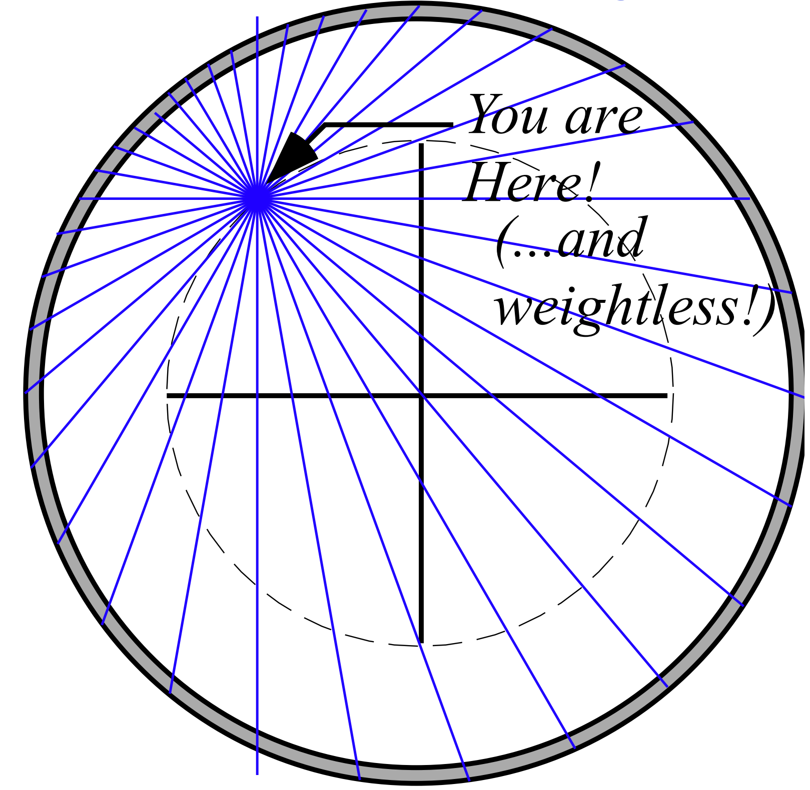
Gravity at r
due to shell mass elements

$$\frac{G\,M}{D^2} - \frac{G\,m}{d^2} =$$

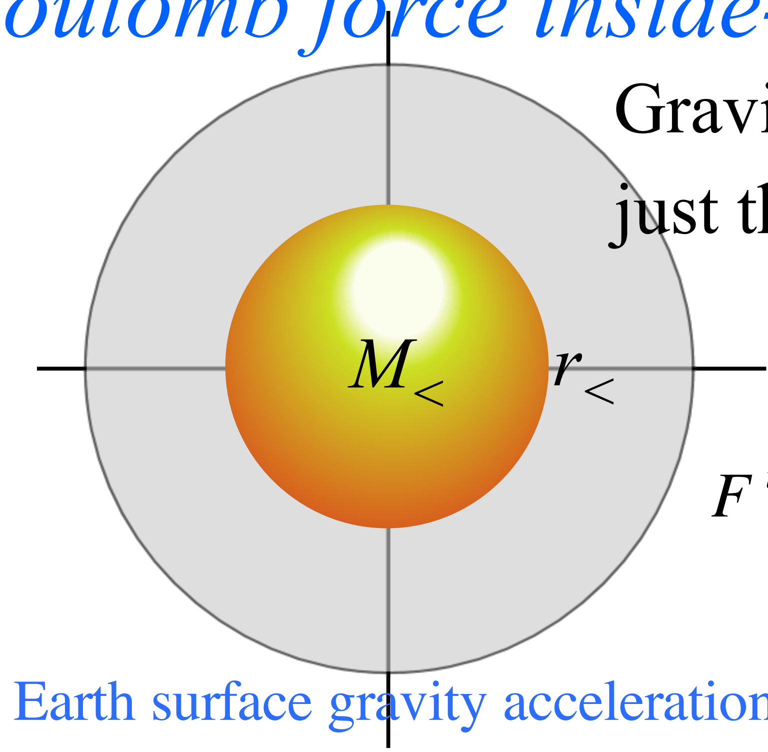
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$

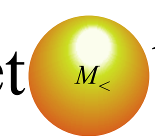
Cancellation of
Shell mass element
M =(solid-angle factor A)D^2





Coulomb force inside-spherical body due to stuff below you, only.



Gravitational force at $r_<$ is
just that of planet  below $r_<$

Note:
Hooke's (linear) force law
for $r_<$ inside uniform body

$$F^{inside}(r_<) = G\frac{mM_<}{r_<^2} = Gm\frac{4\pi}{3}\frac{M_<}{\frac{4\pi}{3}r_<^3}r_< = Gm\frac{4\pi}{3}\rho_\oplus r_< = mg\frac{r_<}{R_\oplus} \equiv mg\cdot x$$

Earth surface gravity acceleration: $g = G\dfrac{M_\oplus}{R_\oplus^2} = G\dfrac{M_\oplus}{R_\oplus^3}R_\oplus = G\dfrac{4\pi}{3}\dfrac{M_\oplus}{\frac{4\pi}{3}R_\oplus^3}R_\oplus = G\dfrac{4\pi}{3}\rho_\oplus R_\oplus = 9.8\,m/s$

G=6.67384(80)·10^-11 Nm²/C² ~(2/3)10^-10

Earth radius: $R_\oplus = 6.371\cdot 10^6\,m \simeq 6.4\cdot 10^6\,m$

Earth mass: $M_\oplus = 5.9722\times 10^{24}\,kg. \simeq 6.0\cdot 10^{24}\,kg.$

Solar radius: $R_\odot = 6.955\times 10^8\,m. \simeq 7.0\cdot 10^8\,m.$

Solar mass: $M_\odot = 1.9889\times 10^{30}\,kg. \simeq 2.0\cdot 10^{30}\,kg.$

Geometry of idealized “Sophomore-physics Earth”

Coulomb field outside *Isotropic Harmonic Oscillator (IHO) field inside*

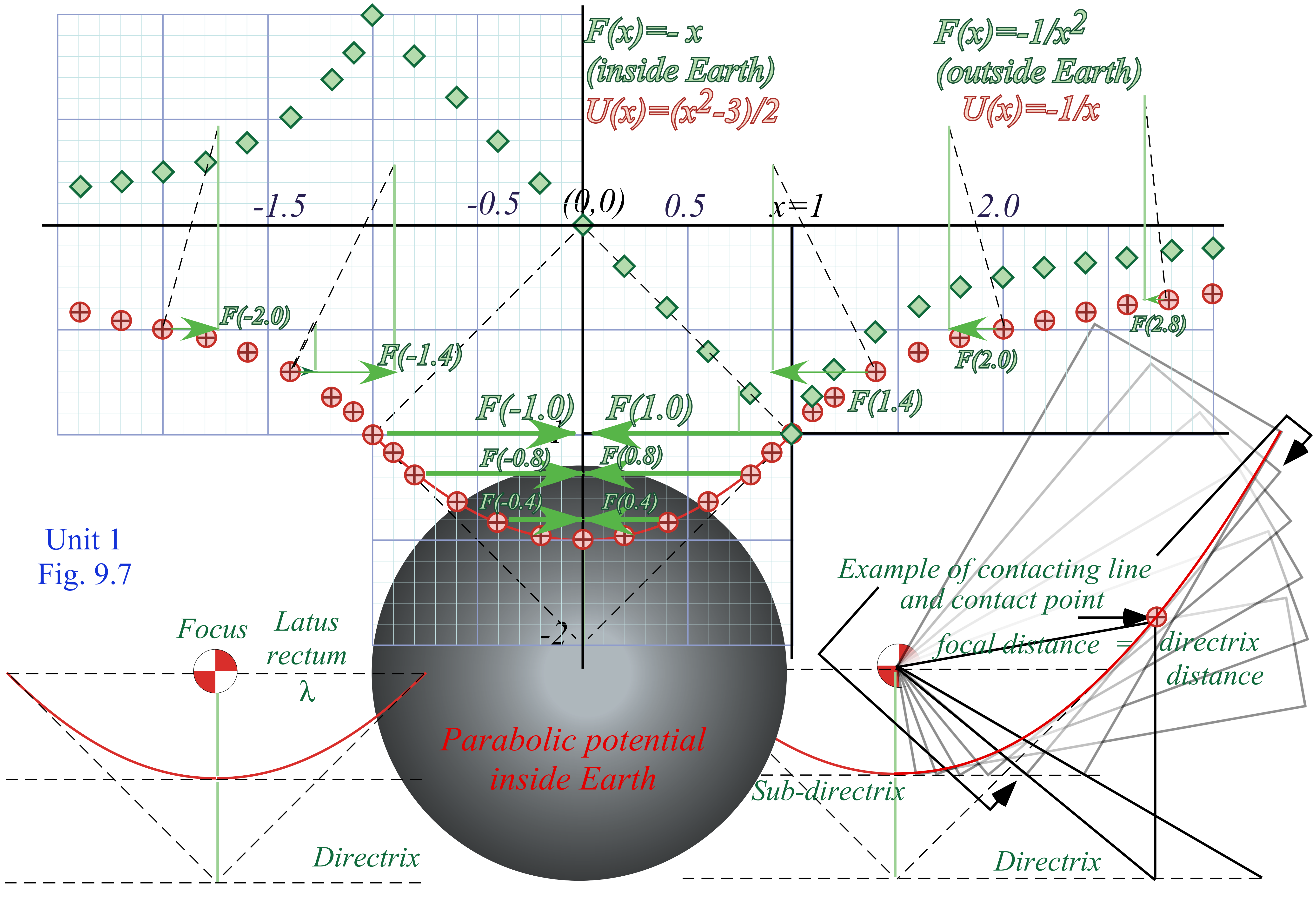
→ *Contact-geometry of potential curve(s)*

“Crushed-Earth” models: 3 key energy “steps” and 4 key energy “levels”

Earth matter vs nuclear matter:

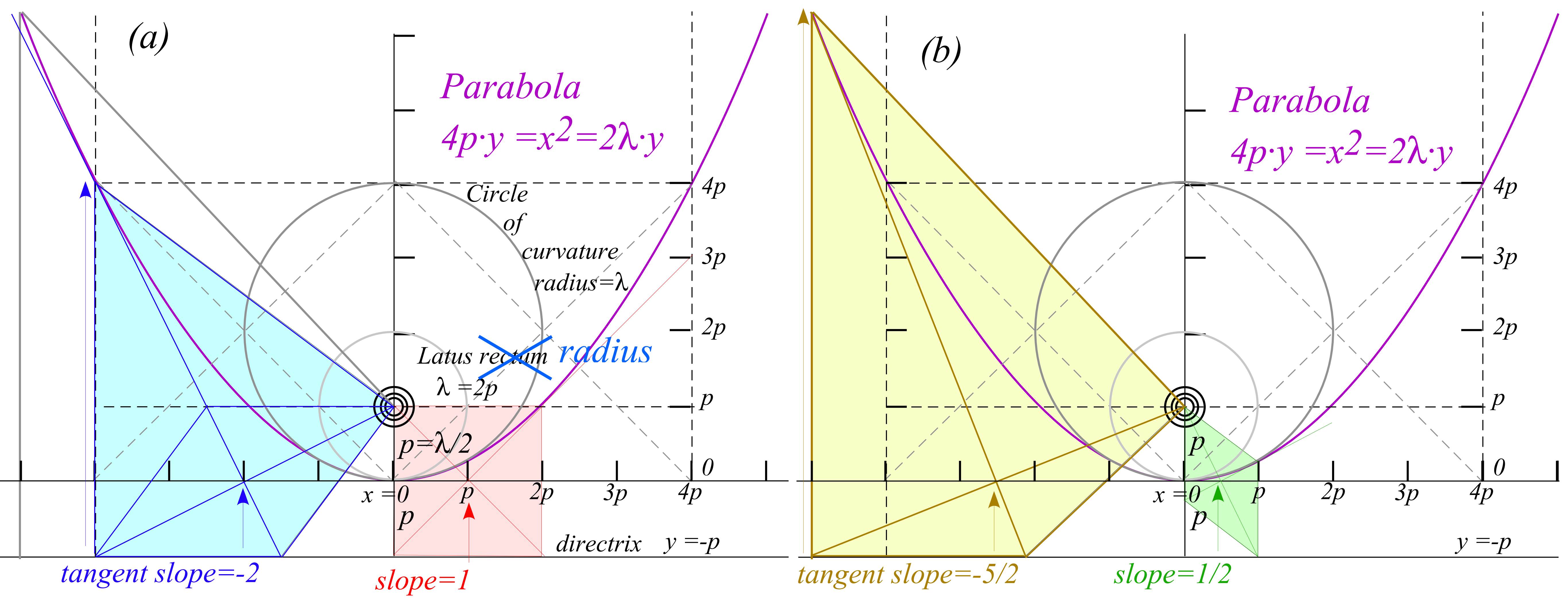
*Introducing the “neutron starlet” and “***Black-Hole-Earth***”*

The ideal "Sophomore-Physics-Earth" model of geo-gravity



...conventional parabolic geometry...carried to extremes...

(From p.18)



Unit 1
Fig. 9.4

Geometry of idealized "Sophomore-physics Earth"

Coulomb field *__outside__* *Isotropic Harmonic Oscillator (IHO) field* *__inside__*

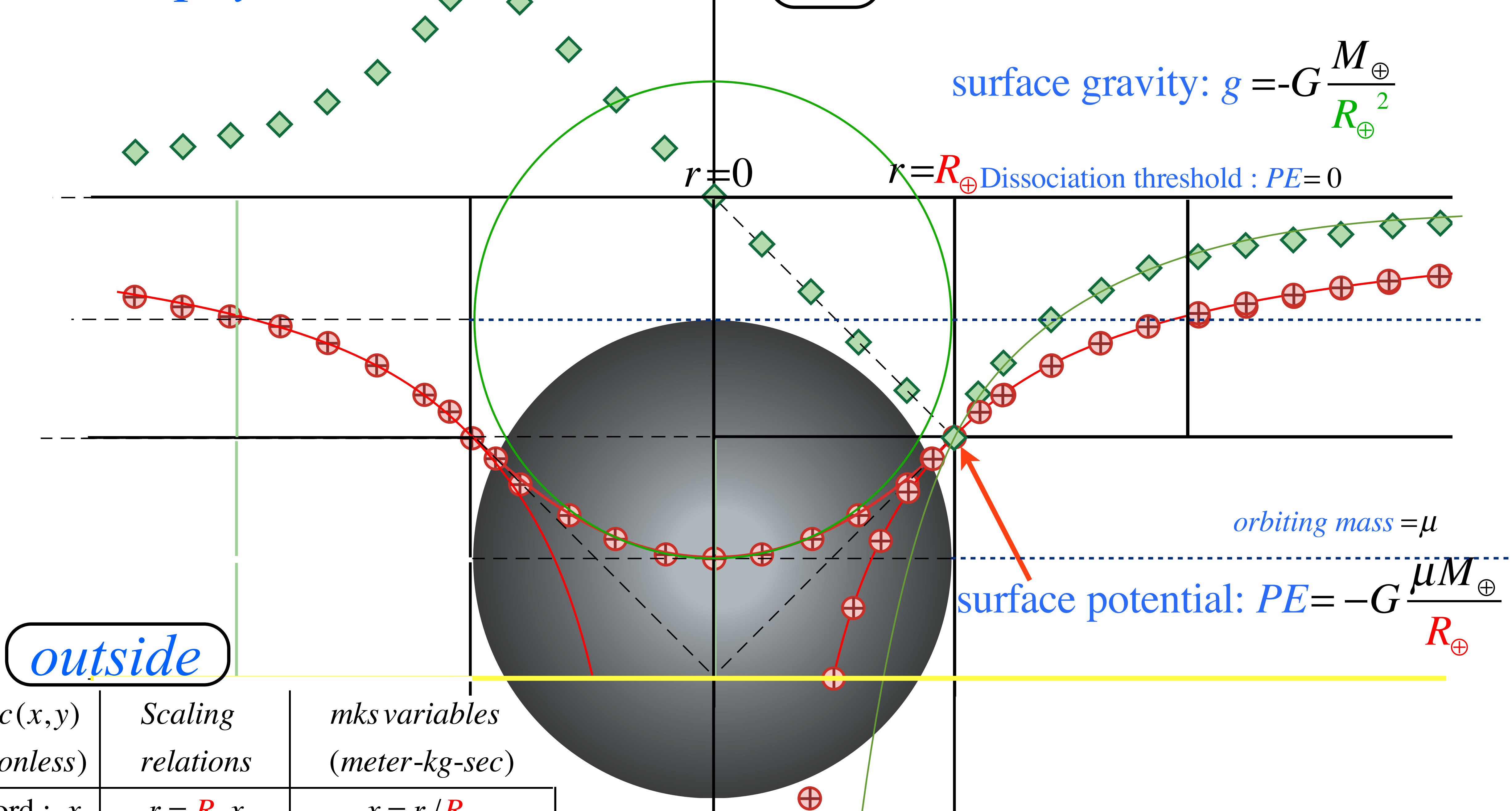
Contact-geometry of potential curve(s)

→ *"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"*

Earth matter vs nuclear matter:

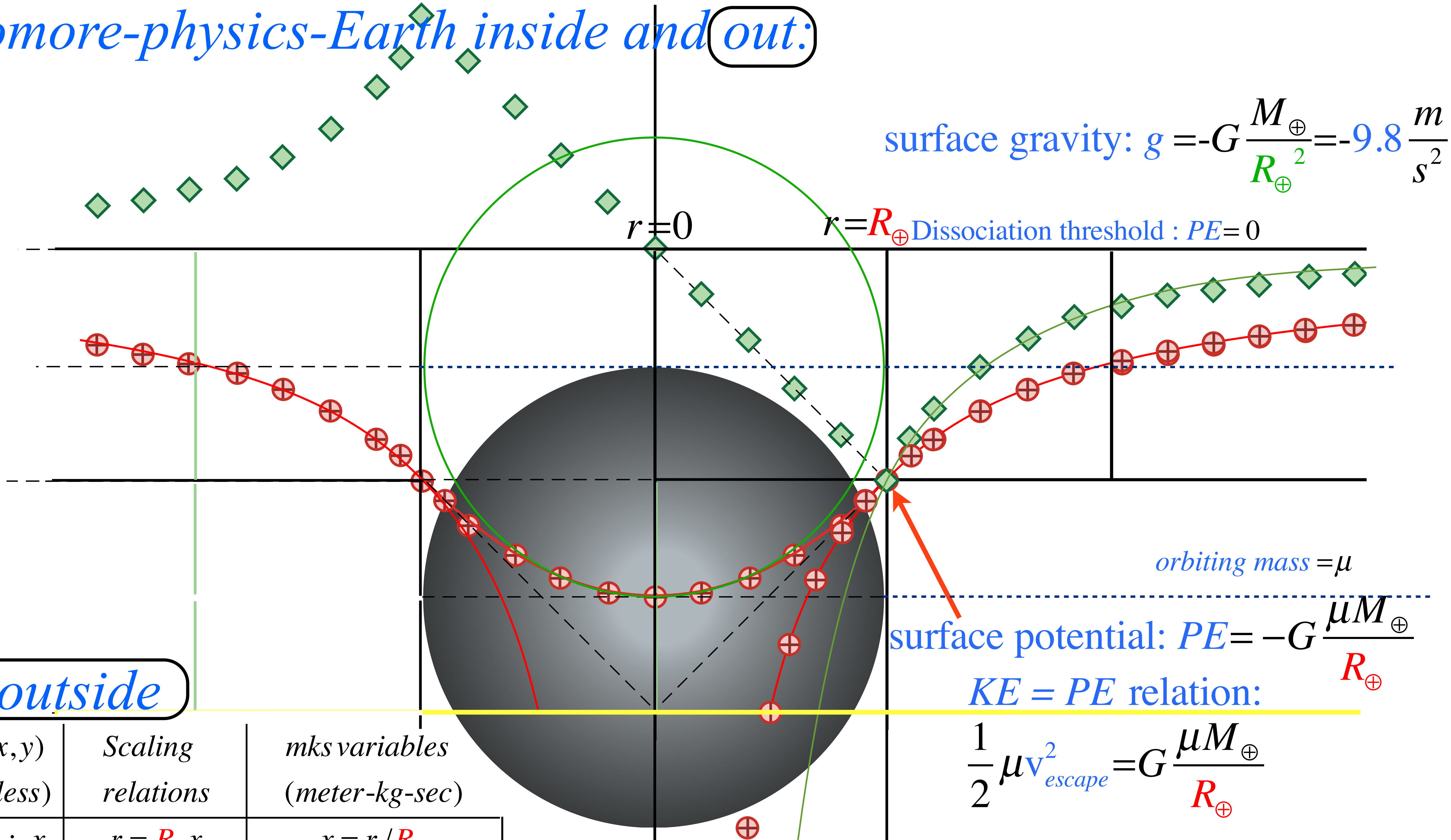
*Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

Sophomore-physics-Earth inside and out:



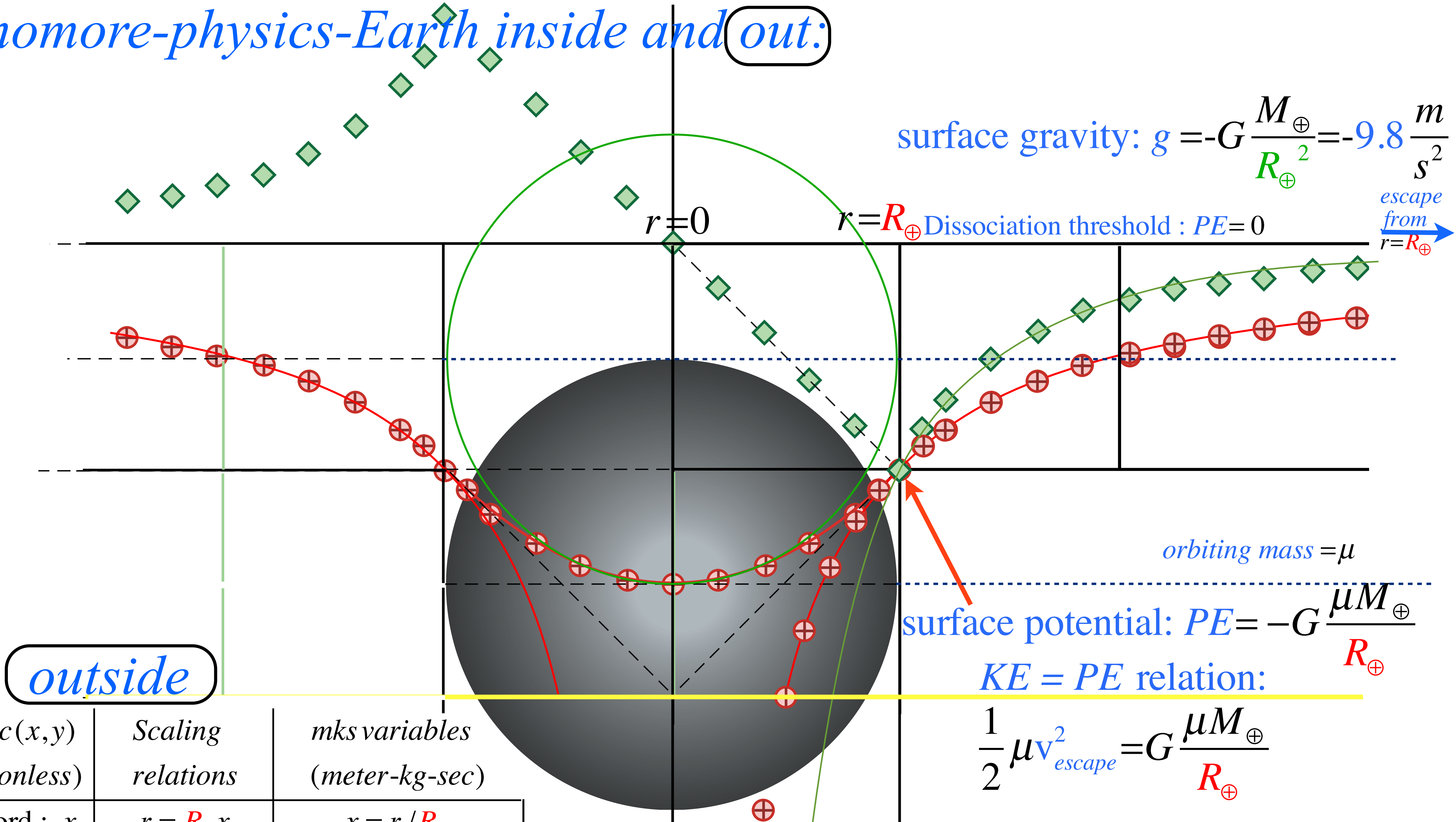
Geometric (x,y) (Dimensionless)	Scaling relations	mks variables (meter-kg-sec)
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$

Sophomore-physics-Earth inside and out:



Geometric (x,y) (*Dimensionless*)	*Scaling relations*	*mks variables* (*meter-kg-sec*)
space coord.: x	$r = R_{\oplus} x$	$x = r / R_{\oplus}$
PE for $\lvert x \rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_{\oplus}} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_{\oplus}}\frac{1}{x}$

Sophomore-physics-Earth inside and out:



surface gravity: $g = -G\dfrac{M_\oplus}{R_\oplus^{\,2}} = -9.8\,\dfrac{m}{s^2}$

surface potential: $PE = -G\dfrac{\mu M_\oplus}{R_\oplus}$

$KE = PE$ relation:

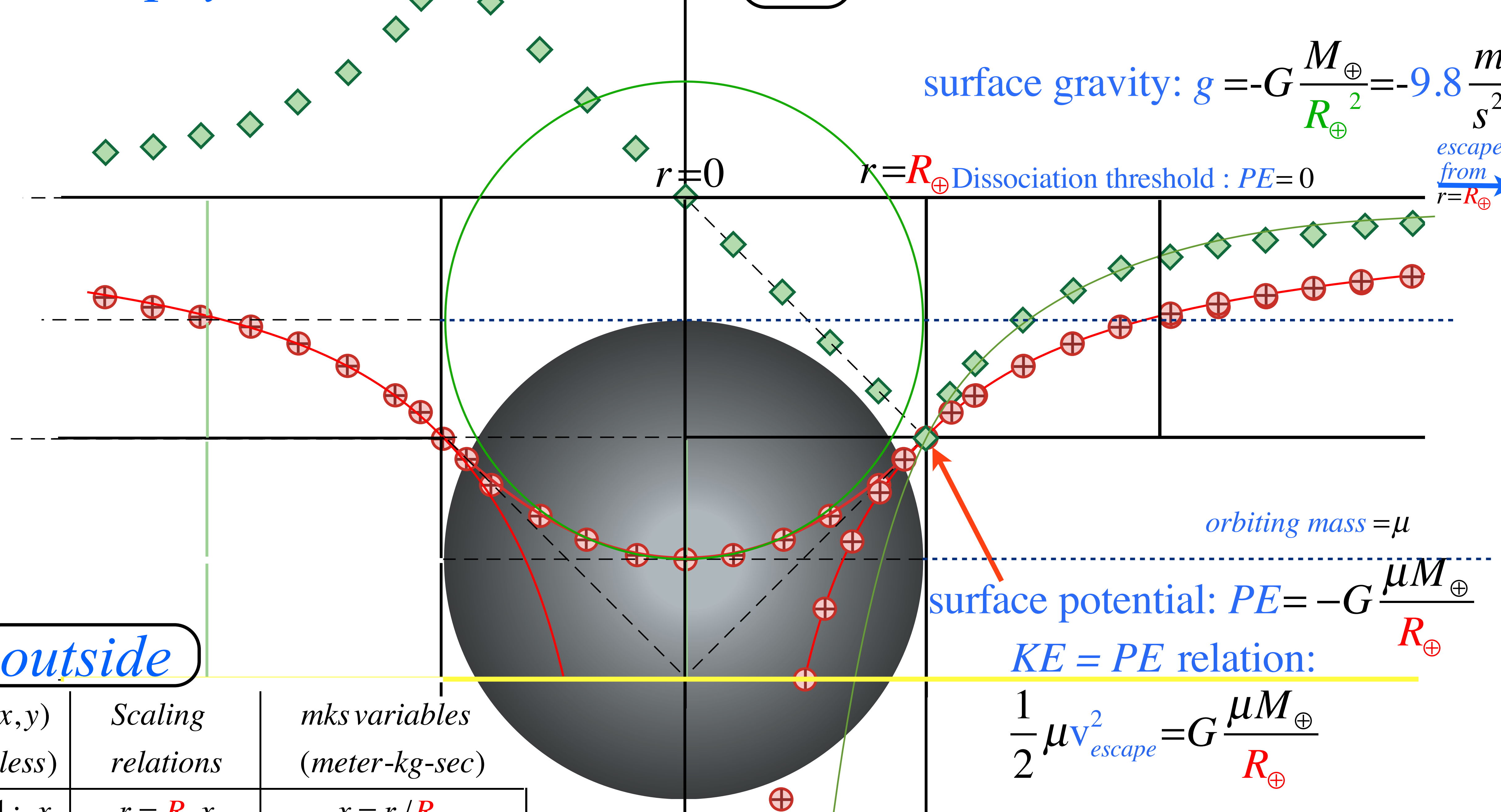
$$\frac{1}{2}\mu v_{escape}^2 = G\frac{\mu M_\oplus}{R_\oplus}$$

$R_\oplus$-escape-velocity

$$v_{escape} = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$$

Geometric (x,y) (*Dimensionless*)	*Scaling relations*	*mks variables* (*meter-kg-sec*)
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \dfrac{-1}{x}$	$PE^{mks}(r) = \dfrac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\dfrac{GM\mu}{r} = -\dfrac{GM\mu}{R_\oplus}\dfrac{1}{x}$

Sophomore-physics-Earth inside and out:



surface gravity: $g = -G\frac{M_\oplus}{R_\oplus^{\ 2}} = -9.8\frac{m}{s^2}$

surface potential: $PE = -G\frac{\mu M_\oplus}{R_\oplus}$

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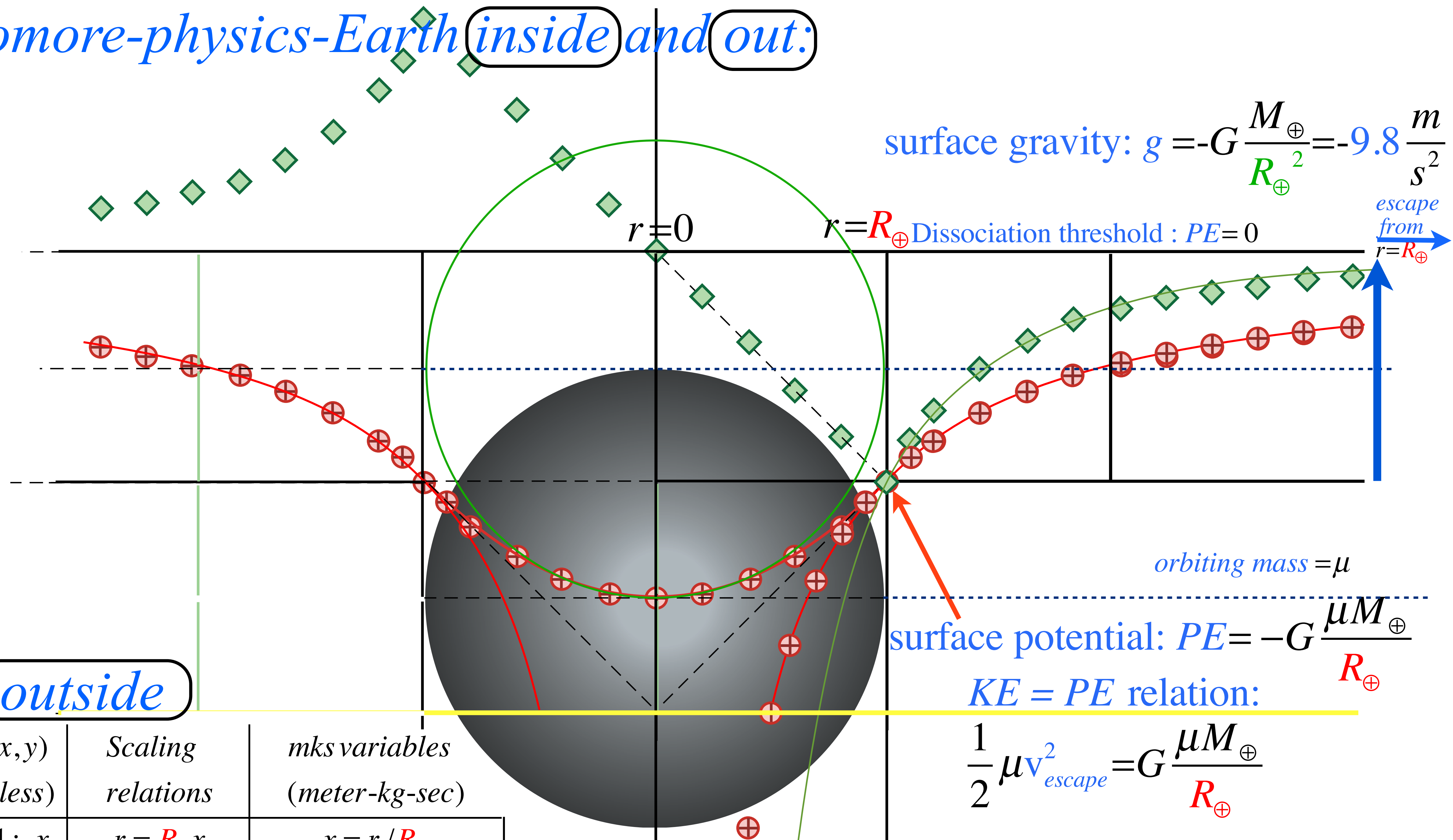
$R_\oplus$-escape-velocity

$$v_{escape} = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$$

Geometric(x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*
space coord.: x	$r = R_\oplus x$	$x = r / R_\oplus$
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$
$Force$ for $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$

Sophomore-physics-Earth inside and out:



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KE = PE relation:

$$\frac{1}{2}\mu v_{escape}^2 = G\frac{\mu M_\oplus}{R_\oplus}$$

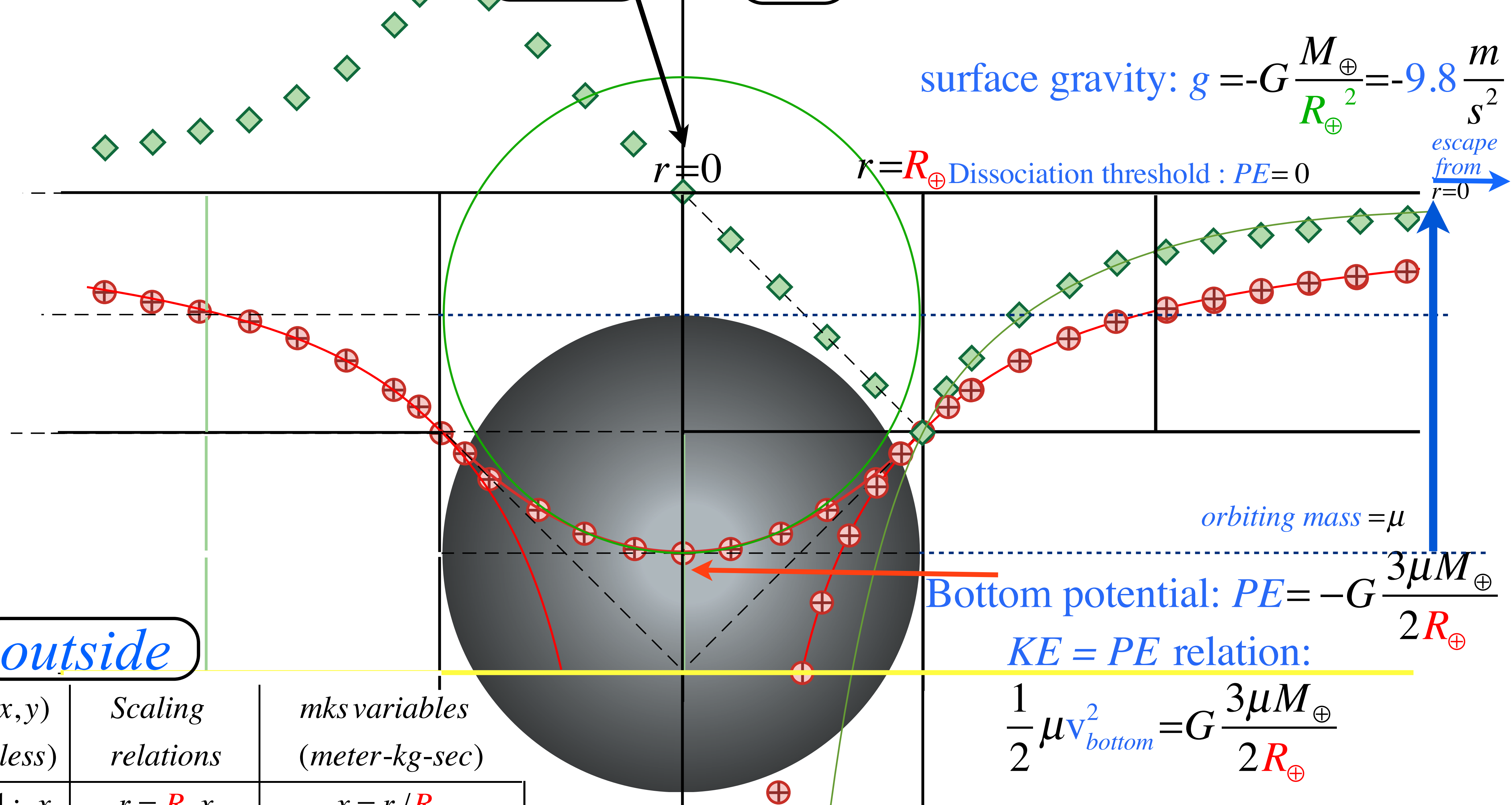
Geometric (x,y) (Dimensionless)	Scaling relations	mks variables (meter-kg-sec)		inside
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$		
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$	PE for $\lvert x\rvert <1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
$Force$ for $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$	$Force$ for $\lvert x\rvert <1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$R_\oplus$-escape-velocity

$$v_{escape} = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$$

11.1km/sec

Sophomore-physics-Earth inside and out:



Geometric (x,y) (Dimensionless)	Scaling relations	mks variables (meter-kg-sec)
space coord.: x	$r = R_\oplus x$	$x = r / R_\oplus$
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$
$Force$ for $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$

inside

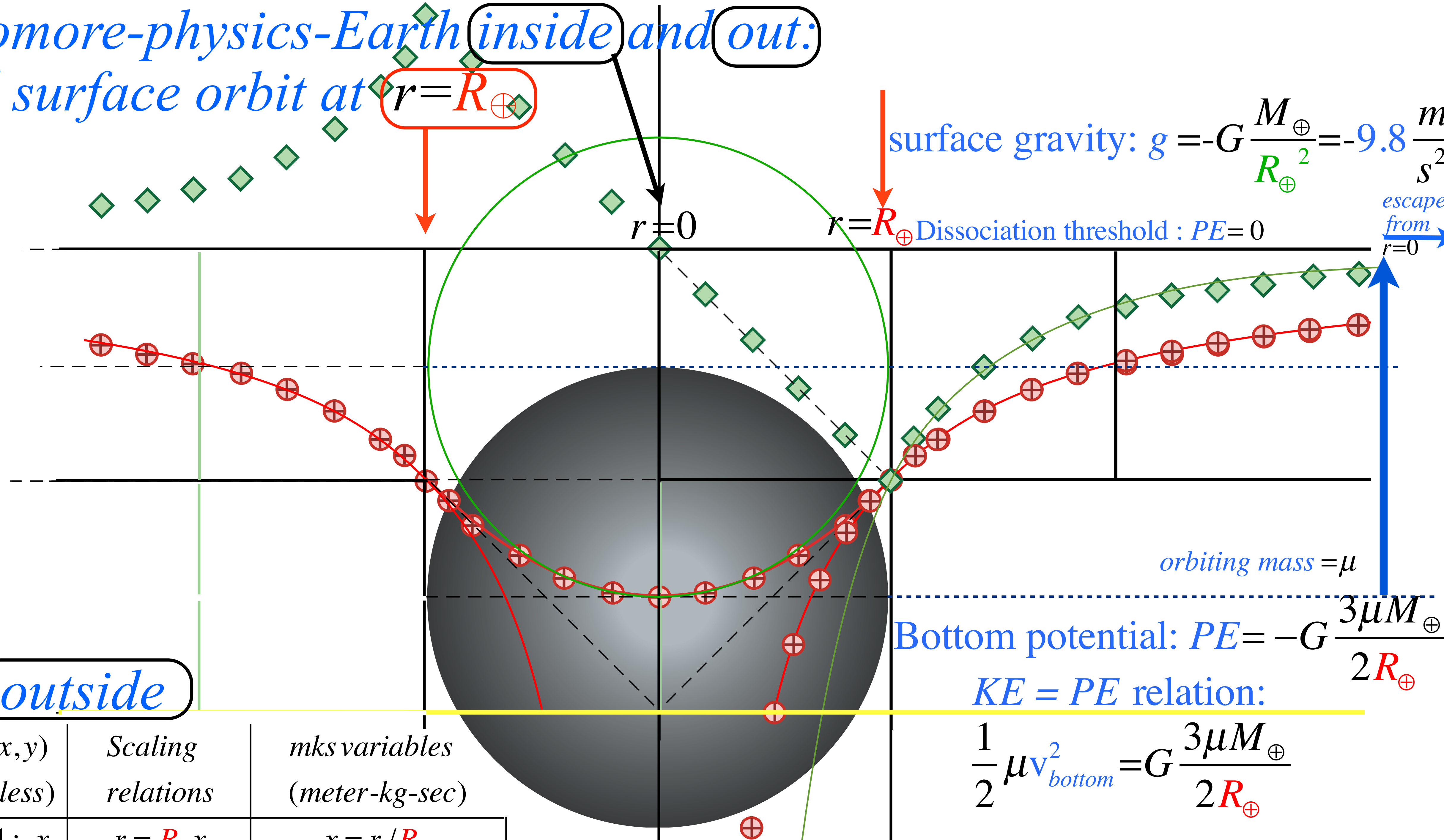
PE for $\lvert x\rvert < 1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
$Force$ for $\lvert x\rvert < 1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$(r=0)$-escape-velocity

$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

13.7km/sec

Sophomore-physics-Earth inside and out:
...and surface orbit at $r=R_\oplus$



Geometric (x,y) *(Dimensionless)*	*Scaling relations*	*mks variables (meter-kg-sec)*
space coord.: x	$r=R_\oplus x$	$x=r/R_\oplus$
PE for $\lvert x\rvert\geq 1$: $y^{PE}=\frac{-1}{x}$	$PE^{mks}(r)=\frac{GM\mu}{R_\oplus}y^{PE}$	$PE^{mks}(r)=-\frac{GM\mu}{r}=-\frac{GM\mu}{R_\oplus}\frac{1}{x}$
$Force$ for $\lvert x\rvert\geq 1$: $y^{Force}=\frac{-1}{x^2}$	$F^{mks}(r)=\frac{GM\mu}{R_\oplus^2}y^{Force}$	$F^{mks}(r)=-\frac{GM\mu}{r^2}=-\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$

inside

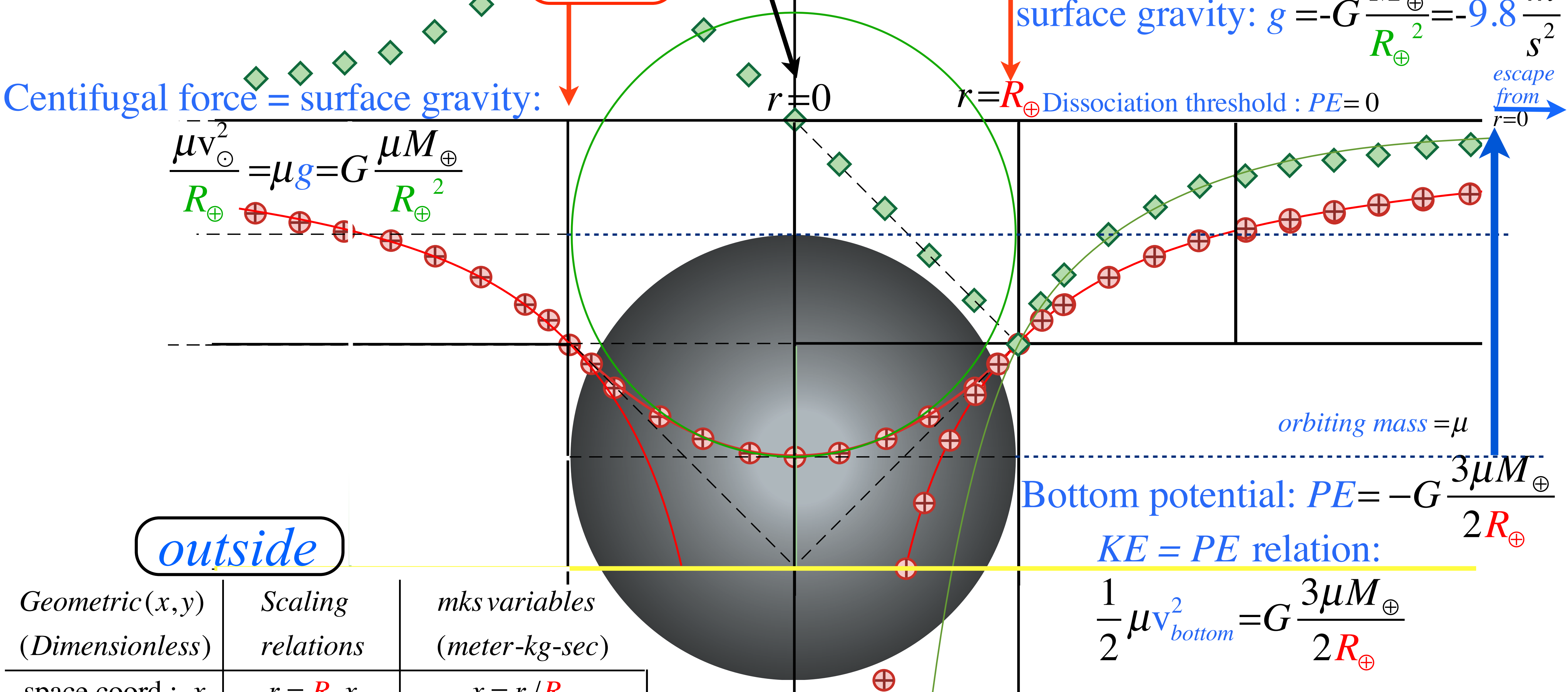
PE for $\lvert x\rvert<1$: $y^{PE}=\frac{x^2}{2}-\frac{3}{2}$	$PE^{mks}(r)=\frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2}-\frac{3}{2}\right)$
$Force$ for $\lvert x\rvert<1$: $y^{Force}=-x$	$F^{mks}(r)=-\frac{GM\mu}{R_\oplus^3}r$

$(r=0)$-escape-velocity

$$v_{bottom}=\sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

13.7km/sec

Sophomore-physics-Earth inside and out:
...and surface orbit at $r=R_\oplus$



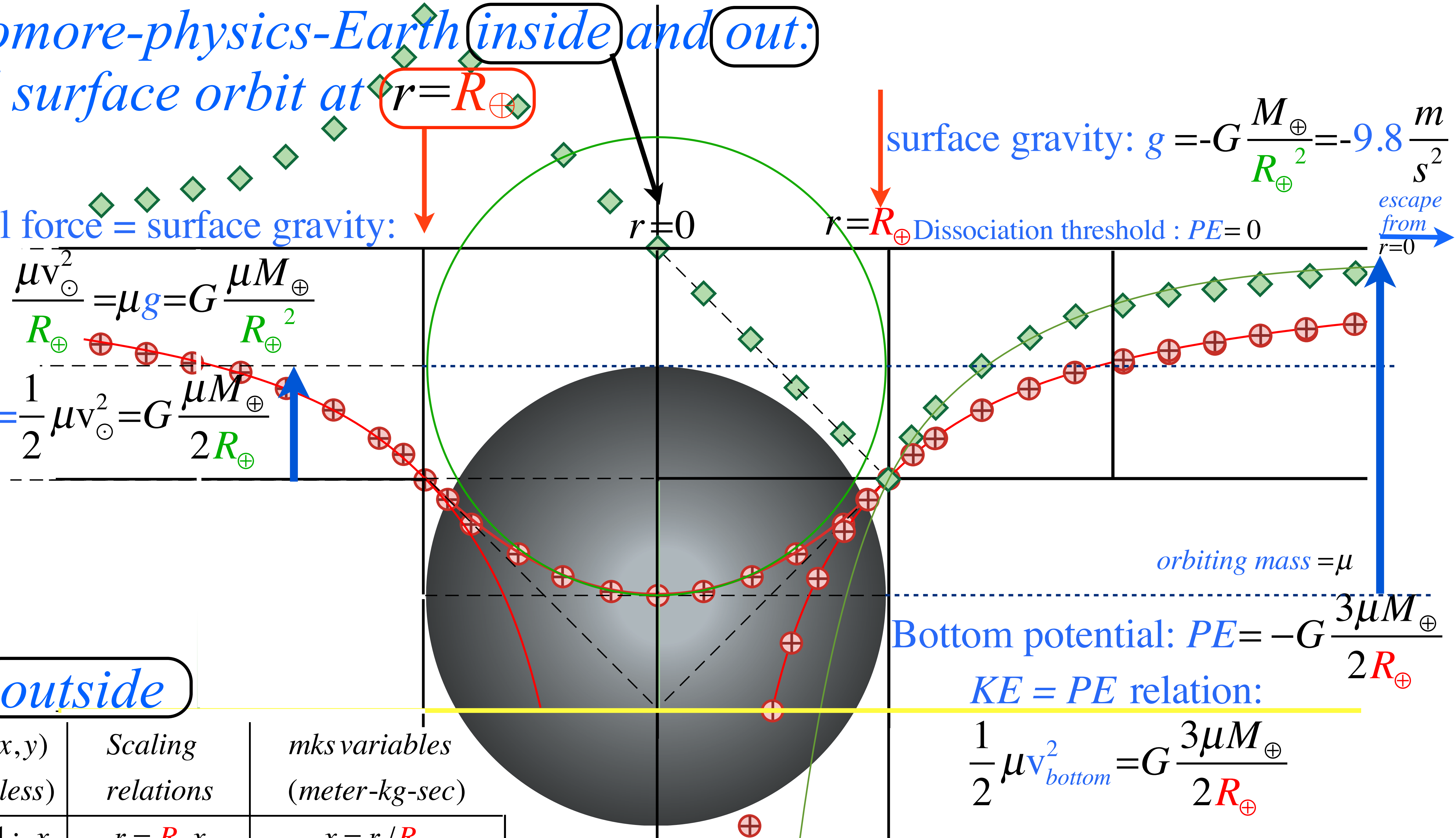
Geometric (x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*		
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$		
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$	PE for $\lvert x\rvert<1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
$Force$ for $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$	$Force$ for $\lvert x\rvert<1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$(r=0)$-escape-velocity

$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

13.7km/sec

Sophomore-physics-Earth inside and out:
...and surface orbit at $r=R_\oplus$



outside / inside

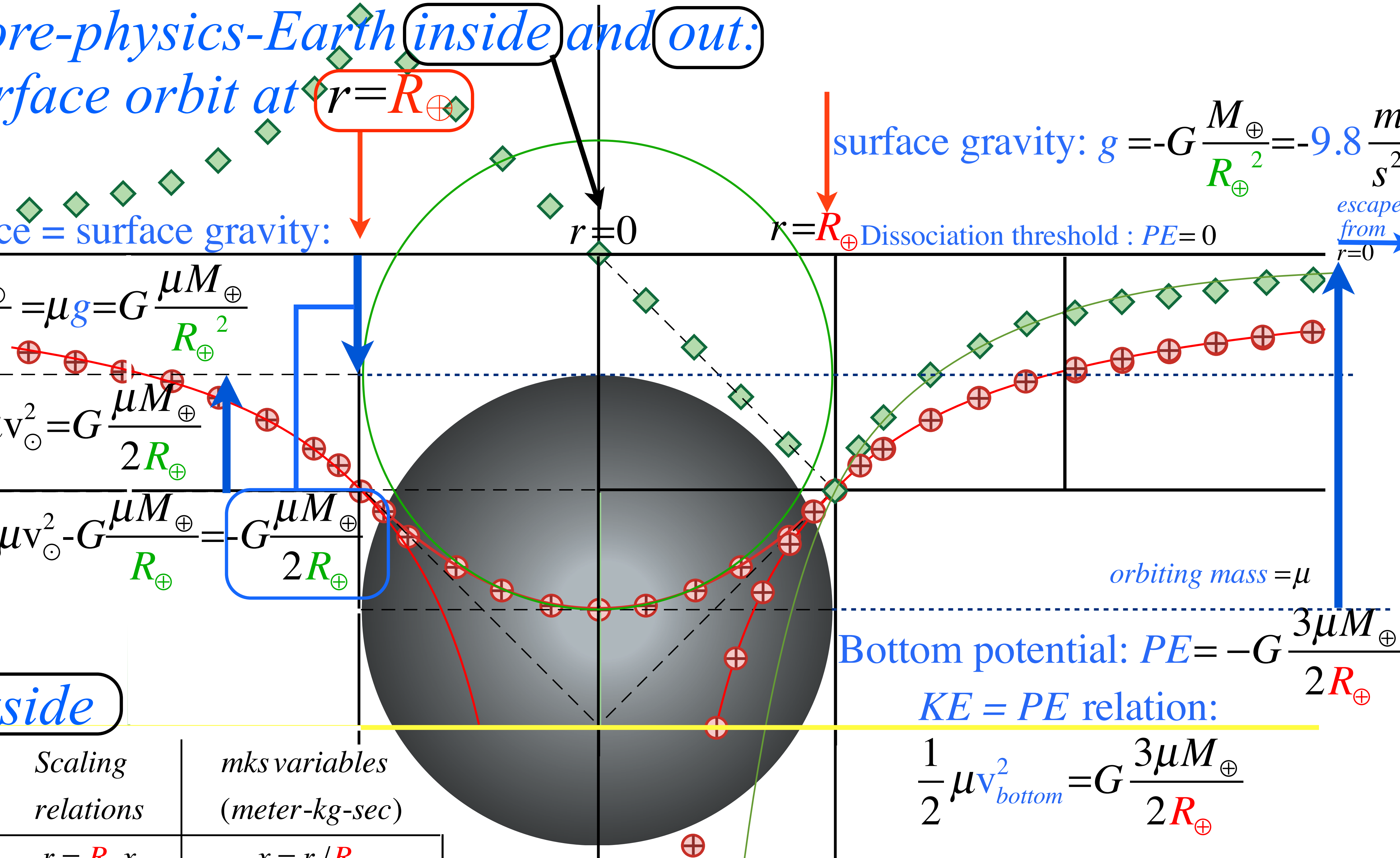
Geometric (x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*		*inside*
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$		
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$	PE for $\lvert x\rvert < 1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
$Force$ for $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$	$Force$ for $\lvert x\rvert < 1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$(r=0)$-escape-velocity

$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

13.7km/sec

Sophomore-physics-Earth inside and out:
...and surface orbit at $r=R_\oplus$



surface gravity: $g=-G\frac{M_\oplus}{R_\oplus^2}=-9.8\frac{m}{s^2}$

Centifugal force = surface gravity:

$$\frac{\mu v_\odot^2}{R_\oplus}=\mu g=G\frac{\mu M_\oplus}{R_\oplus^2}$$

Orbit KE $=\frac{1}{2}\mu v_\odot^2=G\frac{\mu M_\oplus}{2R_\oplus}$

Orbit $E_\odot^{Total}=\frac{1}{2}\mu v_\odot^2-G\frac{\mu M_\oplus}{R_\oplus}=-G\frac{\mu M_\oplus}{2R_\oplus}$

Bottom potential: $PE=-G\frac{3\mu M_\oplus}{2R_\oplus}$

$KE=PE$ relation:

$$\frac{1}{2}\mu v_{bottom}^2=G\frac{3\mu M_\oplus}{2R_\oplus}$$

Geometric (x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*		
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PE for $\lvert x\rvert\geq 1$: $y^{PE}=\frac{-1}{x}$	$PE^{mks}(r)=\frac{GM\mu}{R_\oplus}y^{PE}$	$PE^{mks}(r)=-\frac{GM\mu}{r}=-\frac{GM\mu}{R_\oplus}\frac{1}{x}$	PE for $\lvert x\rvert<1$: $y^{PE}=\frac{x^2}{2}-\frac{3}{2}$	$PE^{mks}(r)=\frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2}-\frac{3}{2}\right)$
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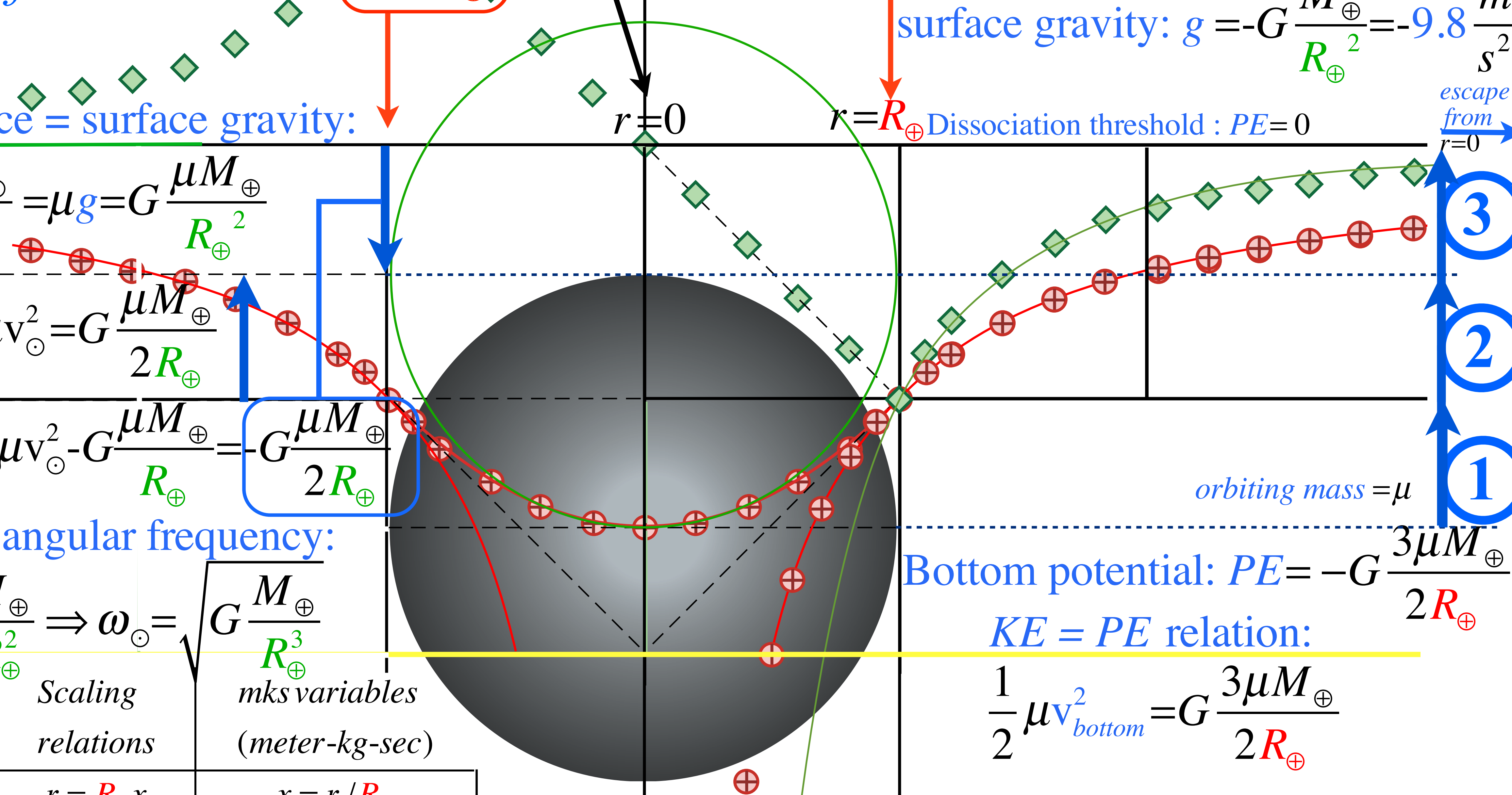
Sophomore-physics-Earth inside and out: "3-steps out of (or into) Hell"

...and surface orbit at $r=R_\oplus$

surface gravity: $g=-G\frac{M_\oplus}{R_\oplus^{2}}=-9.8\frac{m}{s^{2}}$



Centifugal force = surface gravity: $\frac{\mu v_\odot^2}{R_\oplus}=\mu g=G\frac{\mu M_\oplus}{R_\oplus^{2}}$

Orbit KE $=\frac{1}{2}\mu v_\odot^2=G\frac{\mu M_\oplus}{2R_\oplus}$

Orbit $E_\odot^{Total}=\frac{1}{2}\mu v_\odot^2-G\frac{\mu M_\oplus}{R_\oplus}=-G\frac{\mu M_\oplus}{2R_\oplus}$

$(r=R_\oplus)$-orbit angular frequency:

$$\omega_\odot^2 R_\oplus=G\frac{M_\oplus}{R_\oplus^2}\Rightarrow\omega_\odot=\sqrt{G\frac{M_\oplus}{R_\oplus^3}}$$

Bottom potential: $PE=-G\frac{3\mu M_\oplus}{2R_\oplus}$

$KE=PE$ relation: $\frac{1}{2}\mu v_{bottom}^2=G\frac{3\mu M_\oplus}{2R_\oplus}$

Geometric (x,y) *(Dimensionless)*	*Scaling relations*	*mks variables (meter-kg-sec)*		inside
space coord.: x	$r=R_\oplus x$	$x=r/R_\oplus$		
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$v_{bottom}=\sqrt{3G\frac{M_\oplus}{R_\oplus}}$

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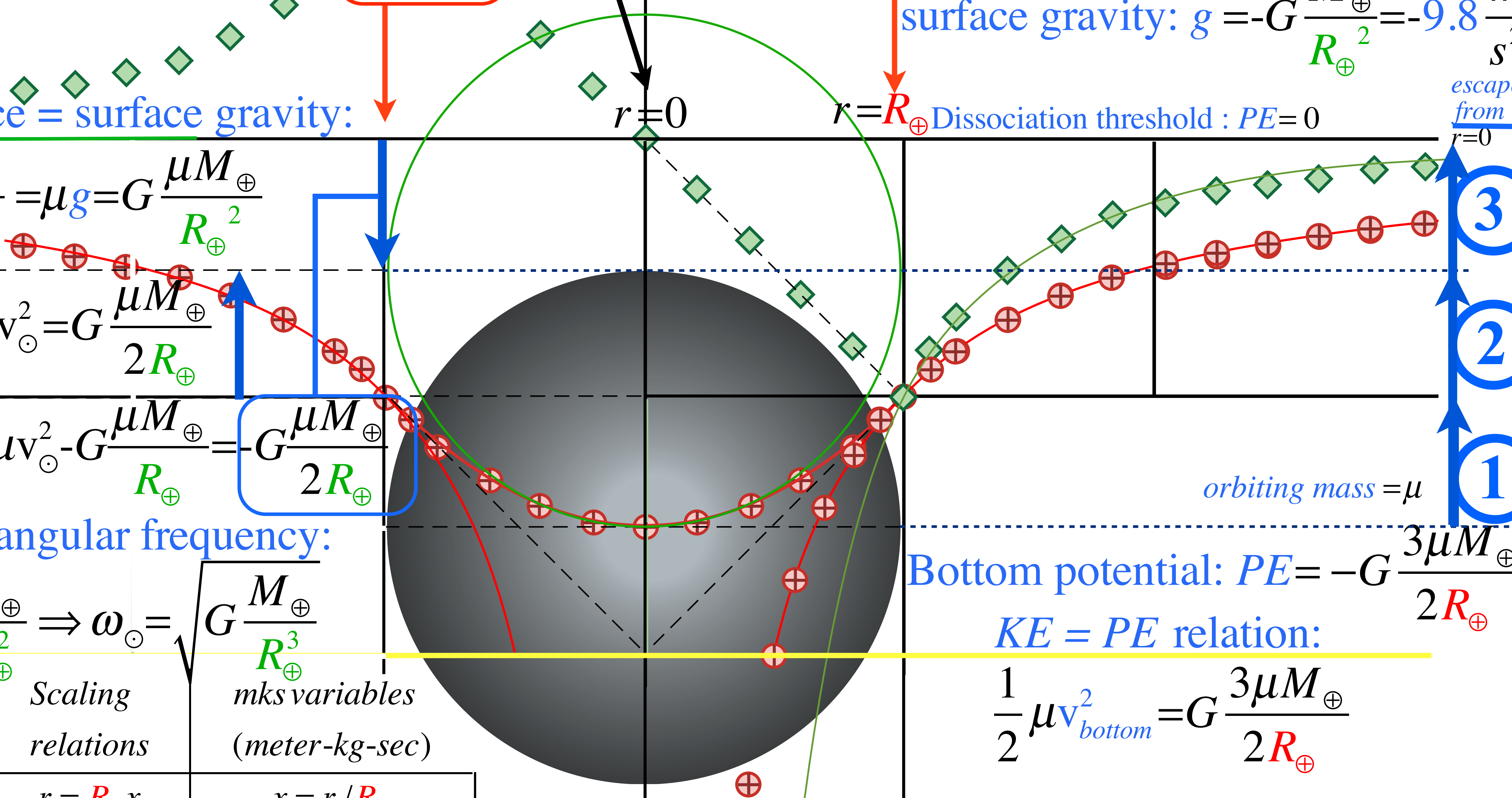
Sophomore-physics-Earth inside and out: "3-steps out of (or into) Hell" ...and surface orbit at $r=R_\oplus$



surface gravity: $g = -G\frac{M_\oplus}{R_\oplus^{\;2}} = -9.8\frac{m}{s^2}$

Centifugal force = surface gravity:

$$\frac{\mu v_\odot^2}{R_\oplus} = \mu g = G\frac{\mu M_\oplus}{R_\oplus^{\;2}}$$

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$(r=R_\oplus)$-orbit angular frequency:

$$\omega_\odot^2 R_\oplus = G\frac{M_\oplus}{R_\oplus^2} \Rightarrow \omega_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus^3}}$$

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Geometric (x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$
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inside

PE for $\lvert x\rvert < 1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
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$(r=0)$-escape-velocity

$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

13.7km/sec

$(r=R_\oplus)$-orbit speed:

$$v_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus}} = \sqrt{gR_\oplus}$$

7.9km/sec

Sophomore-physics-Earth inside and out: "3-steps out of (or into) Hell"
...and surface orbit at $r=R_\oplus$

surface gravity: $g = -G\dfrac{M_\oplus}{R_\oplus^2} = -9.8\dfrac{m}{s^2}$

Centifugal force = surface gravity:

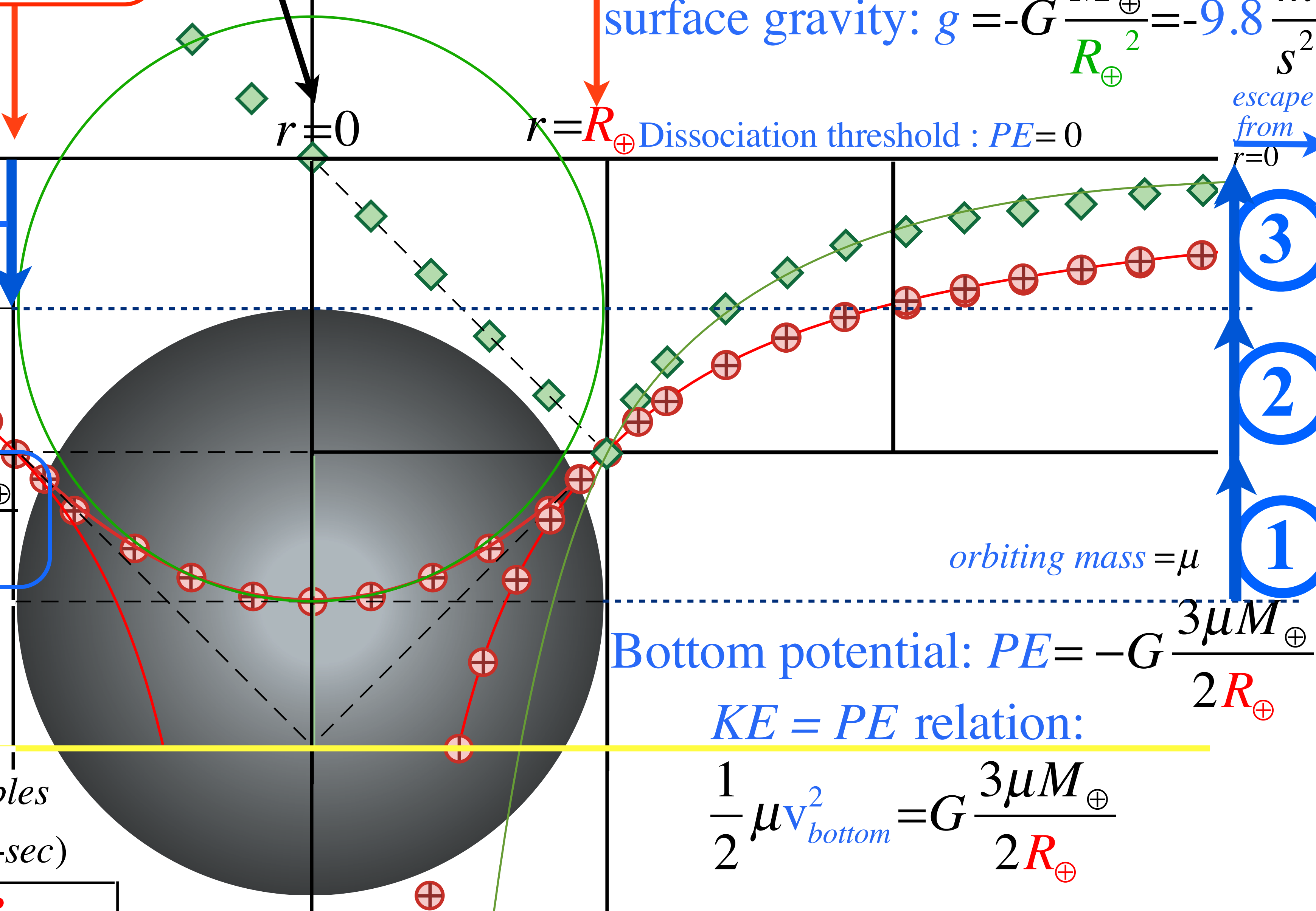
$$\frac{\mu v_\odot^2}{R_\oplus} = \mu g = G\frac{\mu M_\oplus}{R_\oplus^2}$$

Orbit KE $= \dfrac{1}{2}\mu v_\odot^2 = G\dfrac{\mu M_\oplus}{2R_\oplus}$

Orbit $E_\odot^{Total} = \dfrac{1}{2}\mu v_\odot^2 - G\dfrac{\mu M_\oplus}{R_\oplus} = -G\dfrac{\mu M_\oplus}{2R_\oplus}$

$(r=R_\oplus)$-orbit angular frequency:

$$\omega_\odot^2 R_\oplus = G\frac{M_\oplus}{R_\oplus^2} \Rightarrow \omega_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus^3}}$$



Bottom potential: $PE = -G\dfrac{3\mu M_\oplus}{2R_\oplus}$

KE = PE relation:

$$\frac{1}{2}\mu v_{bottom}^2 = G\frac{3\mu M_\oplus}{2R_\oplus}$$

Geometric (x,y) (Dimensionless)	*Scaling relations*	*mks variables (meter-kg-sec)*		*inside*
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$		
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Force for $\lvert x\rvert \geq 1$: $y^{Force} = \dfrac{-1}{x^2}$	$F^{mks}(r) = \dfrac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\dfrac{GM\mu}{r^2} = -\dfrac{GM\mu}{R_\oplus^2}\dfrac{1}{x^2}$	*Force* for $\lvert x\rvert < 1$: $y^{Force} = -x$	$F^{mks}(r) = -\dfrac{GM\mu}{R_\oplus^3} r$

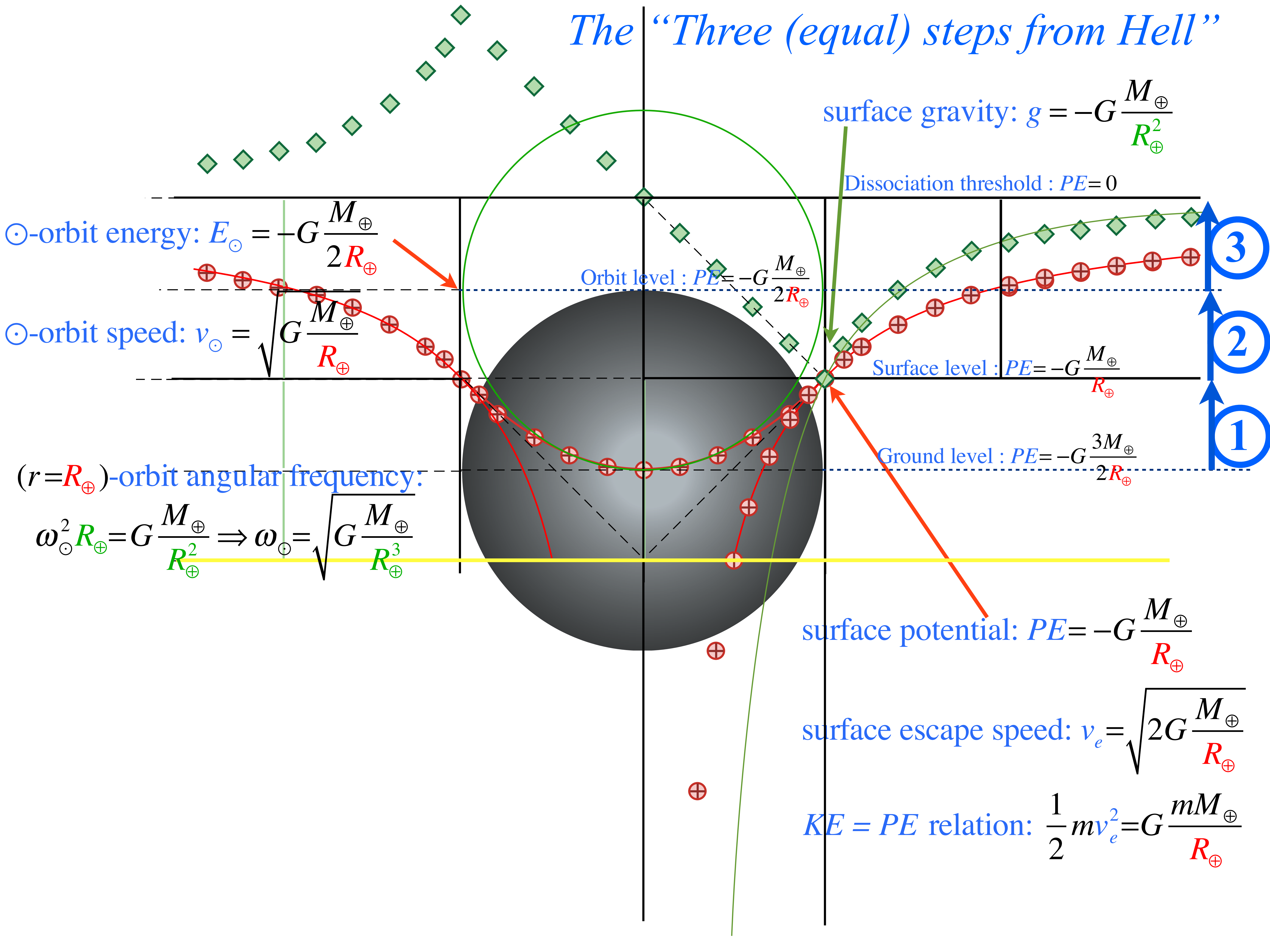
$(r=0)$-escape-velocity

$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

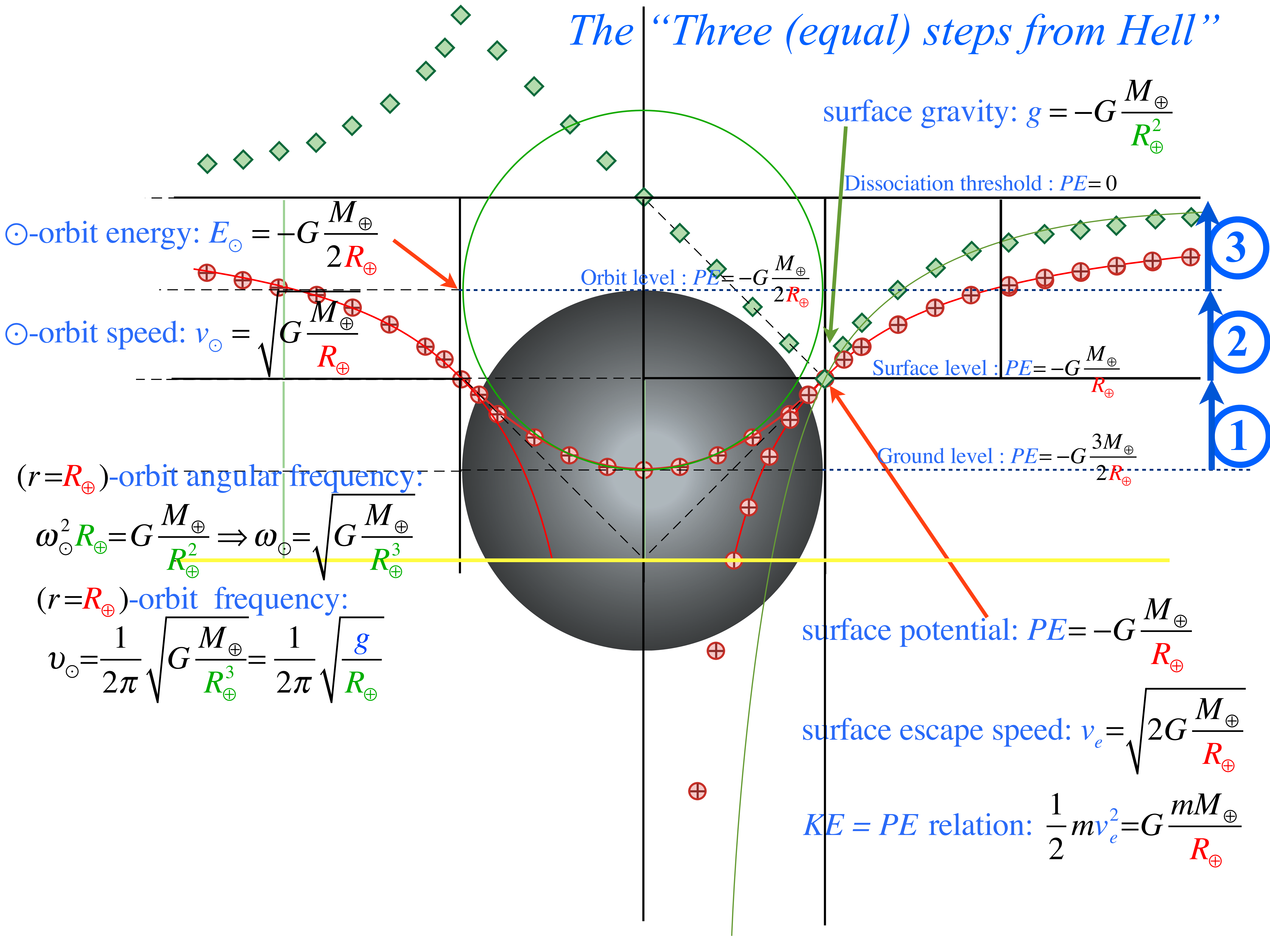
$(r=R_\oplus)$-escape velocity:

$$v_{escape} = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$$

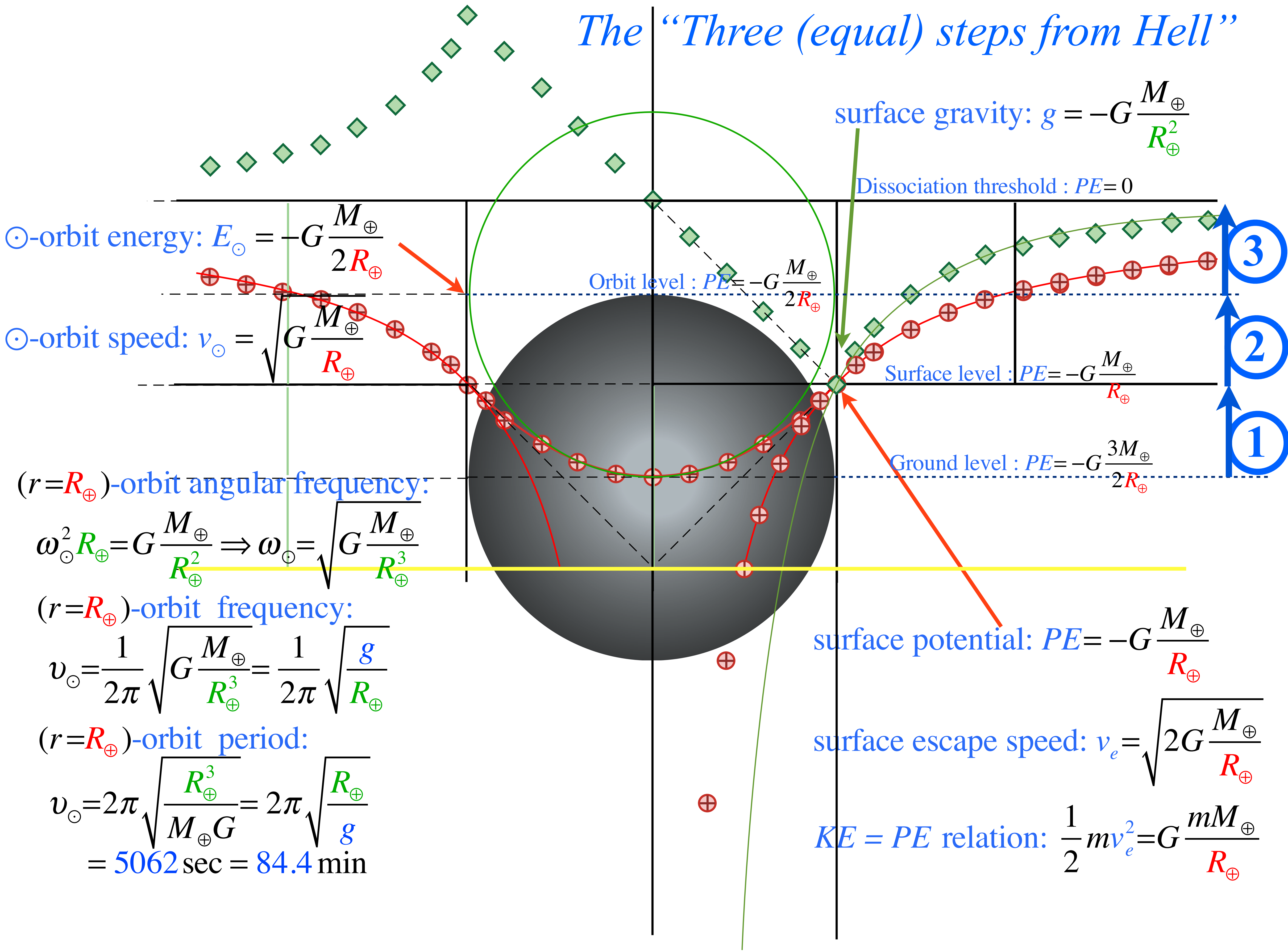
11.1km/sec



The "Three (equal) steps from Hell"
surface gravity: $g = -G\frac{M_\oplus}{R_\oplus^2}$
Dissociation threshold : $PE = 0$
⊙-orbit energy: $E_\odot = -G\frac{M_\oplus}{2R_\oplus}$
Orbit level : $PE = -G\frac{M_\oplus}{2R_\oplus}$
⊙-orbit speed: $v_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus}}$
Surface level : $PE = -G\frac{M_\oplus}{R_\oplus}$
Ground level : $PE = -G\frac{3M_\oplus}{2R_\oplus}$
3
2
1
$(r = R_\oplus)$-orbit angular frequency:
$\omega_\odot^2 R_\oplus = G\frac{M_\oplus}{R_\oplus^2} \Rightarrow \omega_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus^3}}$
surface potential: $PE = -G\frac{M_\oplus}{R_\oplus}$
surface escape speed: $v_e = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$
$KE = PE$ relation: $\frac{1}{2}mv_e^2 = G\frac{mM_\oplus}{R_\oplus}$



The "Three (equal) steps from Hell"
surface gravity: $g=-G\frac{M_\oplus}{R_\oplus^2}$
Dissociation threshold : $PE=0$
$\odot$-orbit energy: $E_\odot=-G\frac{M_\oplus}{2R_\oplus}$
Orbit level : $PE=-G\frac{M_\oplus}{2R_\oplus}$
$\odot$-orbit speed: $v_\odot=\sqrt{G\frac{M_\oplus}{R_\oplus}}$
Surface level : $PE=-G\frac{M_\oplus}{R_\oplus}$
Ground level : $PE=-G\frac{3M_\oplus}{2R_\oplus}$
3
2
1
$(r=R_\oplus)$-orbit angular frequency:
$\omega_\odot^2 R_\oplus=G\frac{M_\oplus}{R_\oplus^2}\Rightarrow\omega_\odot=\sqrt{G\frac{M_\oplus}{R_\oplus^3}}$
$(r=R_\oplus)$-orbit frequency:
$\upsilon_\odot=\frac{1}{2\pi}\sqrt{G\frac{M_\oplus}{R_\oplus^3}}=\frac{1}{2\pi}\sqrt{\frac{g}{R_\oplus}}$
surface potential: $PE=-G\frac{M_\oplus}{R_\oplus}$
surface escape speed: $v_e=\sqrt{2G\frac{M_\oplus}{R_\oplus}}$
$KE=PE$ relation: $\frac{1}{2}mv_e^2=G\frac{mM_\oplus}{R_\oplus}$



The "Three (equal) steps from Hell"
surface gravity: $g=-G\frac{M_\oplus}{R_\oplus^2}$
Dissociation threshold : $PE=0$
$\odot$-orbit energy: $E_\odot=-G\frac{M_\oplus}{2R_\oplus}$
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Surface level : $PE=-G\frac{M_\oplus}{R_\oplus}$
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3
2
1
$(r=R_\oplus)$-orbit angular frequency:
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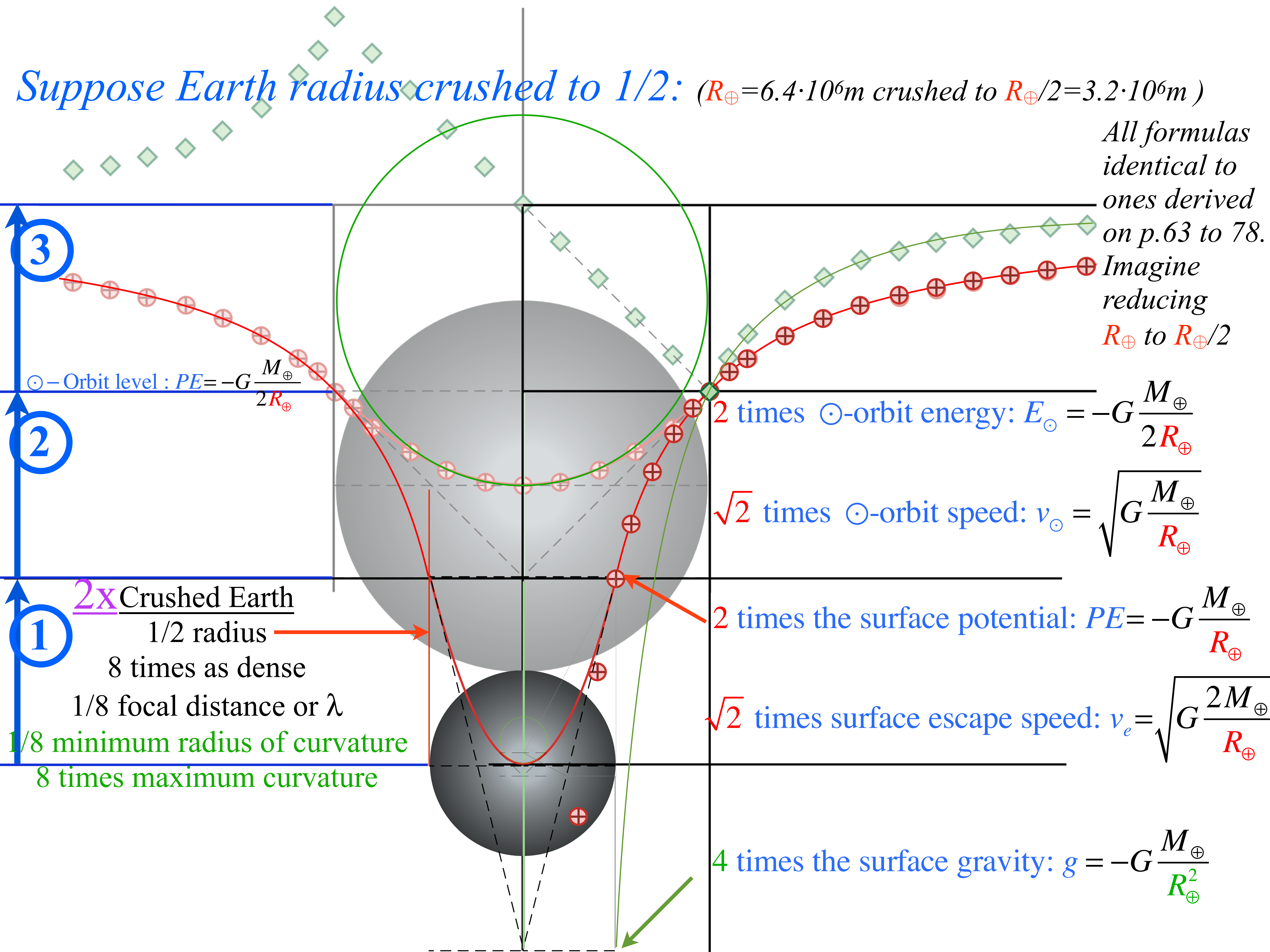
$(r=R_\oplus)$-orbit frequency:
$\upsilon_\odot=\frac{1}{2\pi}\sqrt{G\frac{M_\oplus}{R_\oplus^3}}=\frac{1}{2\pi}\sqrt{\frac{g}{R_\oplus}}$
$(r=R_\oplus)$-orbit period:
$\upsilon_\odot=2\pi\sqrt{\frac{R_\oplus^3}{M_\oplus G}}=2\pi\sqrt{\frac{R_\oplus}{g}}$
= 5062 sec = 84.4 min
surface potential: $PE=-G\frac{M_\oplus}{R_\oplus}$
surface escape speed: $v_e=\sqrt{2G\frac{M_\oplus}{R_\oplus}}$
KE = PE relation: $\frac{1}{2}mv_e^2=G\frac{mM_\oplus}{R_\oplus}$



Suppose Earth radius crushed to 1/2: ($R_\oplus$=6.4·10⁶m crushed to $R_\oplus$/2=3.2·10⁶m)
All formulas identical to ones derived on p.63 to 78.
Imagine reducing $R_\oplus$ to $R_\oplus/2$
3
2
1
⊙ – Orbit level : $PE = -G\frac{M_\oplus}{2R_\oplus}$
2 times ⊙-orbit energy: $E_\odot = -G\frac{M_\oplus}{2R_\oplus}$
$\sqrt{2}$ times ⊙-orbit speed: $v_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus}}$
2x Crushed Earth
1/2 radius
8 times as dense
1/8 focal distance or λ
1/8 minimum radius of curvature
8 times maximum curvature
2 times the surface potential: $PE = -G\frac{M_\oplus}{R_\oplus}$
$\sqrt{2}$ times surface escape speed: $v_e = \sqrt{G\frac{2M_\oplus}{R_\oplus}}$
4 times the surface gravity: $g = -G\frac{M_\oplus}{R_\oplus^2}$

Geometry of idealized "Sophomore-physics Earth"

Coulomb field outside *Isotropic Harmonic Oscillator (IHO) field inside*

Contact-geometry of potential curve(s)

"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

Earth matter vs nuclear matter:

→ *Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

Examples of "crushed" matter

Earth matter

Earth mass : $M_{\oplus} = 5.9722 \times 10^{24}\, kg. \simeq 6.0 \cdot 10^{24}\, kg.$ Density $\rho_{\oplus} = ??$

Earth radius : $R_{\oplus} = 6.371 \cdot 10^{6}\, m \simeq 6.4 \cdot 10^{6}\, m$ *Earth volume* : $(4\pi / 3) R_{\oplus}^{3} \simeq 4 \cdot 260 \cdot 10^{18} \sim 10^{21}\, m^{3}$

$(6.4)^3 \sim 262$ and $(4\pi/3)260 = 1098 \sim 10^3$

Examples of "crushed" matter

$$\rho_\oplus = \frac{M_\oplus}{(4\pi/3)R_\oplus{}^3}$$

Earth matter

$Earth\,mass: M_\oplus = 5.9722 \times 10^{24}\,kg. \simeq 6.0 \cdot 10^{24}\,kg.$ Density $\rho_\oplus \sim 6.0 \cdot 10^{24\text{-}21} \sim 6 \cdot 10^3 kg/m^3$

$Earth\,radius: R_\oplus = 6.371 \cdot 10^6\,m \simeq 6.4 \cdot 10^6\,m$ $\quad Earth\,volume: (4\pi/3)R_\oplus^3 \simeq 4 \cdot 260 \cdot 10^{18} \sim 10^{21}\,m^3$

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$(6.4)^3 \sim 262$ and $(4\pi/3)260 = 1089 \sim 10^3$

Density of solid $Fe = 7.9 \cdot 10^3 kg/m^3$

Density of liquid $Fe = 6.9 \cdot 10^3 kg/m^3$

Examples of "crushed" matter

$$\rho_{\oplus} = \frac{M_{\oplus}}{(4\pi/3)R_{\oplus}^{3}}$$

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Nuclear matter

Nucleon mass $=1.67 \cdot 10^{-27} kg. \sim 2 \cdot 10^{-27} kg.$ *("fingertip physics")*

Say a nucleus of atomic weight *50* has a radius of *3 fm*, or *50* nucleons each with a mass $2 \cdot 10^{-27} kg$.

$$\rho_\oplus = \frac{M_\oplus}{(4\pi/3)R_\oplus{}^3}$$

Examples of "crushed" matter

Earth matter

Earth mass : $M_\oplus = 5.9722 \times 10^{24}\,kg. \simeq 6.0 \cdot 10^{24}\,kg.$ Density $\rho_\oplus \sim 6.0 \cdot 10^{24-21} \sim 6 \cdot 10^3 kg/m^3$

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That's $100 \cdot 10^{-27} = 10^{-25}\,kg$ packed into a volume of ${}^{4\pi}/_{3} r^3 = {}^{4\pi}/_{3} (3 \cdot 10^{-15})^3\,m^3$ or about $10^{-43}\,m^3$.

$[4\pi 3^2 = 36\pi = 113 \sim 10^2]\,10^{-45}$

Examples of "crushed" matter

$$\rho_\oplus = \frac{M_\oplus}{(4\pi/3)R_\oplus^{\ 3}}$$

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$[4\pi 3^2 = 36\pi = 113 \sim 10^2]10^{-45}$

Nuclear density is $10^{-25+43} = 10^{18} kg/m^3$ or a *trillion* (10^{12}) kilograms in a fingertip$(1cm)^3$.

$(1cm)^3 = (10^{-2}m)^3 = 10^{-6}m^3$

Examples of "crushed" matter

$\rho_\oplus = \frac{M_\oplus}{(4\pi/3)R_\oplus^3}$

Earth matter

$Earth\,mass: M_\oplus = 5.9722 \times 10^{24}\,kg. \simeq 6.0 \cdot 10^{24}\,kg.$ Density $\rho_\oplus \sim 6.0 \cdot 10^{24-21} \sim 6 \cdot 10^3 kg/m^3$

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$(1cm)^3 = (10^{-2}m)^3 = 10^{-6}m^3$

Earth radius crushed by a factor of $0.5 \cdot 10^{-5}$ to $R_{crush\oplus} \simeq 300m$ would approach neutron-star density.

Geometry and algebra of idealized "Sophomore-physics Earth" fields

Coulomb field <u>outside</u> *Isotropic Harmonic Oscillator (IHO) field <u>inside</u>*

Contact-geometry of potential curve(s) and "kite" geometry

"Ordinary-Earth" models: 3 key energy "steps" and 4 key energy "levels"

"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

Earth matter vs nuclear matter:

→ *Introducing the "neutron starlet"*

*Fantasizing a "***Black-Hole-Earth***"*

$\rho_{\oplus} = \frac{M_{\oplus}}{(4\pi/3)R_{\oplus}^3}$

Examples of "crushed" matter

Earth matter

$Earth\,mass: M_{\oplus} = 5.9722 \times 10^{24}\,kg. \simeq 6.0 \cdot 10^{24}\,kg.$ Density $\rho_{\oplus} \sim 6.0 \cdot 10^{24-21} \sim 6 \cdot 10^3 kg/m^3$

$Earth\,radius: R_{\oplus} = 6.371 \cdot 10^6\,m \simeq 6.4 \cdot 10^6\,m$ $\quad Earth\,volume: (4\pi/3)R_{\oplus}^3 \simeq 4 \cdot 260 \cdot 10^{18} \sim 10^{21}\,m^3$

Nuclear matter

Nucleon mass $=1.67 \cdot 10^{-27} kg. \sim 2 \cdot 10^{-27} kg.$

Say a nucleus of atomic weight *50* has a radius of *3 fm*, or *50* nucleons each with a mass $2 \cdot 10^{-27} kg$.

That's $100 \cdot 10^{-27} = 10^{-25}\,kg$ packed into a volume of $\frac{4\pi}{3} r^3 = \frac{4\pi}{3}(3 \cdot 10^{-15})^3\,m^3$ or about $10^{-43}\,m^3$.

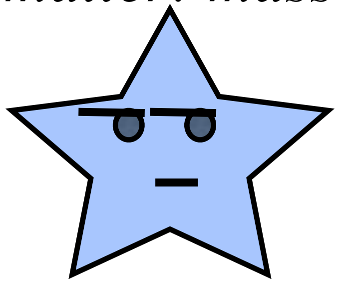
$[4\pi 3^2 = 36\pi = 113 \sim 10^2]10^{-45}$

Nuclear density is $10^{-25+43} = 10^{18} kg/m^3$ or a *trillion* (10^{12}) kilograms in the size of a fingertip.

Earth radius crushed by a factor of $0.5 \cdot 10^{-5}$ to $R_{crush\oplus} \simeq 300m$ would approach neutron-star density.

Introducing the "Neutron starlet"

1 cm^3 *of nuclear matter: mass=* 10^{12} *kg.*



Geometry and algebra of idealized "Sophomore-physics Earth" fields

Coulomb field outside *Isotropic Harmonic Oscillator (IHO) field inside*

Contact-geometry of potential curve(s) and "kite" geometry

"Ordinary-Earth" models: 3 key energy "steps" and 4 key energy "levels"

"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

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Introducing the "neutron starlet"

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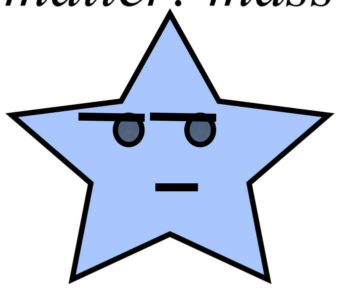

*Fantasizing the "***Black Hole Earth***"*

Suppose Earth is crushed so that its surface escape velocity is the speed of light $c \cong 3.0 \cdot 10^8 m/s$.

$c \equiv 299{,}792{,}458 m/s$ (EXACTLY)

$V_{escape} = \sqrt{(2GM/R_\otimes)}$

(from p. 67,..,82)

Uncrushed Earth radius : $R_\oplus = 6.371 \cdot 10^6\,m \simeq 6.4 \cdot 10^6\,m$

Earth mass : $M_\oplus = 5.9722 \times 10^{24}\,kg. \simeq 6.0 \cdot 10^{24}\,kg.$

$G = 6.673 \cdot 10^{-11} Nm^2/C^2$

$\sim (2/3) 10^{-10}$

(from p. 60)

Examples of "crushed" matter

$\rho_\oplus = \dfrac{M_\oplus}{(4\pi/3)R_\oplus^{\,3}}$

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Nuclear matter
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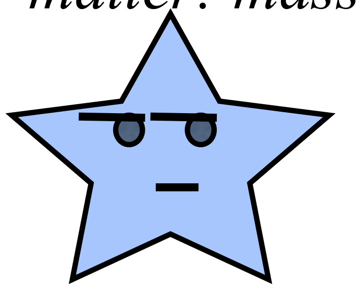

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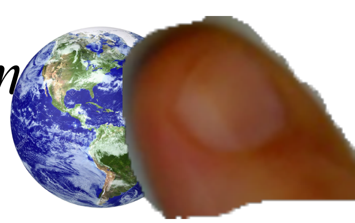
(from p. 60)

$R_\otimes = 2GM/c^2 = 2\,^2/_3 10^{-10}\, 6 \cdot 10^{24}/(9 \cdot 10^{16}) = \,^8/_9 10^{-2} = 8.9mm \sim 1cm$

(Then Earth would be fingertip size!)

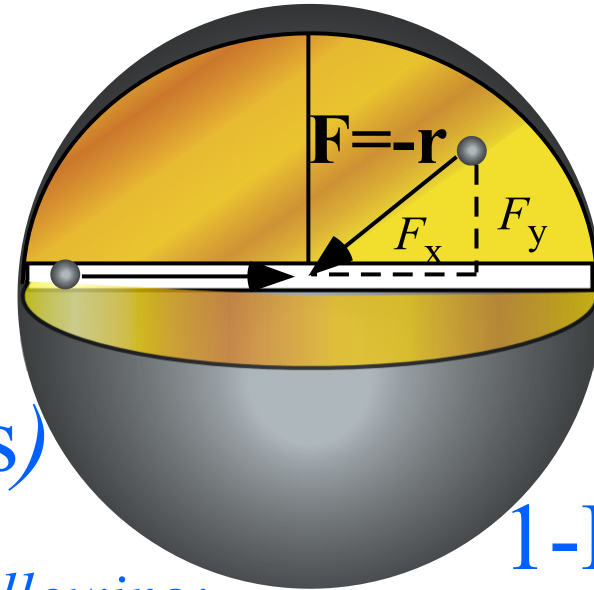


→ *Introducing 2D IHO orbits and phasor geometry*

Phasor "clock" geometry

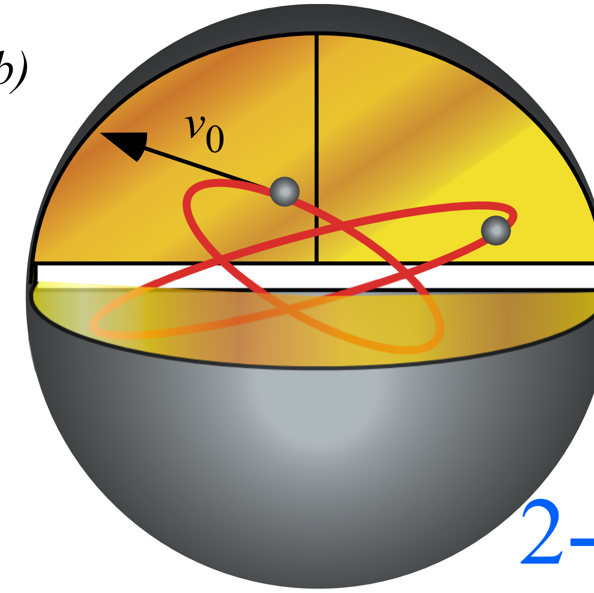
Isotropic Harmonic Oscillator phase dynamics in uniform-body

(a)



1-D

(b)



2-D

Unit 1
Fig. 9.10

(Paths are *always* 2-D ellipses if viewed right!)

I.H.O. Force law

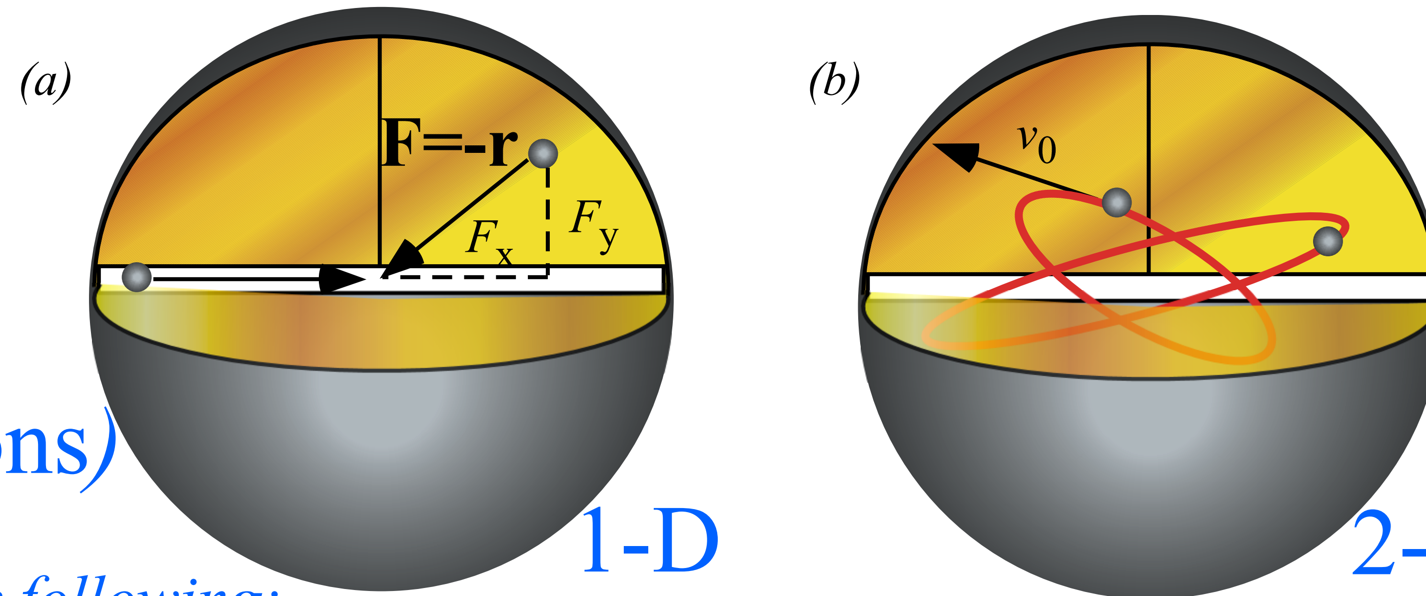
$F = -x$ (1-Dimension)

$\mathbf{F} = -\mathbf{r}$ (2 or 3-Dimensions)

Each dimension x, y, or z obeys the following:

$$Total\ E = KE + PE = \frac{1}{2}mv^2 + U(x) = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = const.$$

Isotropic Harmonic Oscillator phase dynamics in uniform-body



1-D

2-D or 3-D

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Unit 1
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Isotropic Harmonic Oscillator phase dynamics in uniform-body

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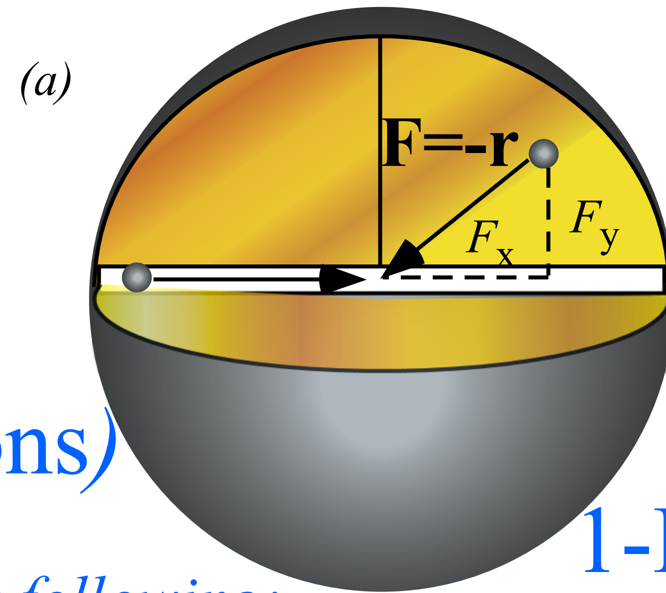
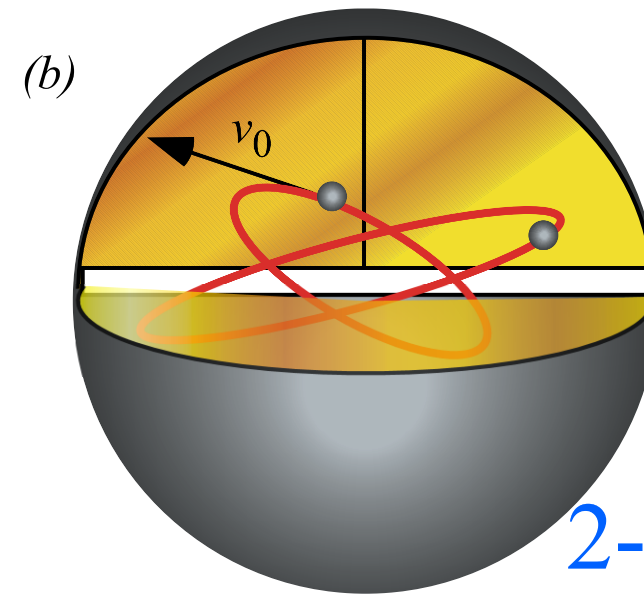


1-D

(b)



2-D or 3-D

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Unit 1
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Another example of the old "scale-a-circle" trick...

velocity: *position:*

$$Let: \ \mathbf{(1)}\ v = \sqrt{2E/m}\cos\theta, \quad and: \ \mathbf{(2)}\ x = \sqrt{2E/k}\sin\theta$$

Isotropic Harmonic Oscillator phase dynamics in uniform-body

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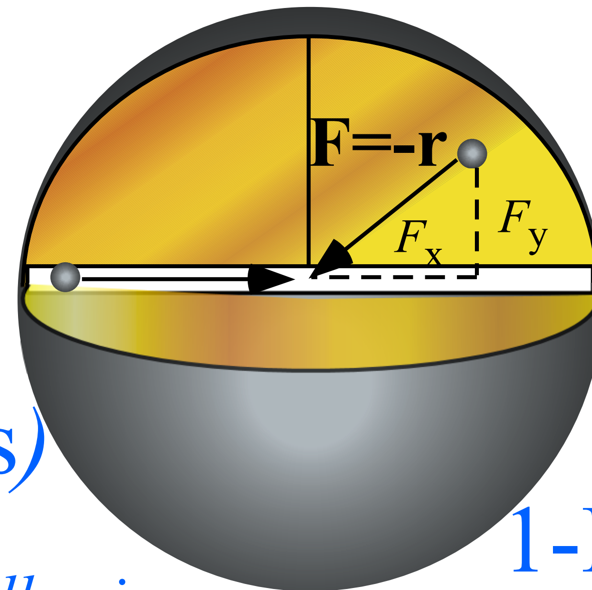
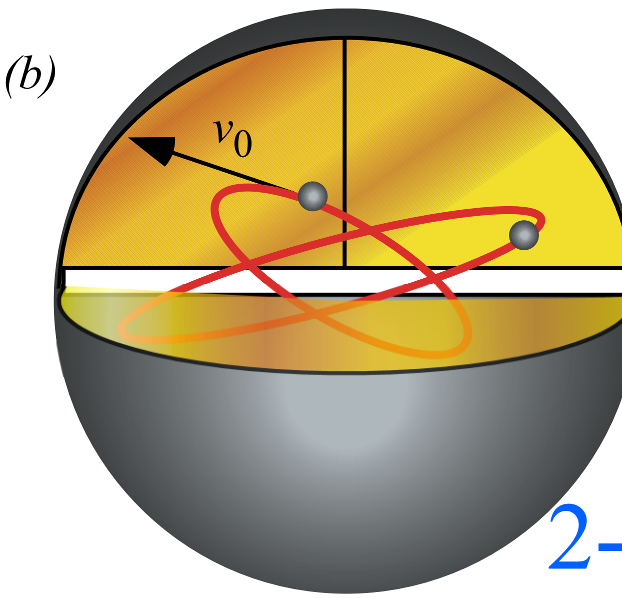


1-D

(b)



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Unit 1
Fig. 9.10

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Isotropic Harmonic Oscillator phase dynamics in uniform-body

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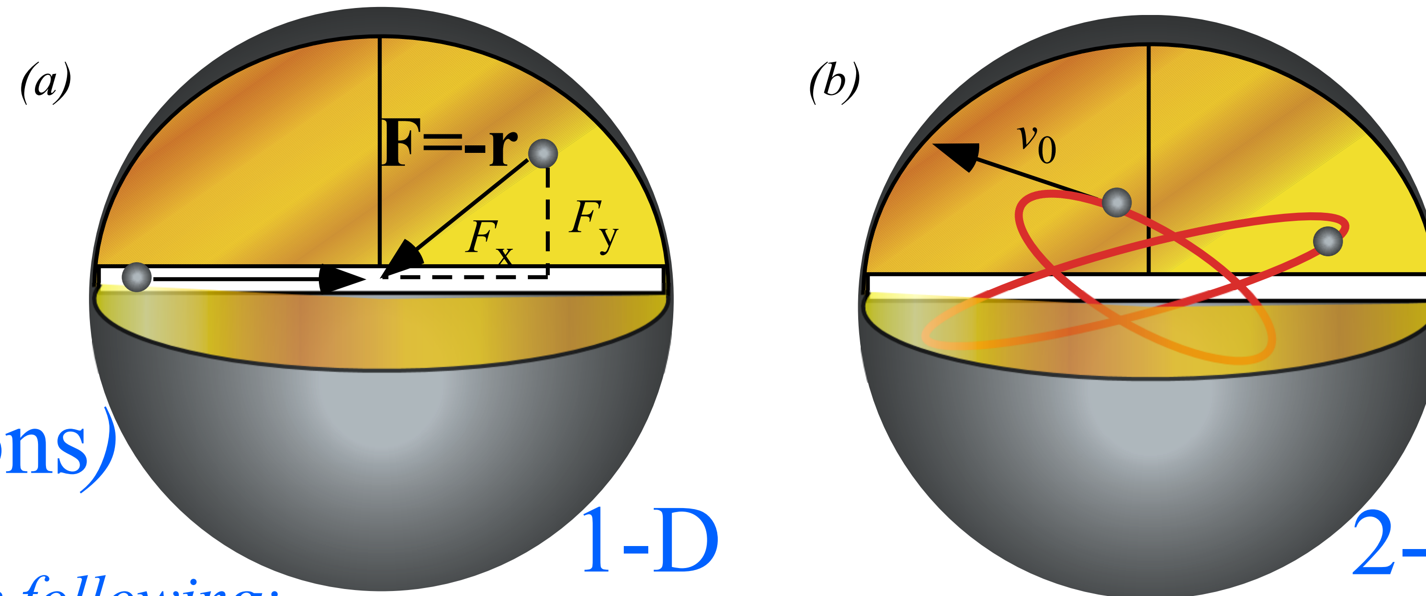

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$$\sqrt{\frac{2E}{m}}\cos\theta = v = \frac{dx}{dt}$$

by **(1)**

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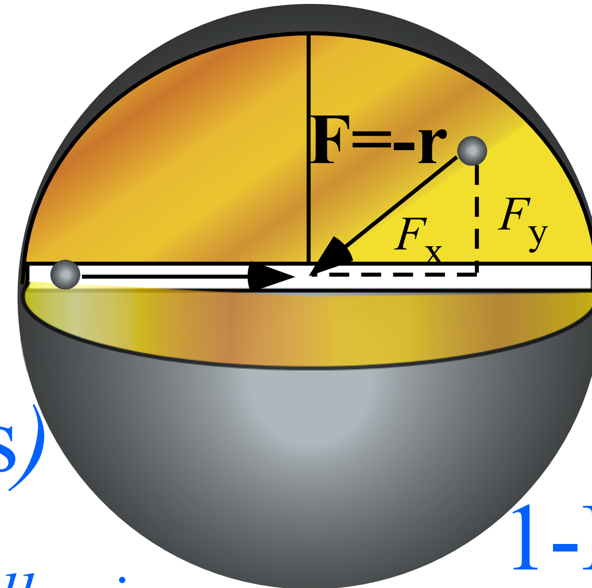
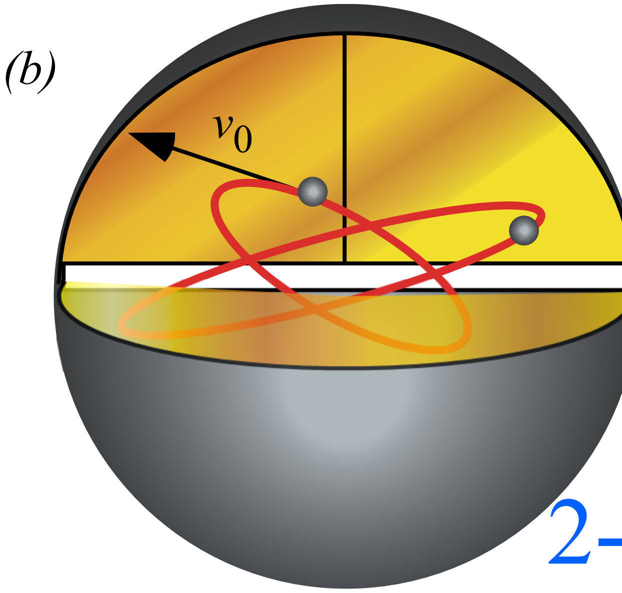


1-D

(b)



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angular velocity: *def.* **(3)** $\omega = \frac{d\theta}{dt}$

$$\sqrt{\frac{2E}{m}}\cos\theta = v = \frac{dx}{dt} = \frac{d\theta}{dt}\frac{dx}{d\theta}$$

by **(1)**

Isotropic Harmonic Oscillator phase dynamics in uniform-body

I.H.O. Force law

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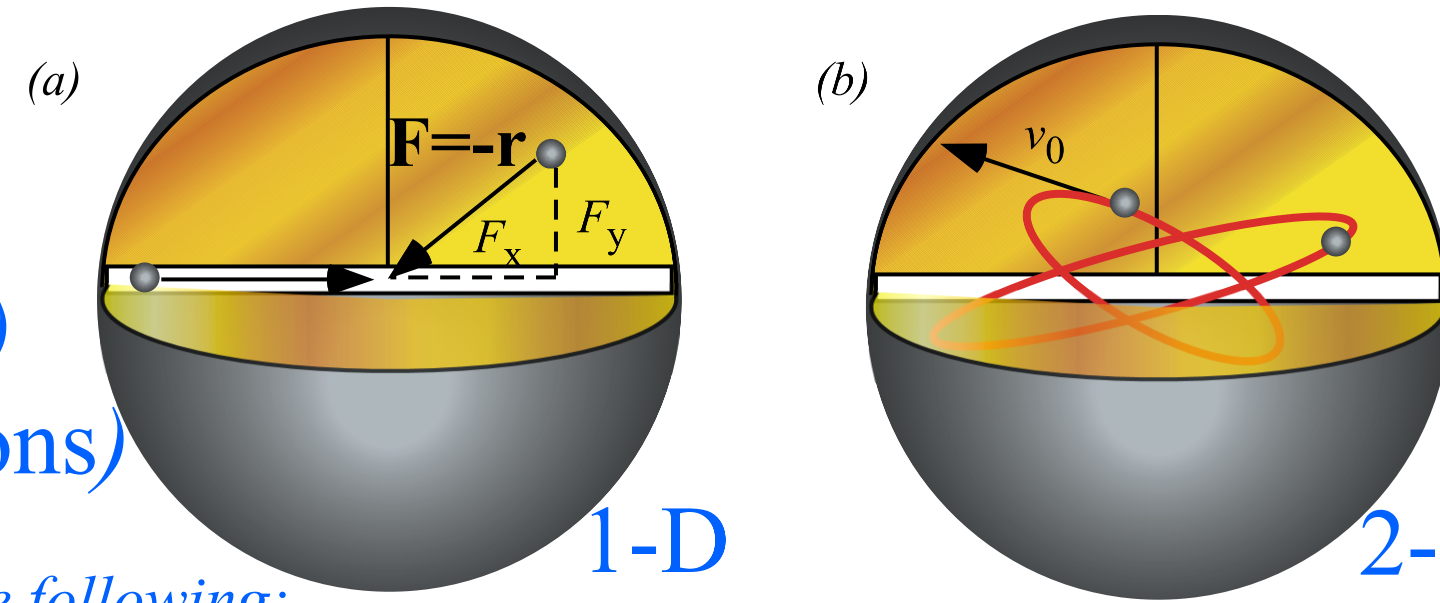

Unit 1
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by **(1)** *by def.* **(3)**

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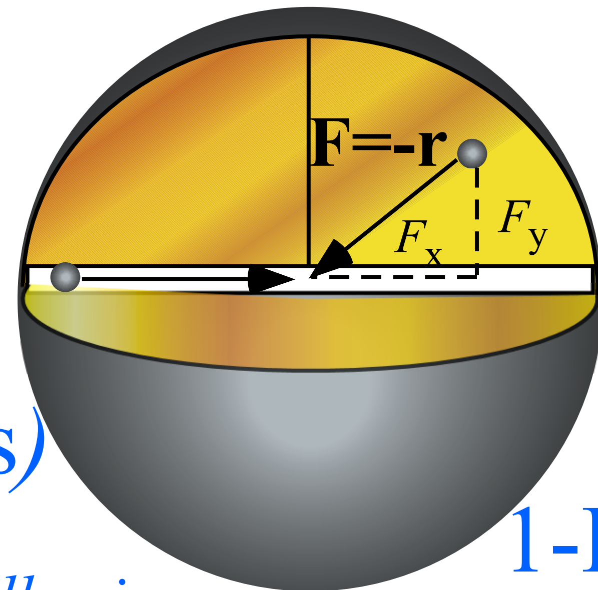
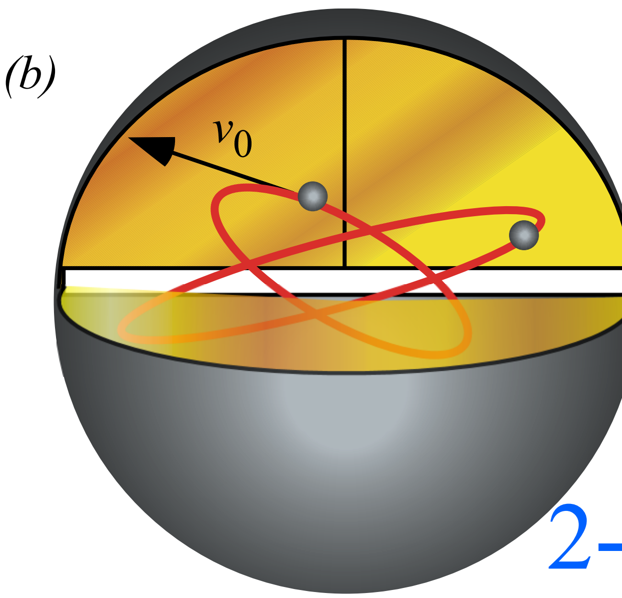


1-D

(b)



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by (1) *by def.* (3) *by* (2)

Isotropic Harmonic Oscillator phase dynamics in uniform-body

I.H.O. Force law

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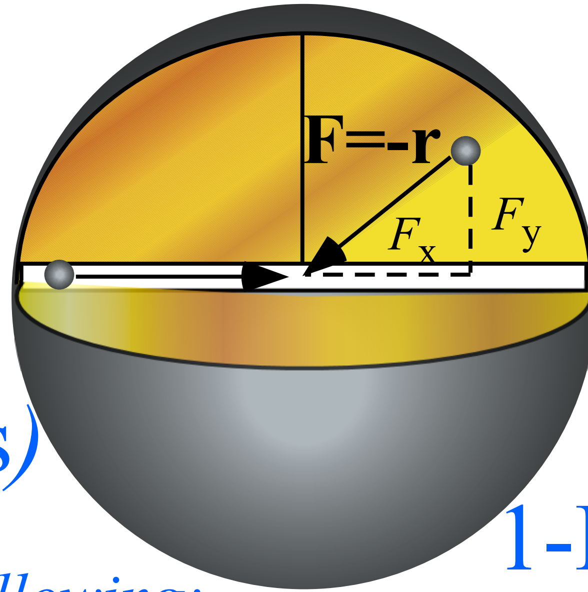
(a)



1-D

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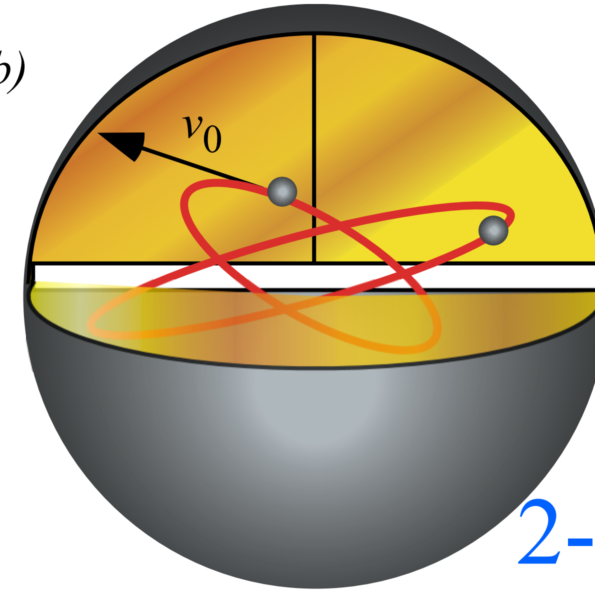

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Unit 1
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by **(1)** *by def.* **(3)** *by* **(2)**

by def. **(3)**

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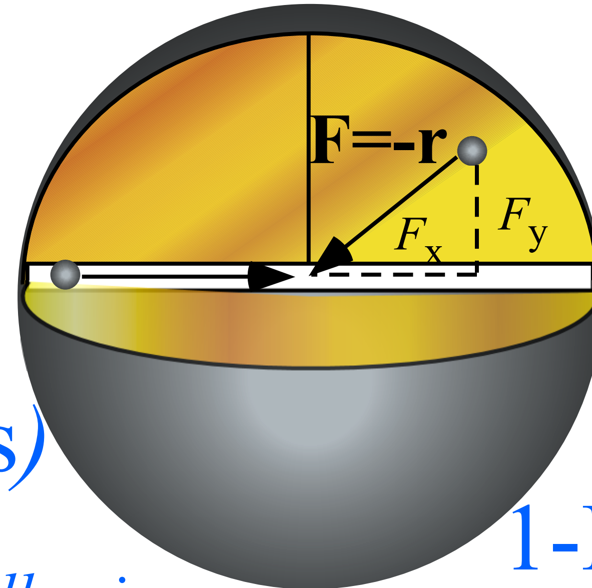
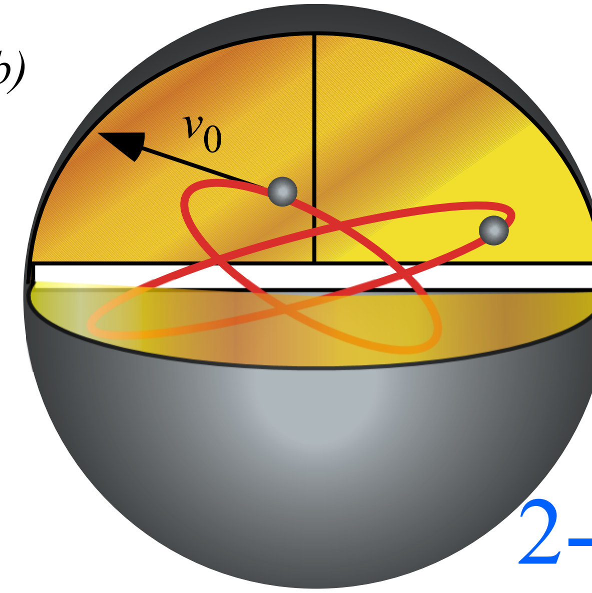


1-D

(b)



Unit 1
Fig. 9.10

2-D or 3-D

(Paths are *always* 2-D ellipses if viewed right!)

Each dimension x, y, or z obeys the following:

$$Total\ E = KE + PE = \frac{1}{2}mv^2 + U(x) = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = const.$$

Equations for x-motion [x(t) and v_x=v(t)] are given first. They apply as well to dimensions [y(t) and v_y=v(t)] and [z(t) and v_z=v(t)] in the ideal isotropic case.

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$$1 = \frac{mv^2}{2E} + \frac{kx^2}{2E} = (\cos\theta)^2 + (\sin\theta)^2$$

Another example of the old "scale-a-circle" trick...

$$Let:\ \textbf{(1)}\ v = \sqrt{2E/m}\cos\theta, \quad and:\ \textbf{(2)}\ x = \sqrt{2E/k}\sin\theta$$

def. **(3)** $\omega = \frac{d\theta}{dt}$

$$\sqrt{\frac{2E}{m}}\cos\theta = v = \frac{dx}{dt} = \frac{d\theta}{dt}\frac{dx}{d\theta} = \omega\frac{dx}{d\theta} = \omega\sqrt{\frac{2E}{k}}\cos\theta$$

by **(1)** — *by def.* **(3)** — *by* **(2)**

by def. **(3)** *divide* **(1)**

$$\omega = \frac{d\theta}{dt} = \frac{\sqrt{\frac{2E}{m}}\cos\theta}{\sqrt{\frac{2E}{k}}\cos\theta}$$

by **(2)** *derivative*

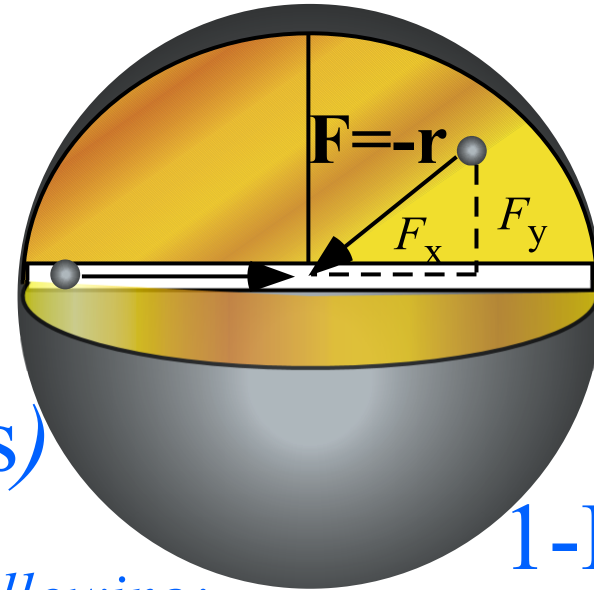
Isotropic Harmonic Oscillator phase dynamics in uniform-body

I.H.O. Force law

$F = -x$ (1-Dimension)

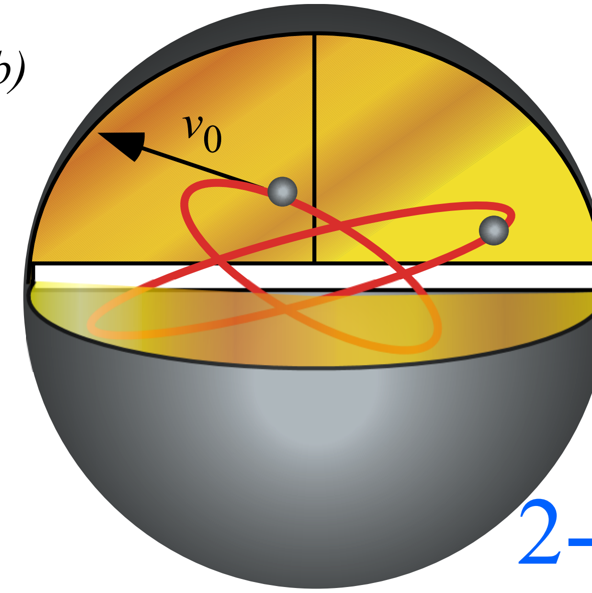
$\mathbf{F} = -\mathbf{r}$ (2 or 3-Dimensions)

(a)



1-D

(b)



Unit 1
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by (1) — by def. (3) — by (2)

by def. (3)

$$\omega = \frac{d\theta}{dt} = \frac{\sqrt{\frac{2E}{m}}\cos\theta}{\sqrt{\frac{2E}{k}}\cos\theta} = \sqrt{\frac{k}{m}}$$

divide (1)

by (2) derivative

Isotropic Harmonic Oscillator phase dynamics in uniform-body

I.H.O. Force law

$F = -x$ (1-Dimension)

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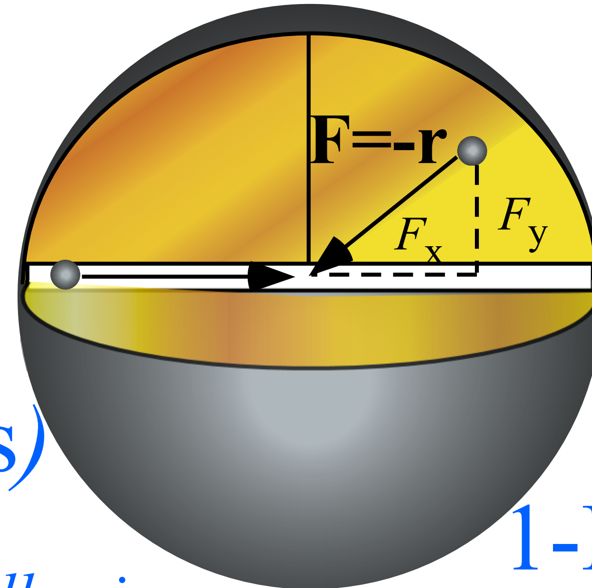
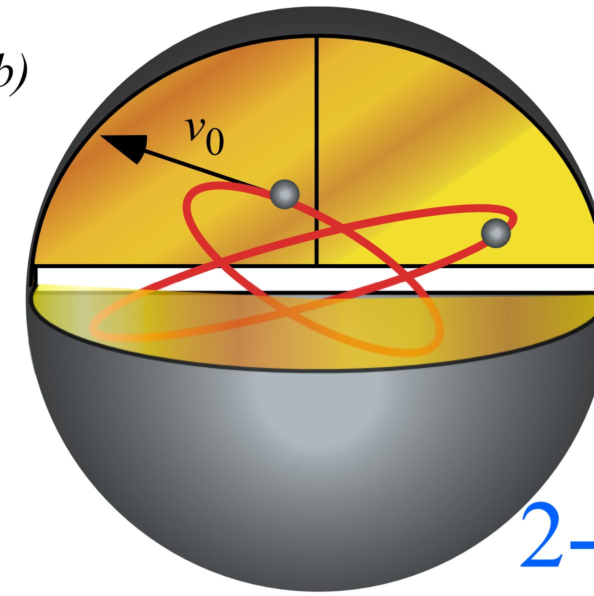


1-D

(b)



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Unit 1
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by (1) — by def. (3) — by (2)

by def. (3)

$$\omega = \frac{d\theta}{dt} = \sqrt{\frac{k}{m}}$$

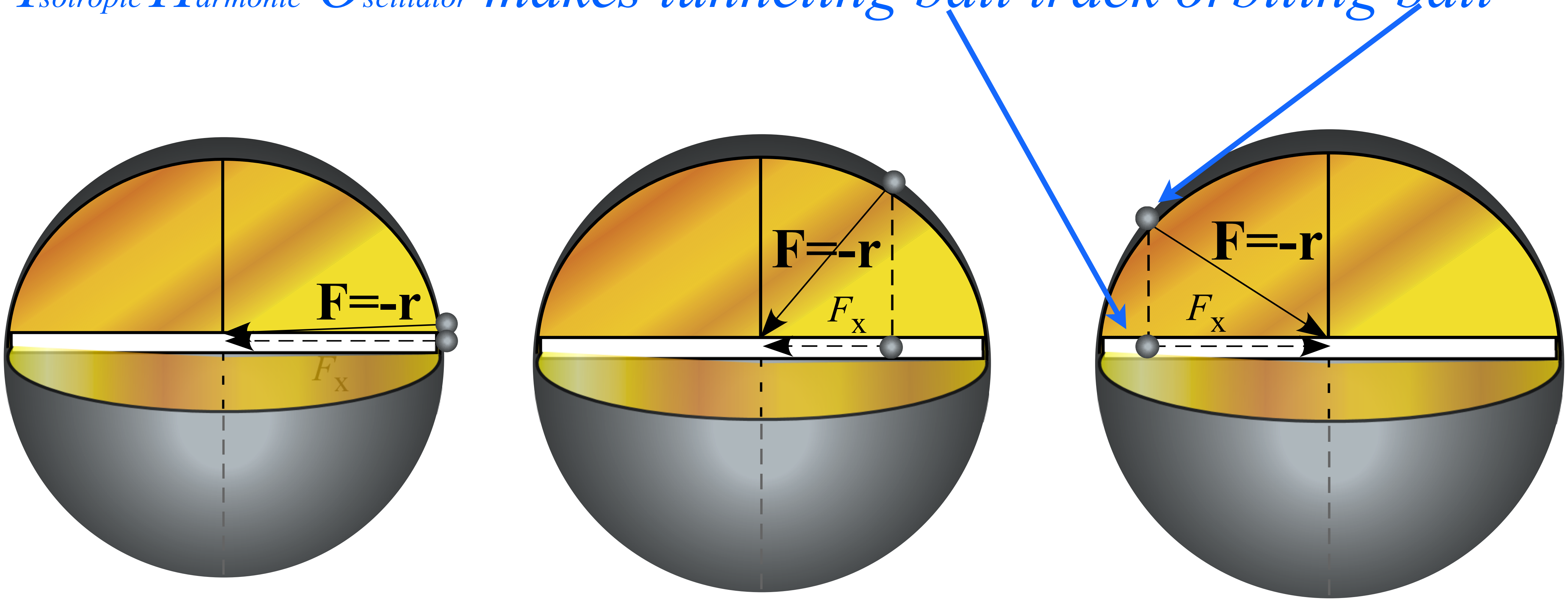
by integration given constant ω:

$$\theta = \int \omega \cdot dt = \omega \cdot t + \alpha$$

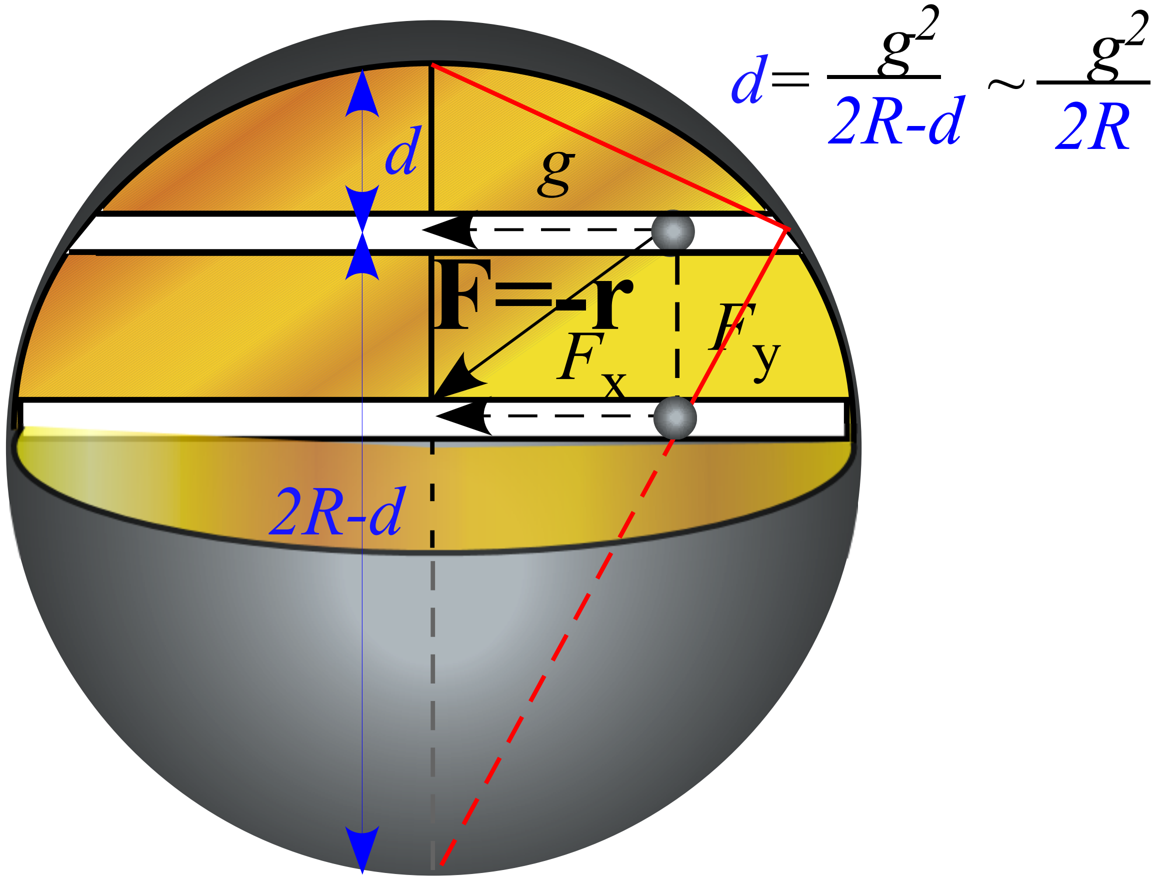
→ *Introducing 2D IHO orbits and phasor geometry*

Phasor "clock" geometry

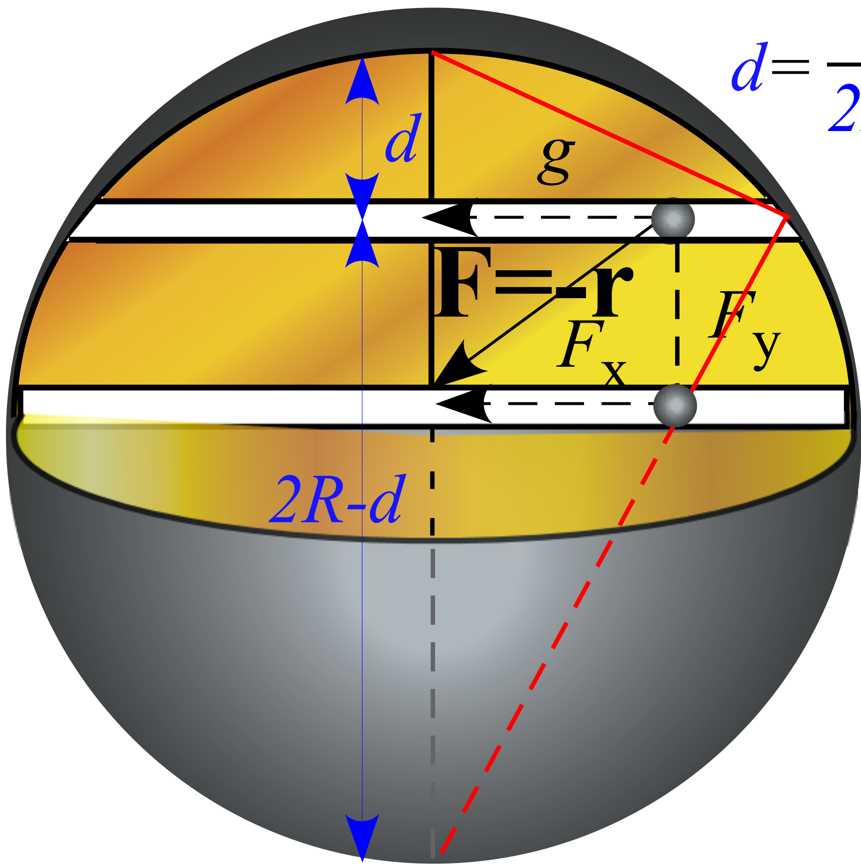
*I*sotropic *H*armonic *O*scillator *makes tunneling ball track orbiting ball*



Isotropic Harmonic Oscillator makes balls in parallel tunnel track each other



$I_{sotropic}\,H_{armonic}\,O_{scillator}$ makes balls in parallel tunnels track each other...



$$d = \frac{g^2}{2R-d} \sim \frac{g^2}{2R}$$

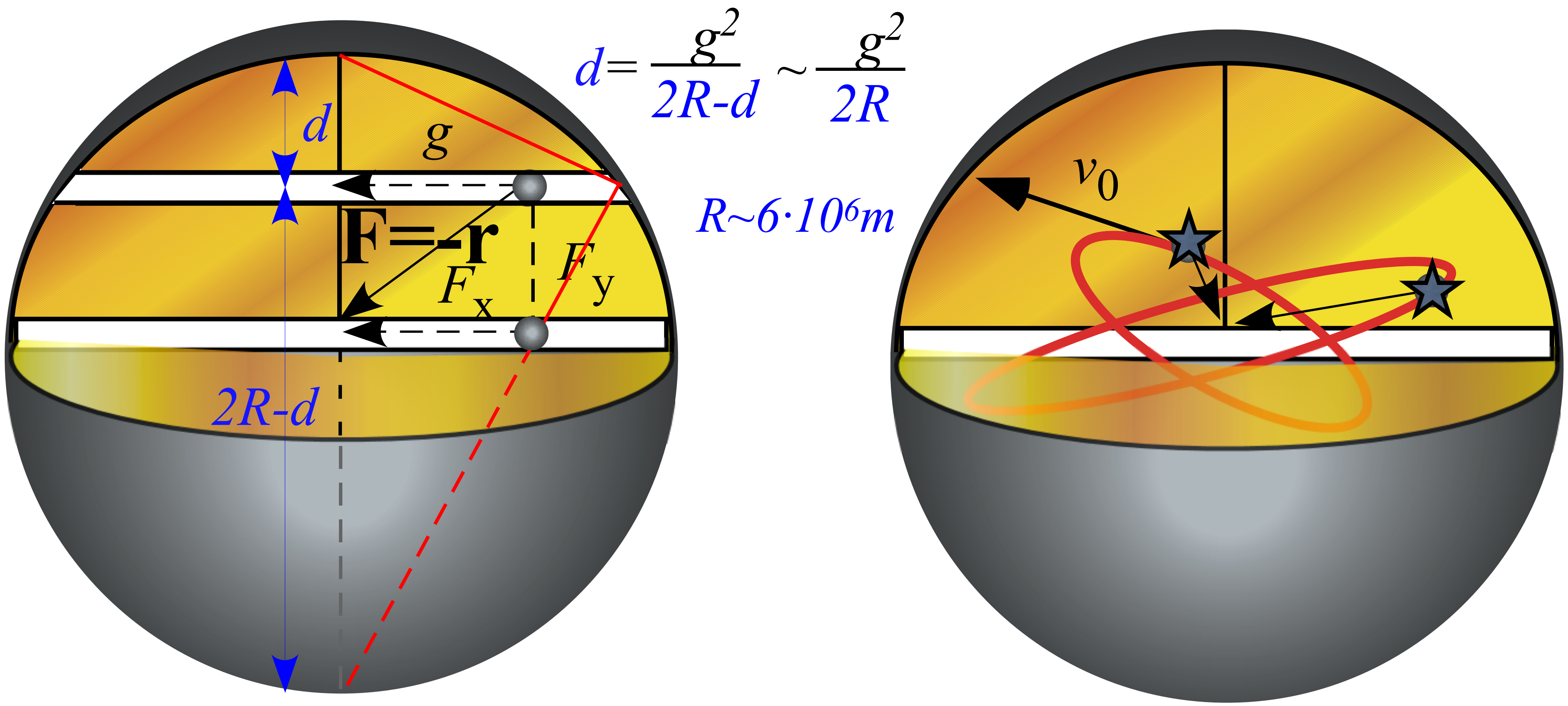
$R \sim 6 \cdot 10^6 m$

$$d \sim \frac{1}{2R}$$

...even if track length is just $g = 1m$ so $d \sim (1/12)$micron

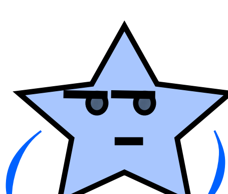
They all take about 84 minutes to go from right to left and back, again.

Isotropic Harmonic Oscillator makes balls in parallel tunnels track each other...



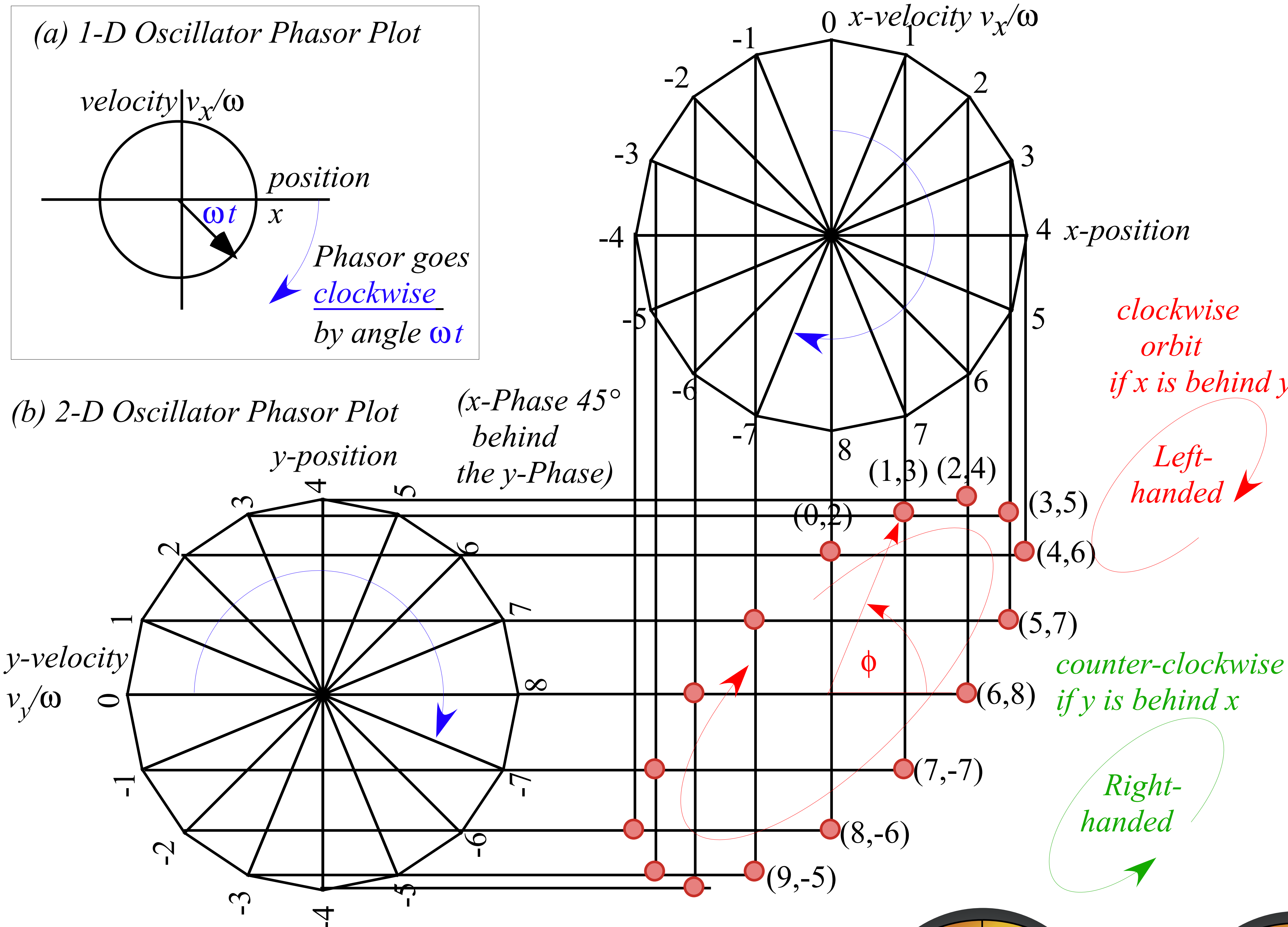
...even if track length is just g =1m so d=(1/12)micron

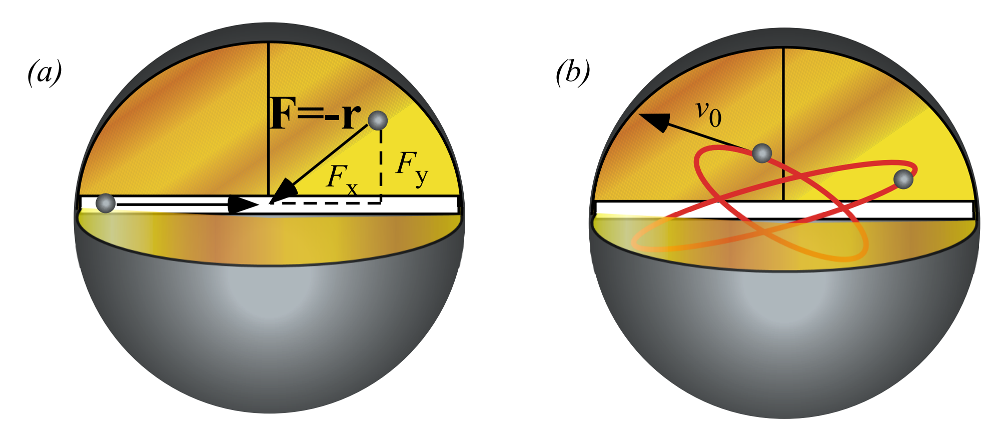
The all take about 84 minutes to go from right to left and back, again.

Most neutron starlet ()orbits are centered ellipses

Isotropic Harmonic Oscillator phase dynamics in uniform-body

Unit 1
Fig. 9.10





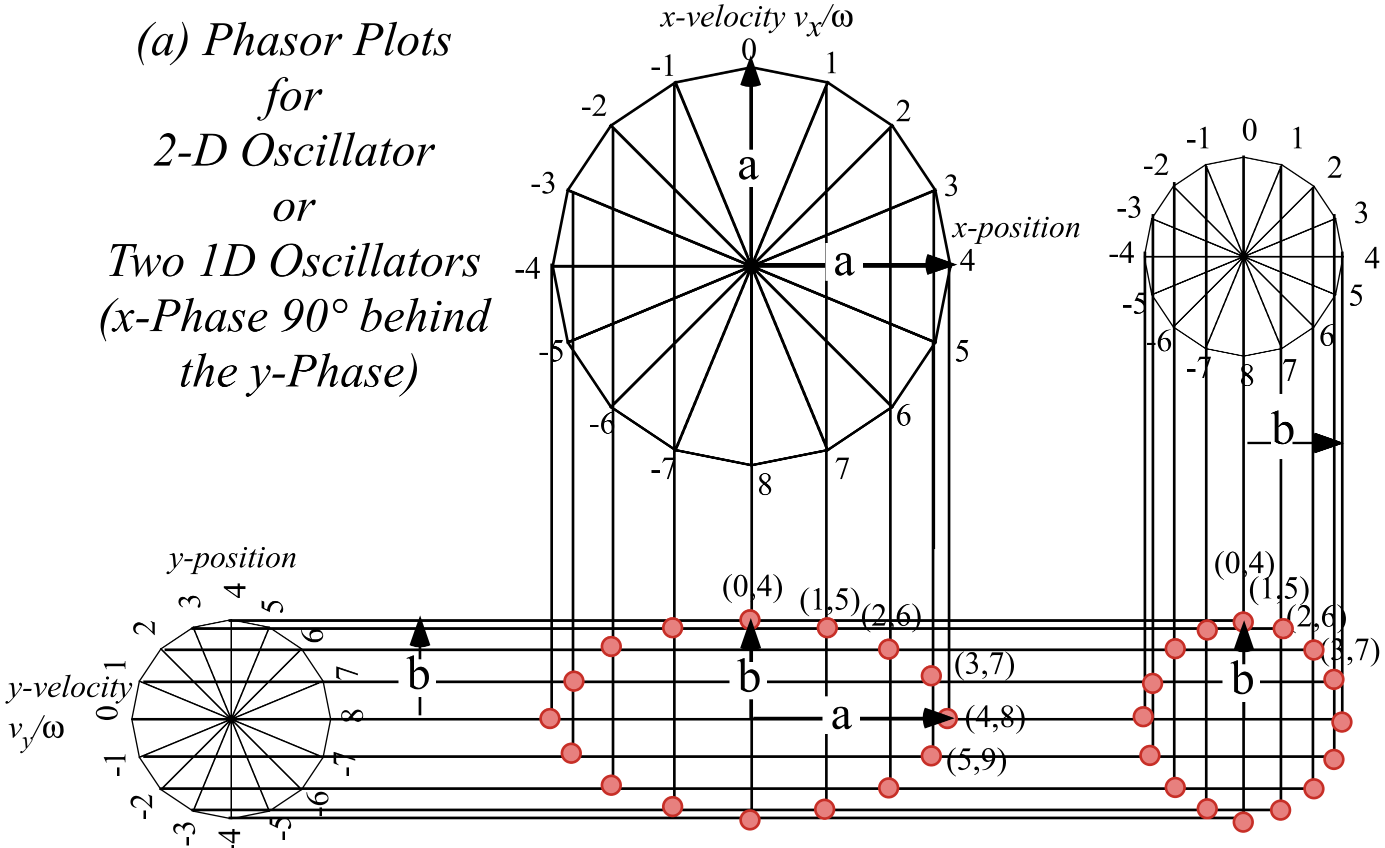
RelaWavity web simulation - Contact ellipsometry

Introduction to Phasors at our Pirelli Relativity Site

BoxIt web simulation - *With y-Phasor is on other side of xy plot*

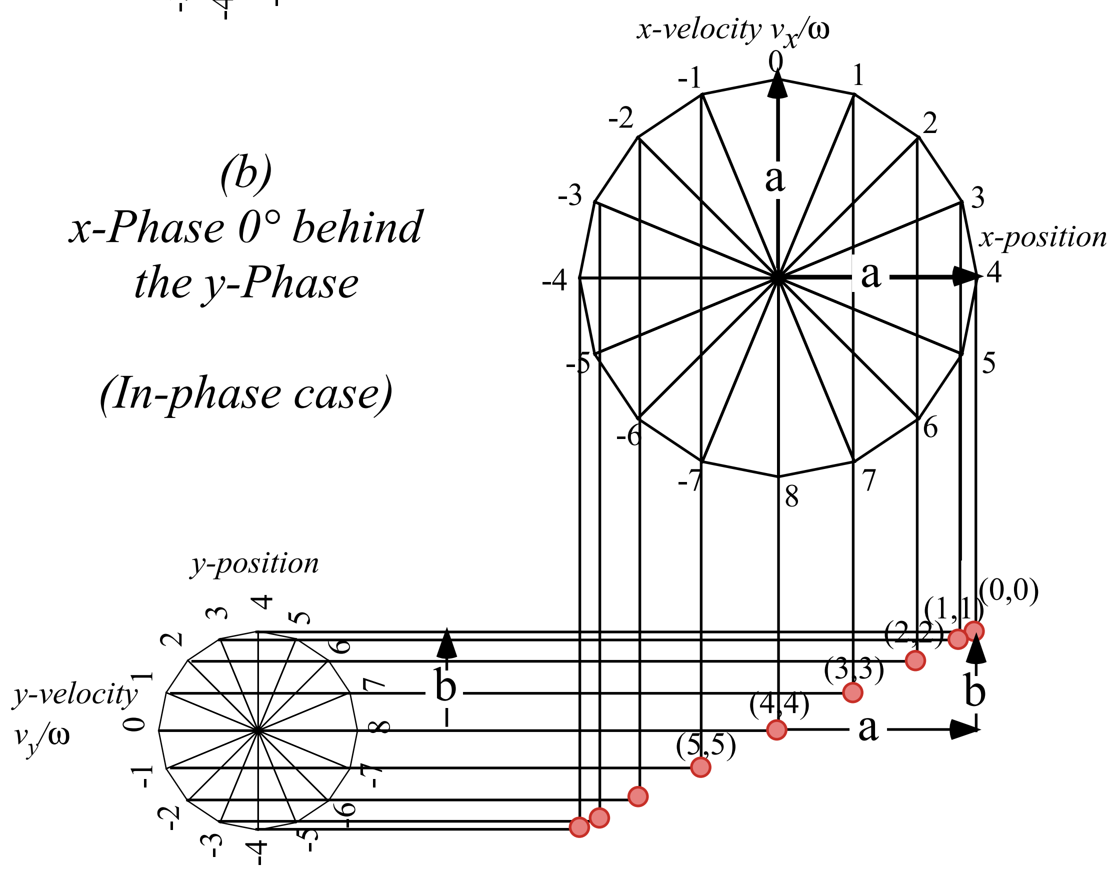
Unit 1
Fig. 9.12

(a) Phasor Plots for 2-D Oscillator or Two 1D Oscillators (x-Phase 90° behind the y-Phase)



(b) x-Phase 0° behind the y-Phase

(In-phase case)



These are more generic examples with radius of x-phasor differing from that of the y-phasor.

RelaWavity web simulation - Contact ellipsometry *(User Mouse Input allowed for setting phasor values)*