Lecture 6
Thur. 9.07.2017

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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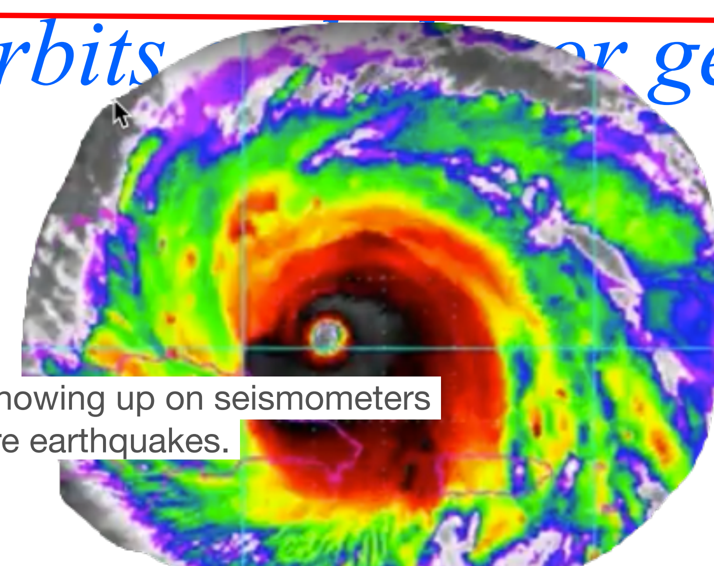
MONSTERS!

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.

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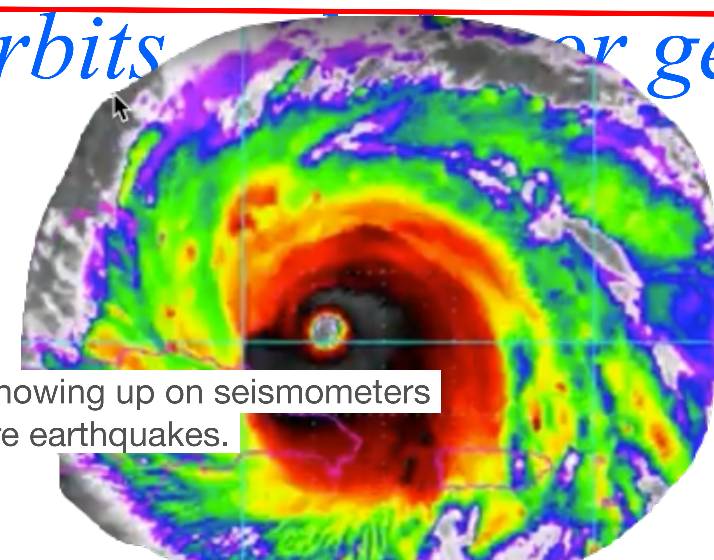

Hurricane Irma is so strong it's showing up on seismometers — equipment designed to measure earthquakes.

Climate change is **Chinese Hoax!**

Geometry of common power-law potentials

Geometric (Power) series

→ *"Zig-Zag" exponential geometry*

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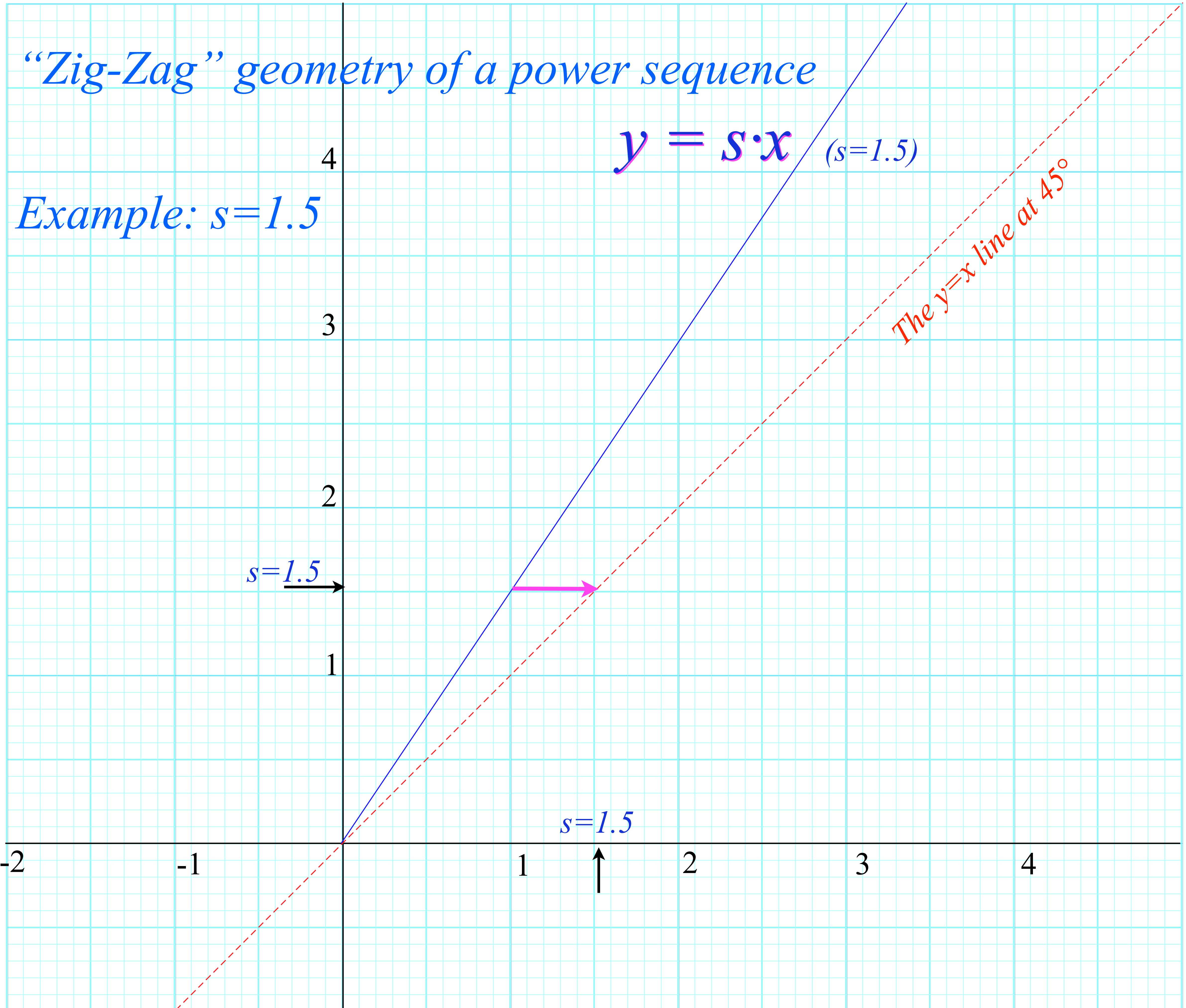
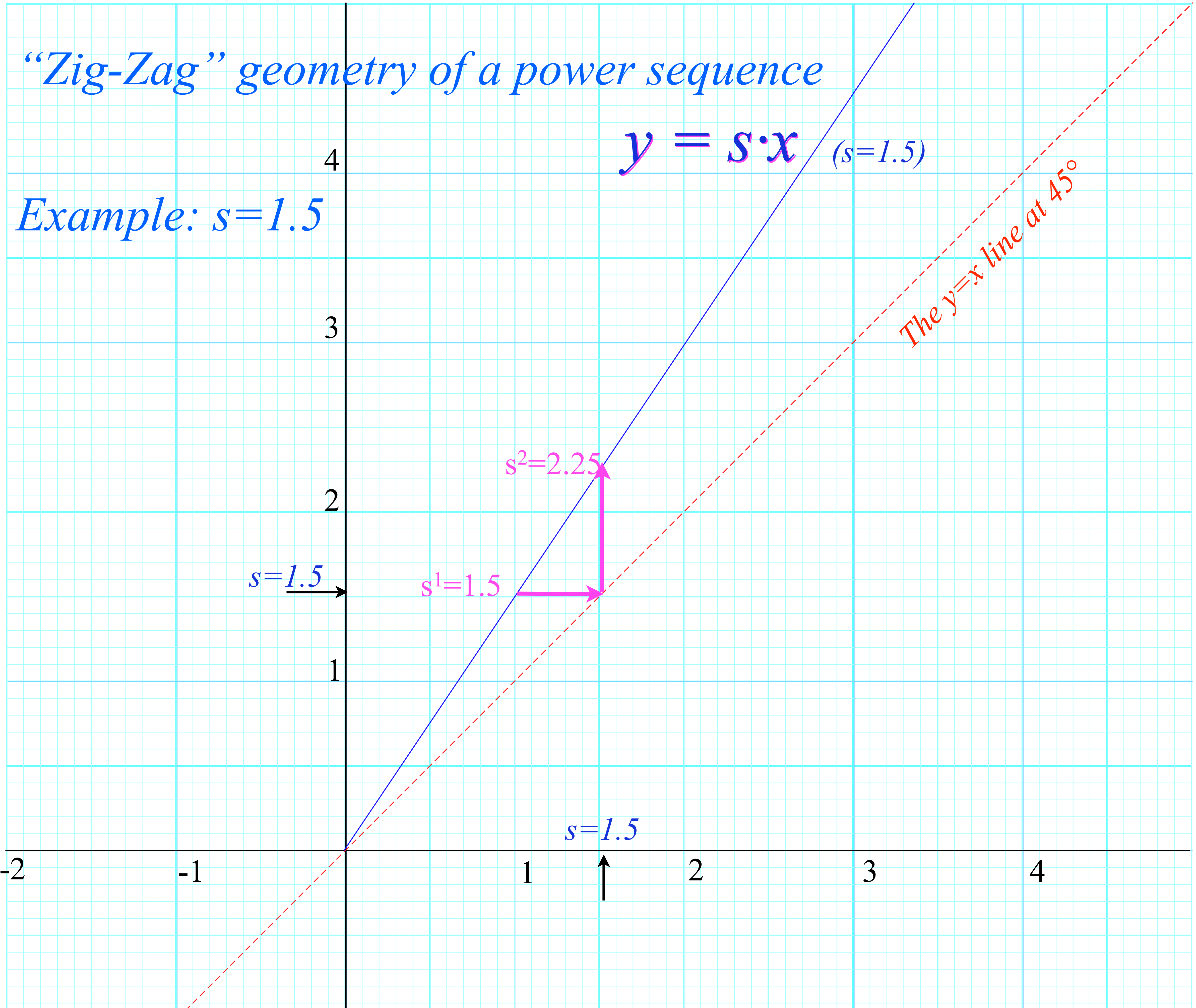
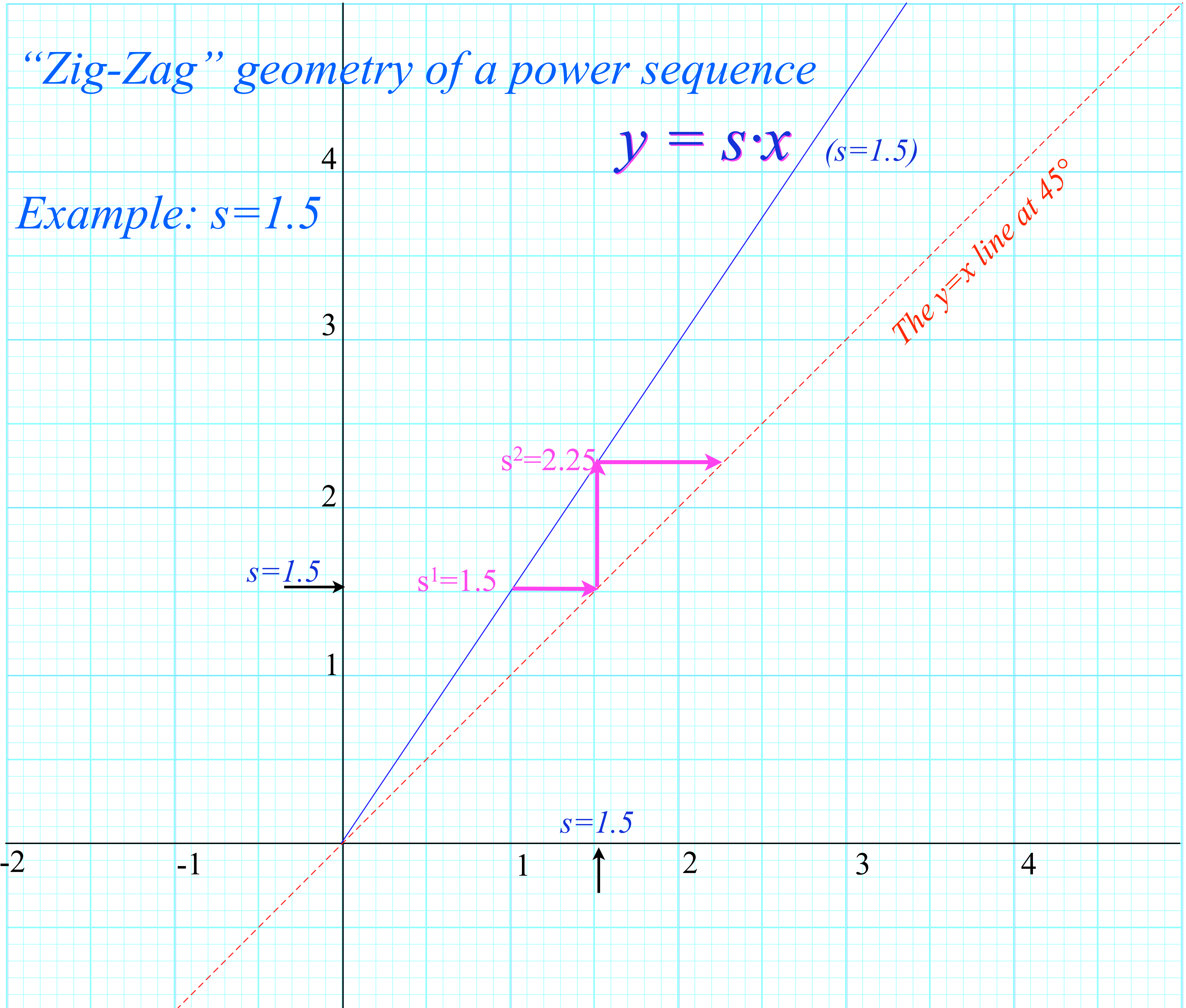

"Zig-Zag" geometry of a power sequence
$y = s \cdot x$ (s=1.5)
Example: s=1.5
The y=x line at 45°
s=1.5
s=1.5
4
3
2
1
-2
-1
1
2
3
4


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



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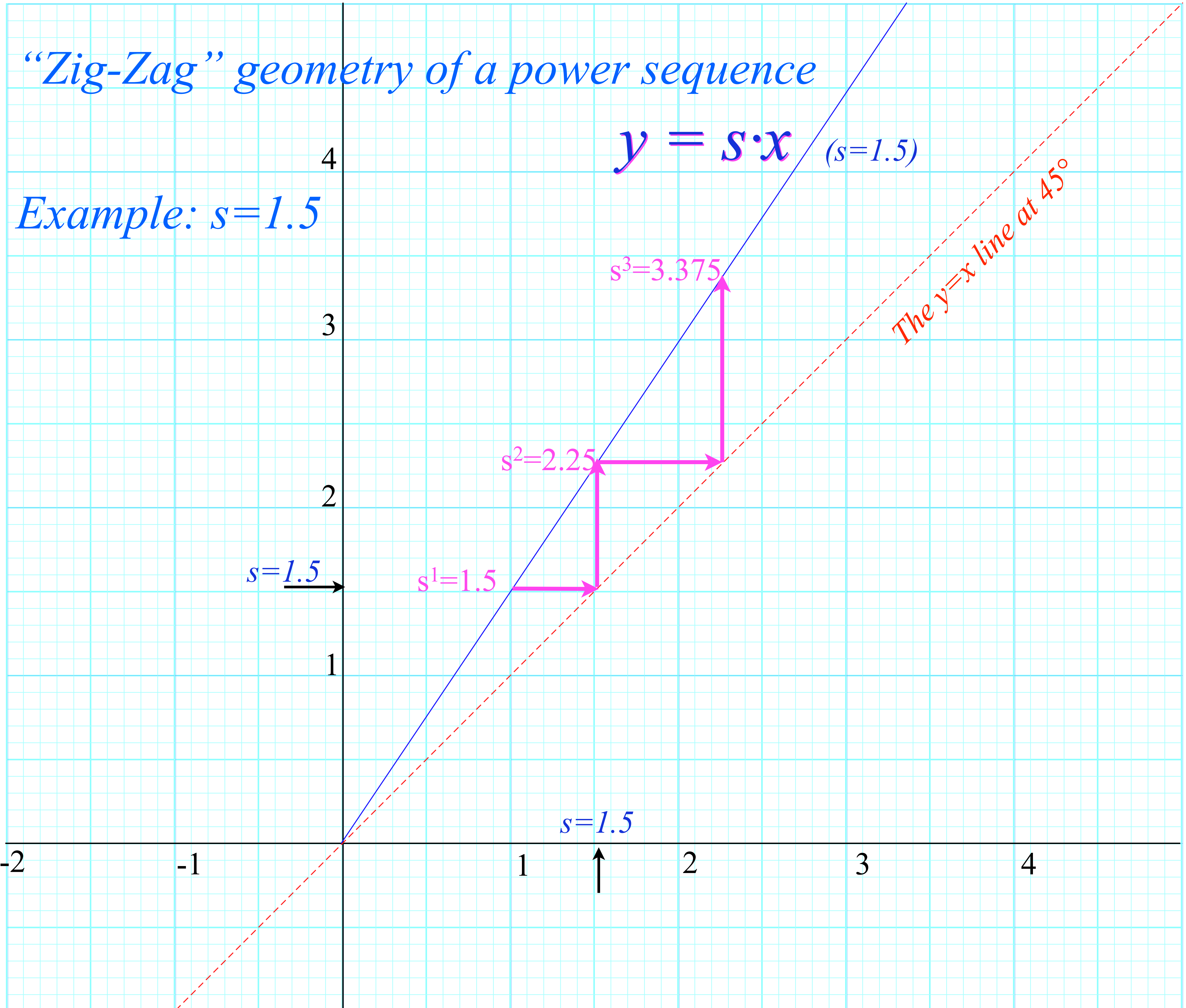
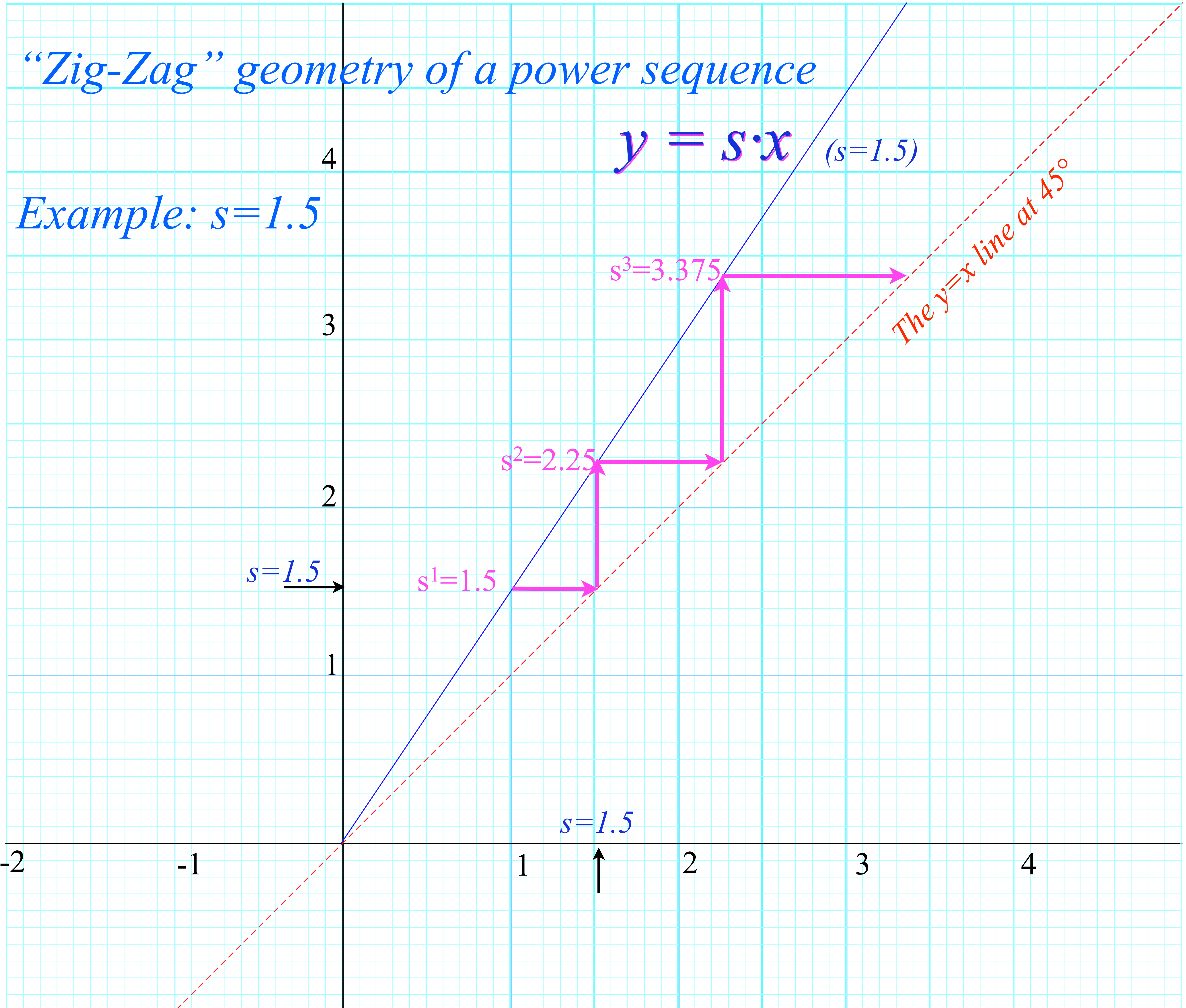
3
2
1
-2
-1
1
2
3
4


"Zig-Zag" geometry of a power sequence
Example: s=1.5
y = s·x (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



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s²=2.25
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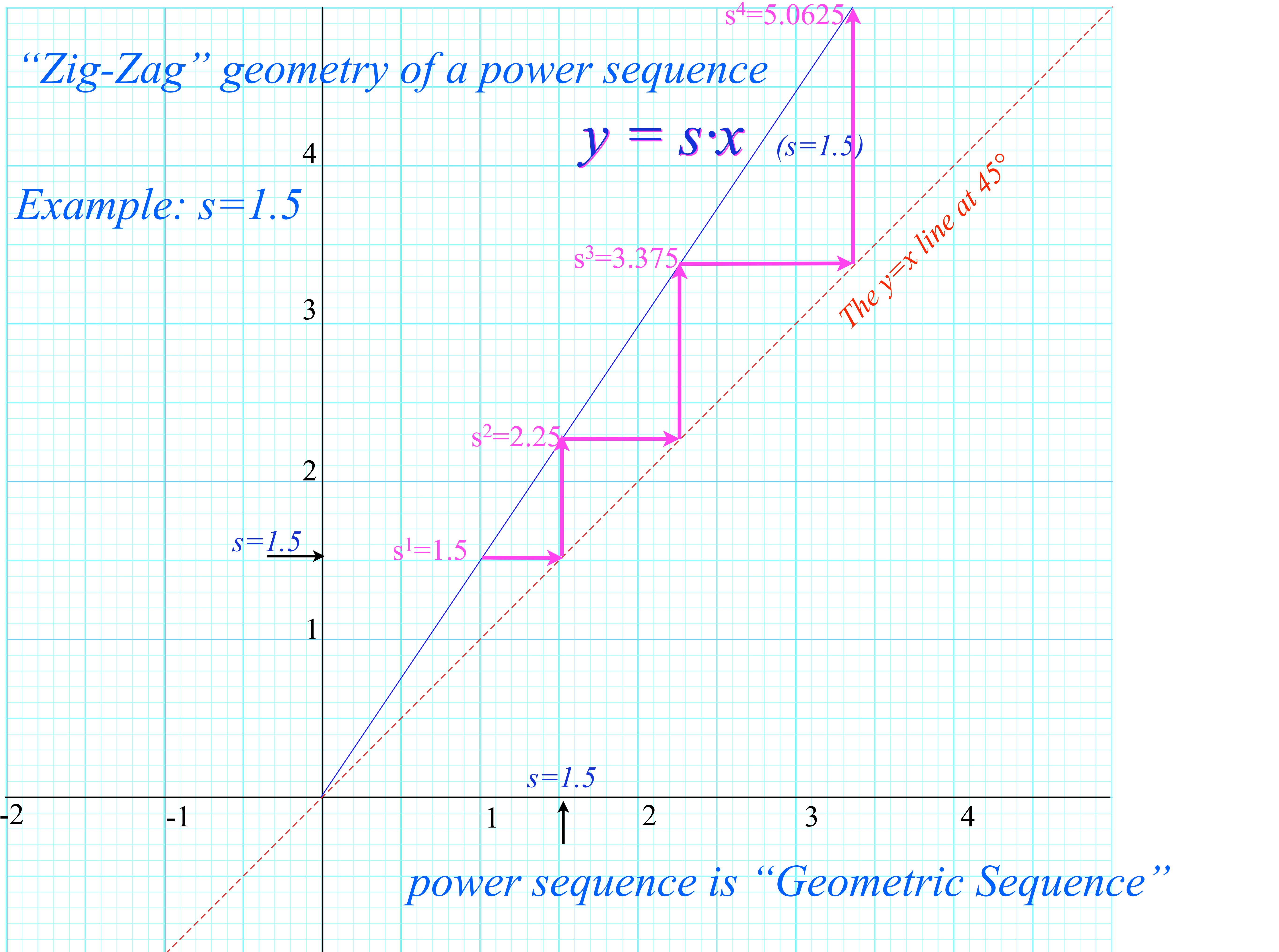
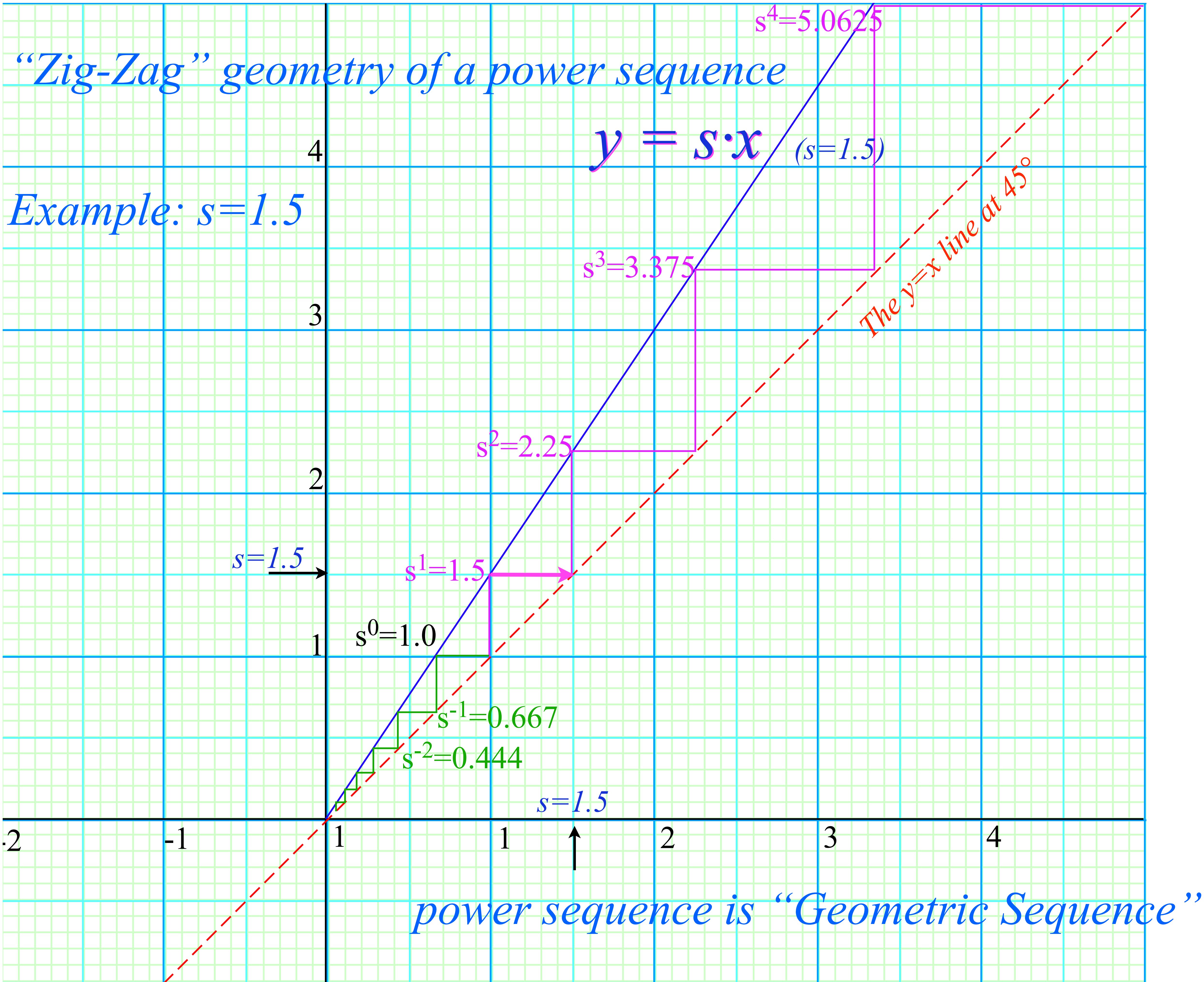
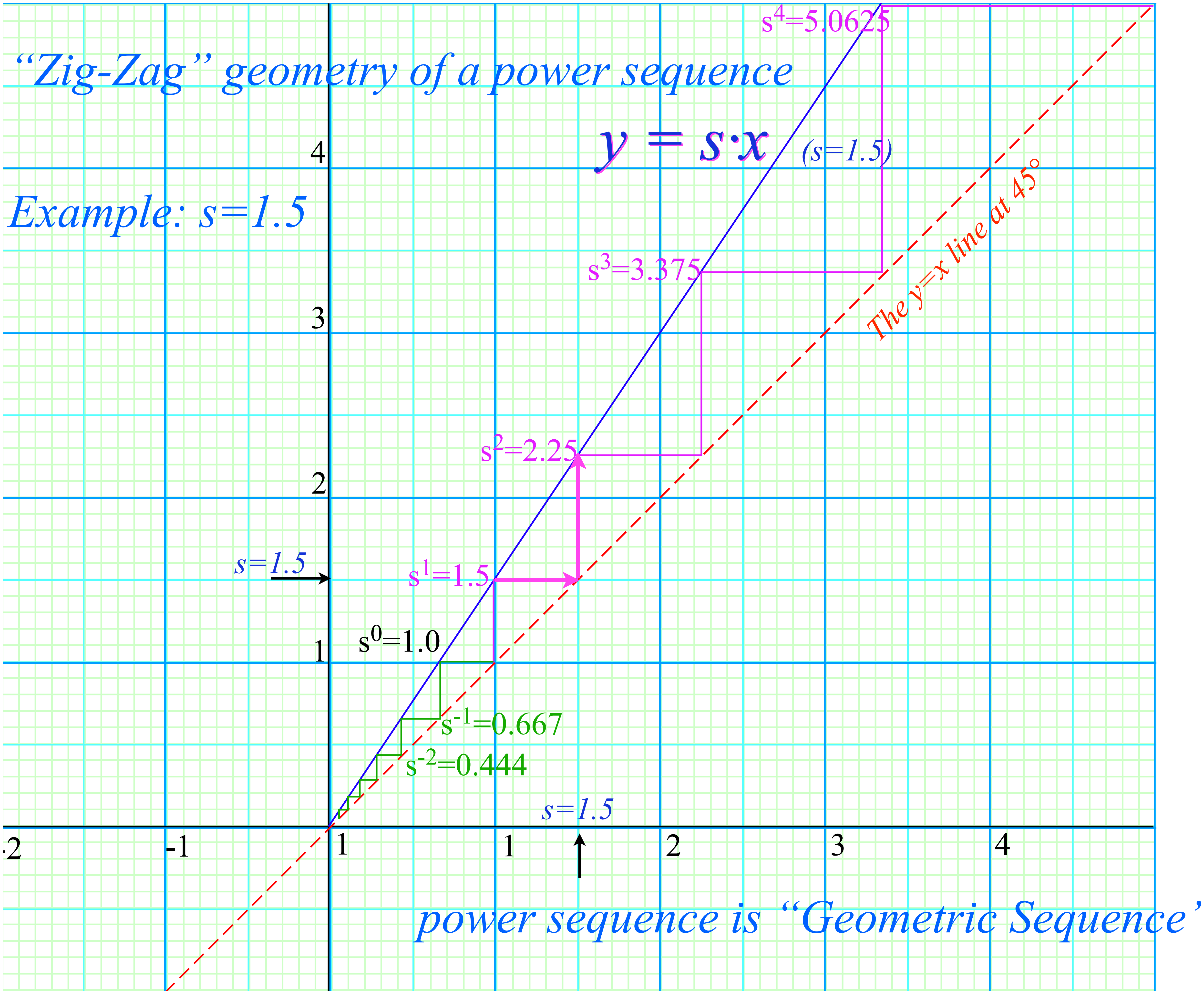
4
3
2
1
-2
-1
1
2
3
4


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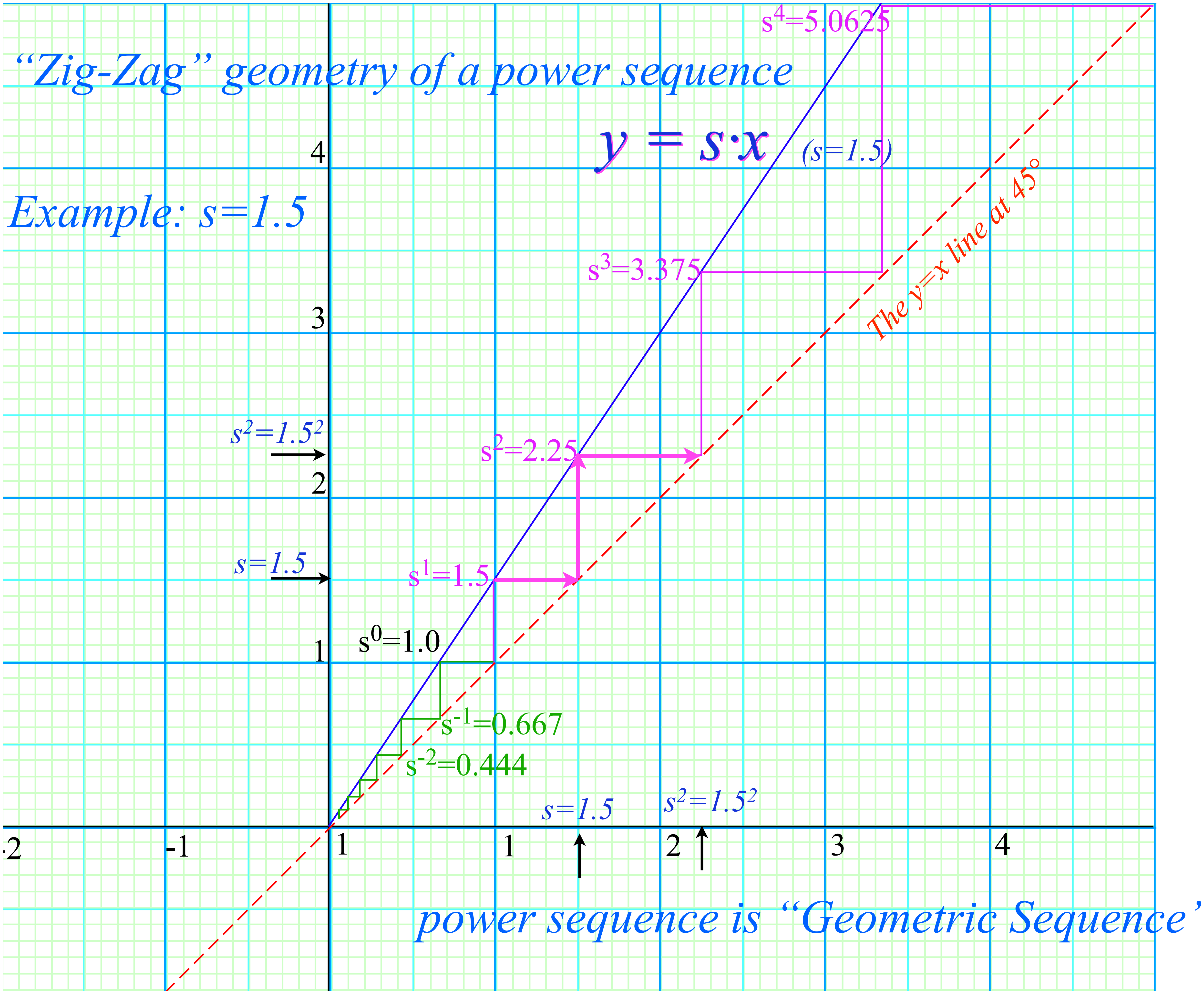

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s=1.5
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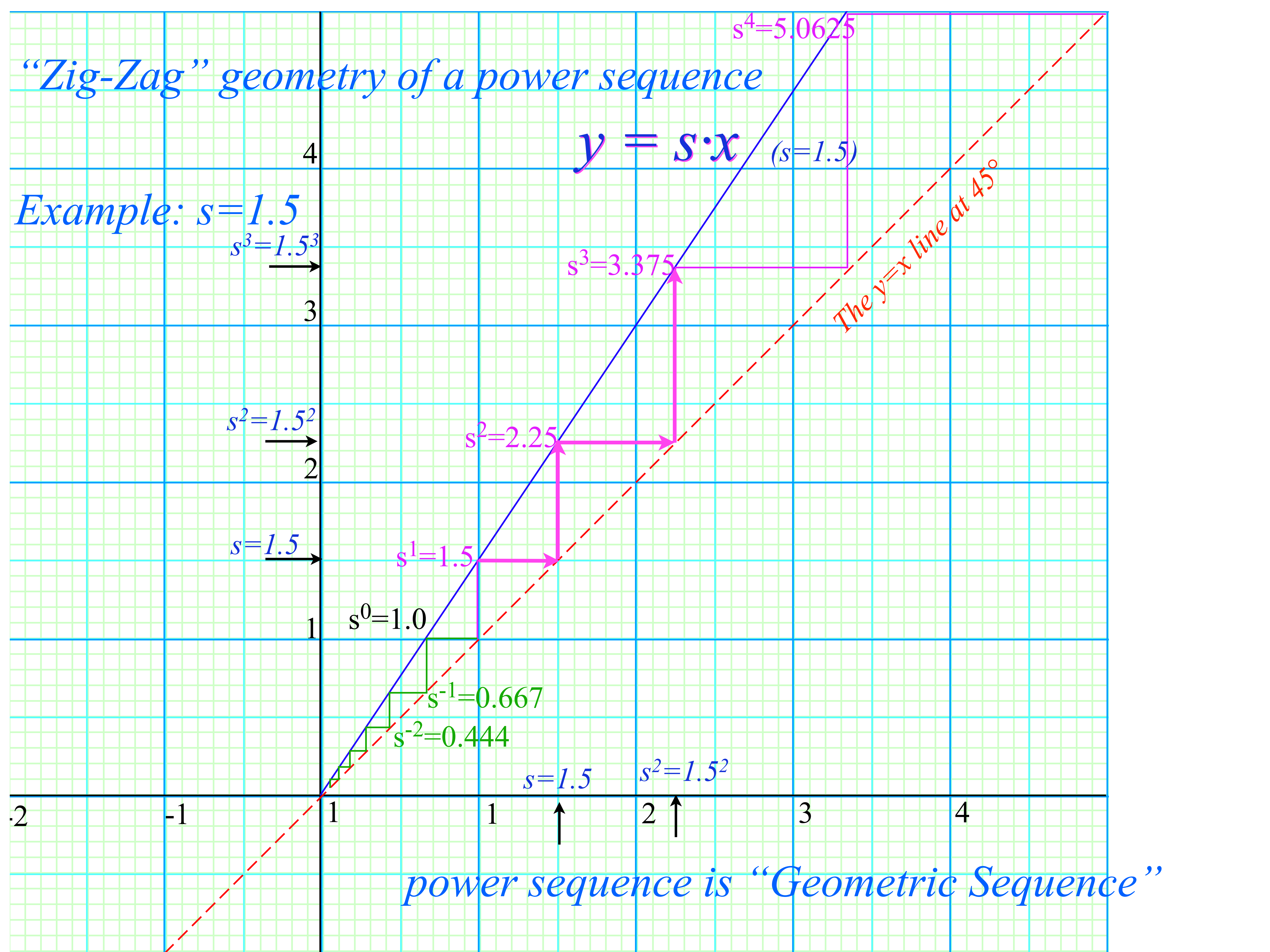
s=1.5
s²=1.5²
-2
-1
1
1
2
3
4
1
2
3
4
power sequence is "Geometric Sequence"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The y=x line at 45°
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-2
-1
1
1
2
3
4
1
2
3
4
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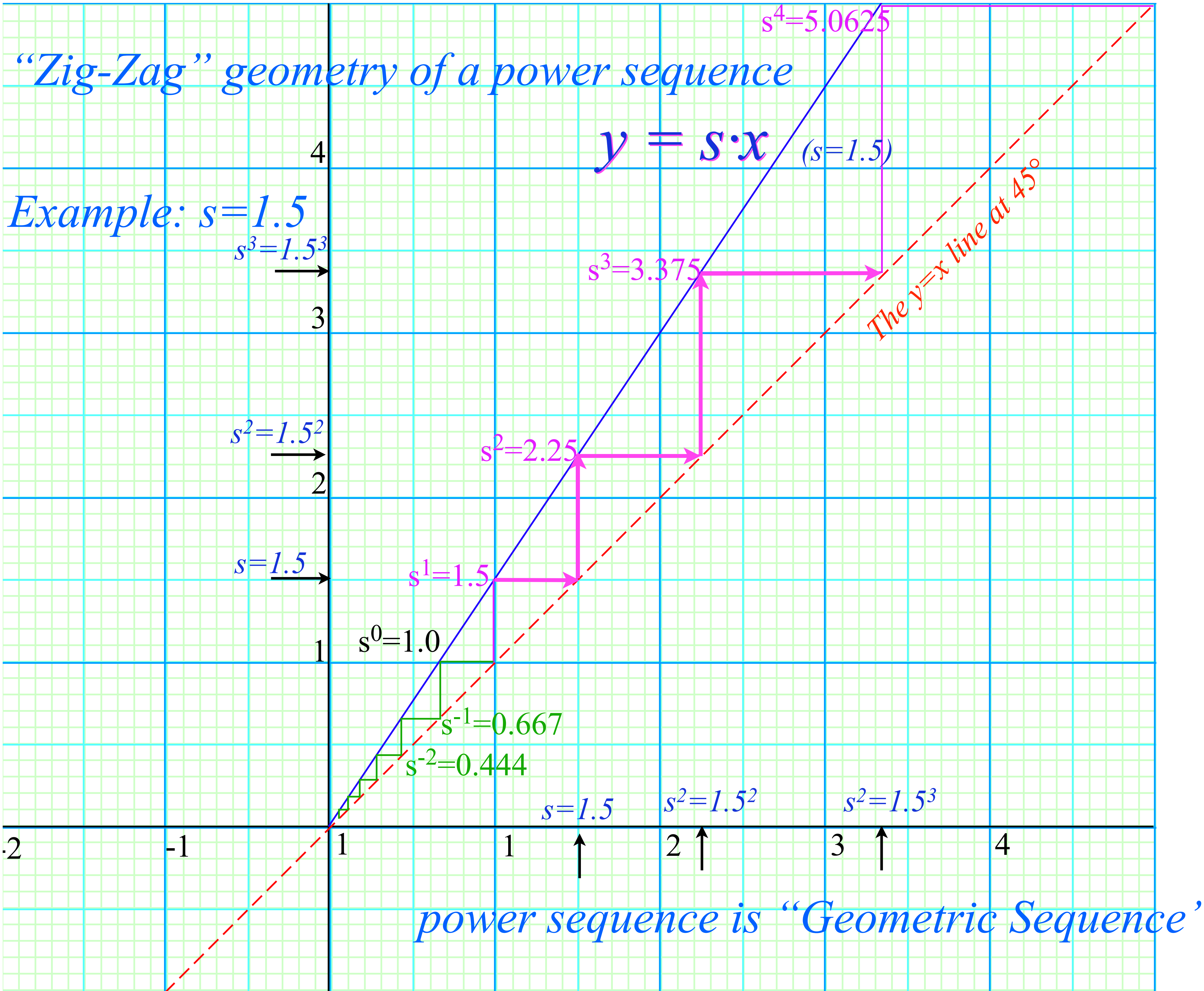
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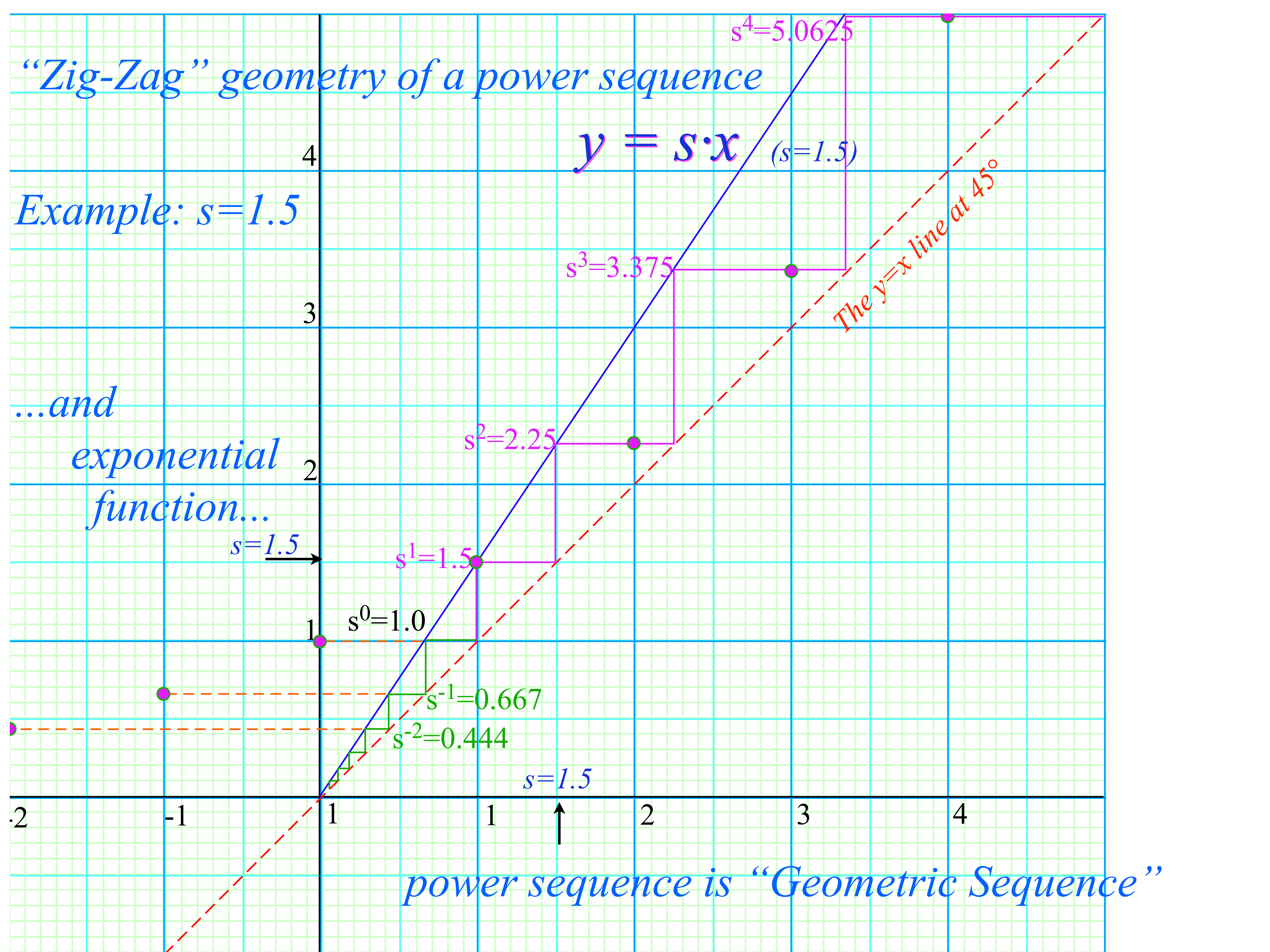
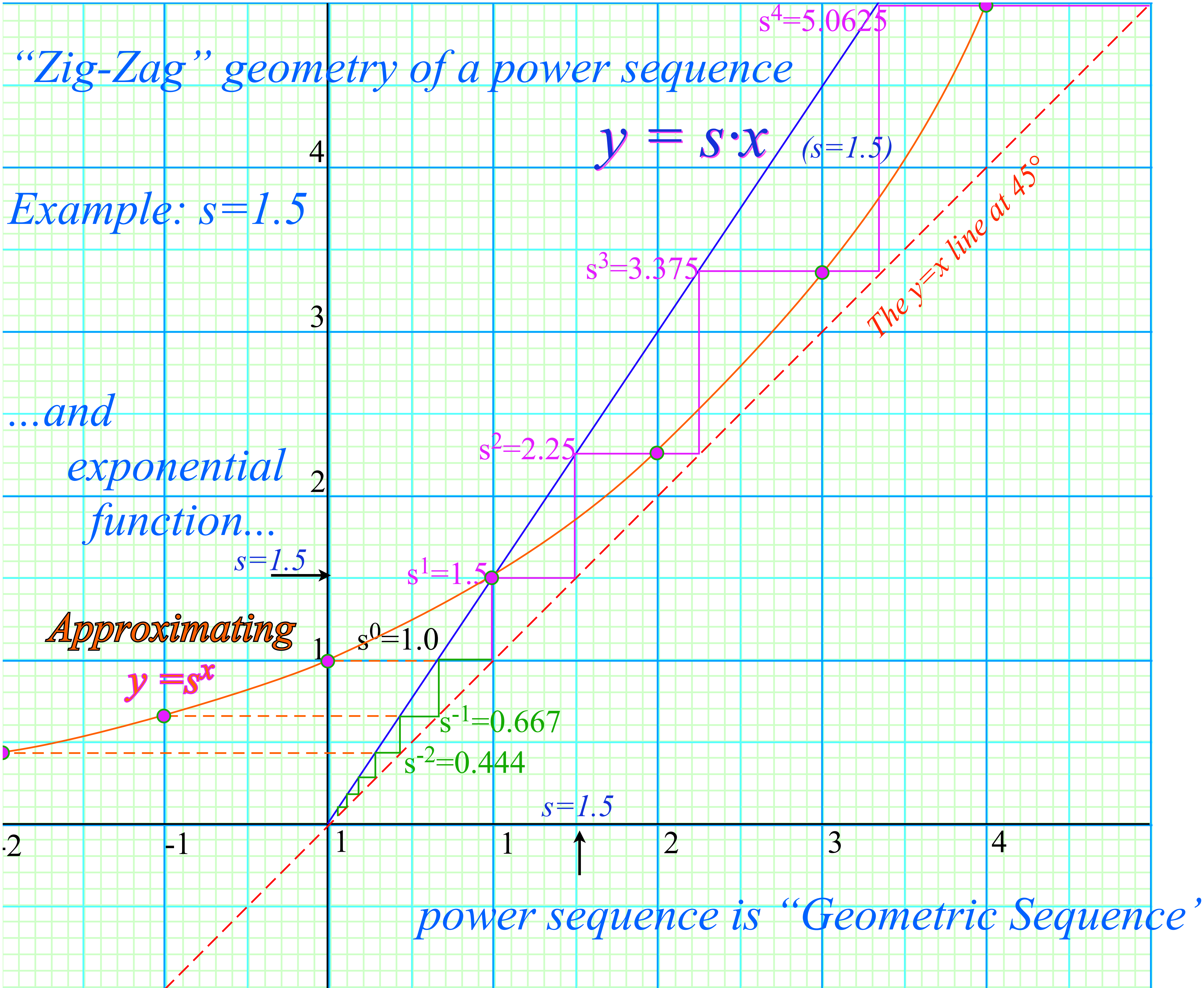
s²=1.5²
s²=1.5³
4
3
2
1
-2
-1
1
1
2
3
4
power sequence is "Geometric Sequence"



"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
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
The y=x line at 45°
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)
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s^4=5.0625
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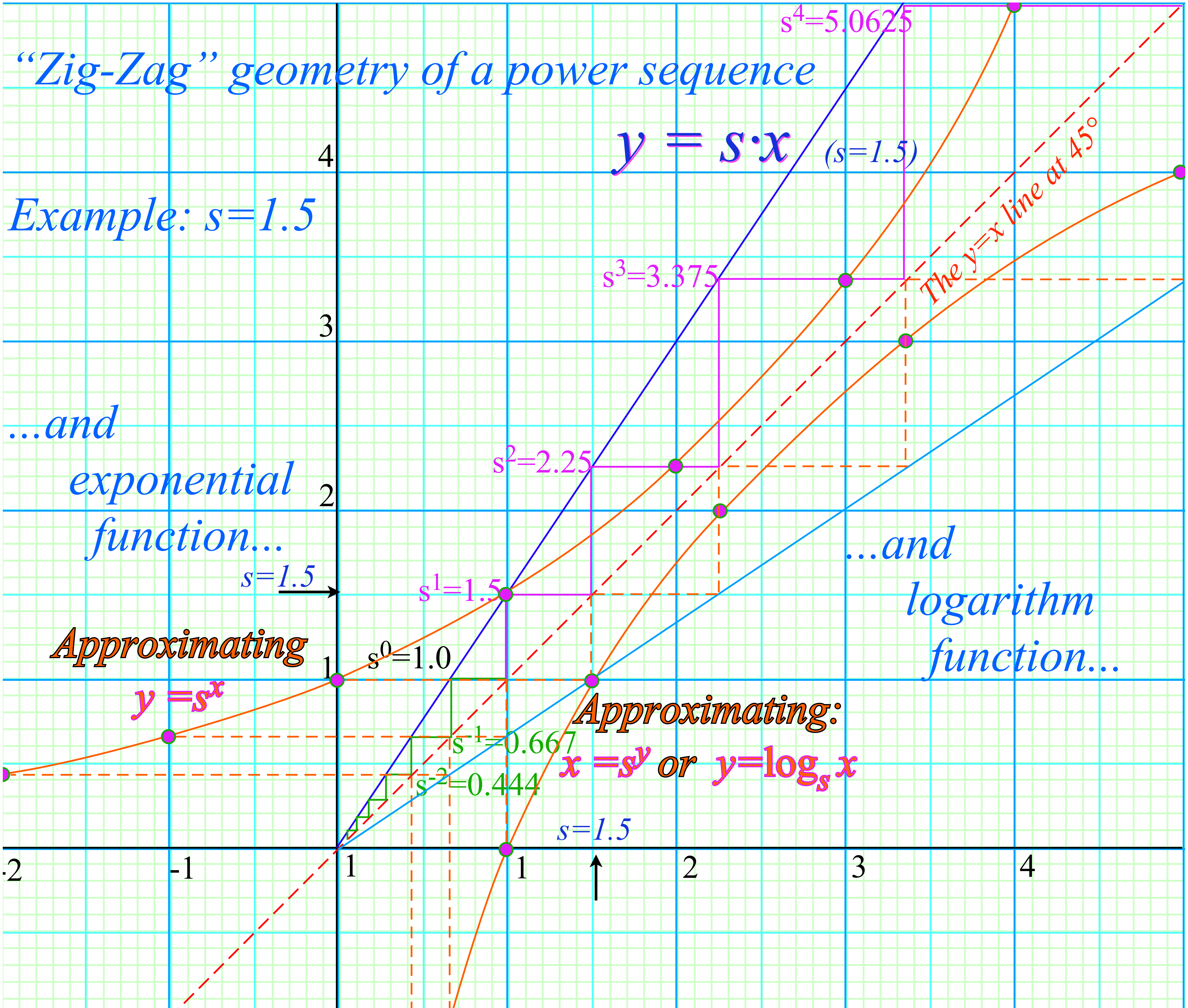
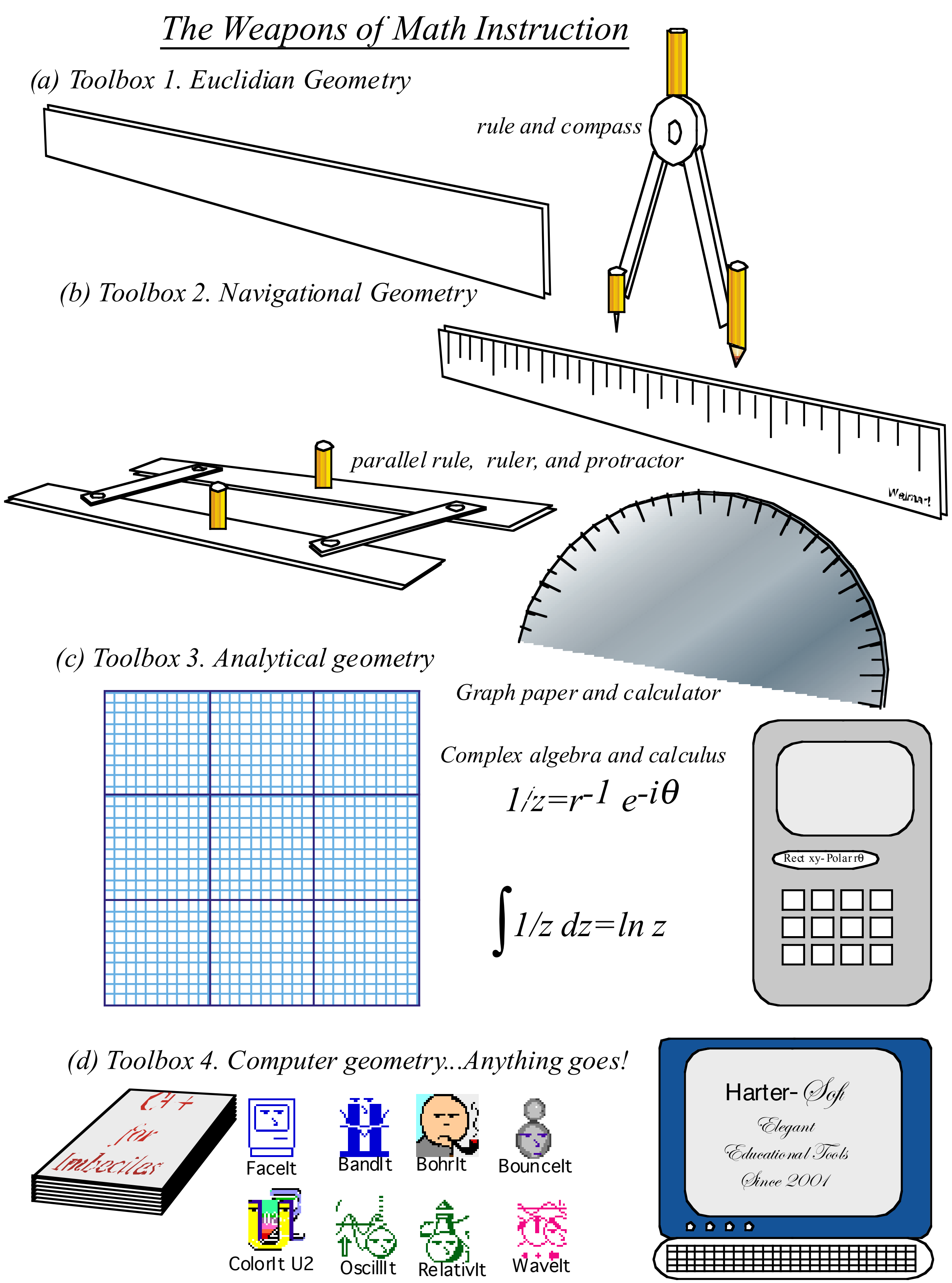


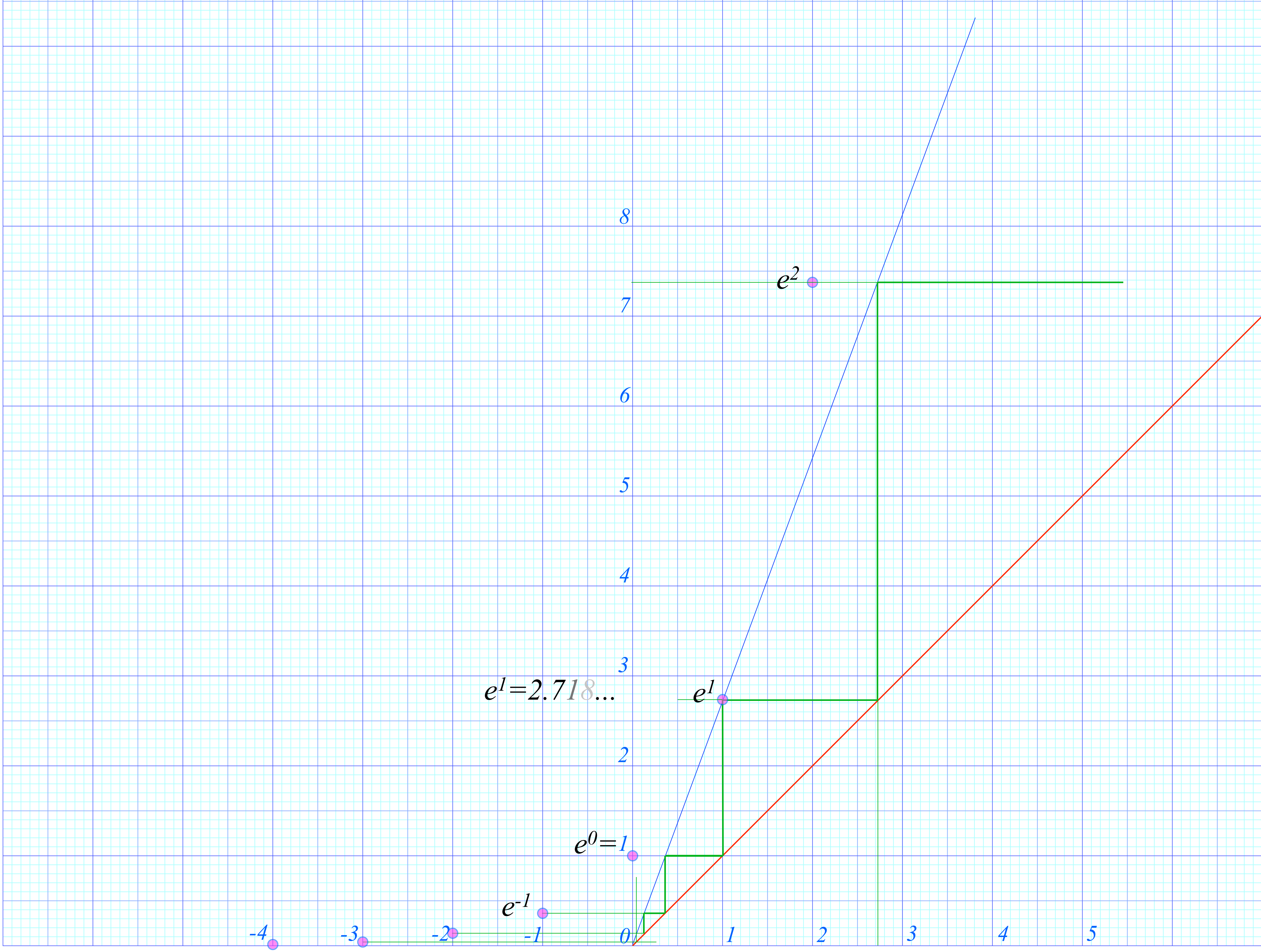
“Zig-Zag” geometry of a power sequence
y = s·x (s=1.5)
Example: s=1.5
...and exponential function...
s=1.5
Approximating
y =s^x
s^0=1.0
s^1=1.5
s^2=2.25
s^3=3.375
s^4=5.0625
s^-1=0.667
s^-2=0.444
The y=x line at 45°
Approximating:
x =s^y or y=log_s x
...and logarithm function...
s=1.5
-2
-1
1
1
2
3
4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



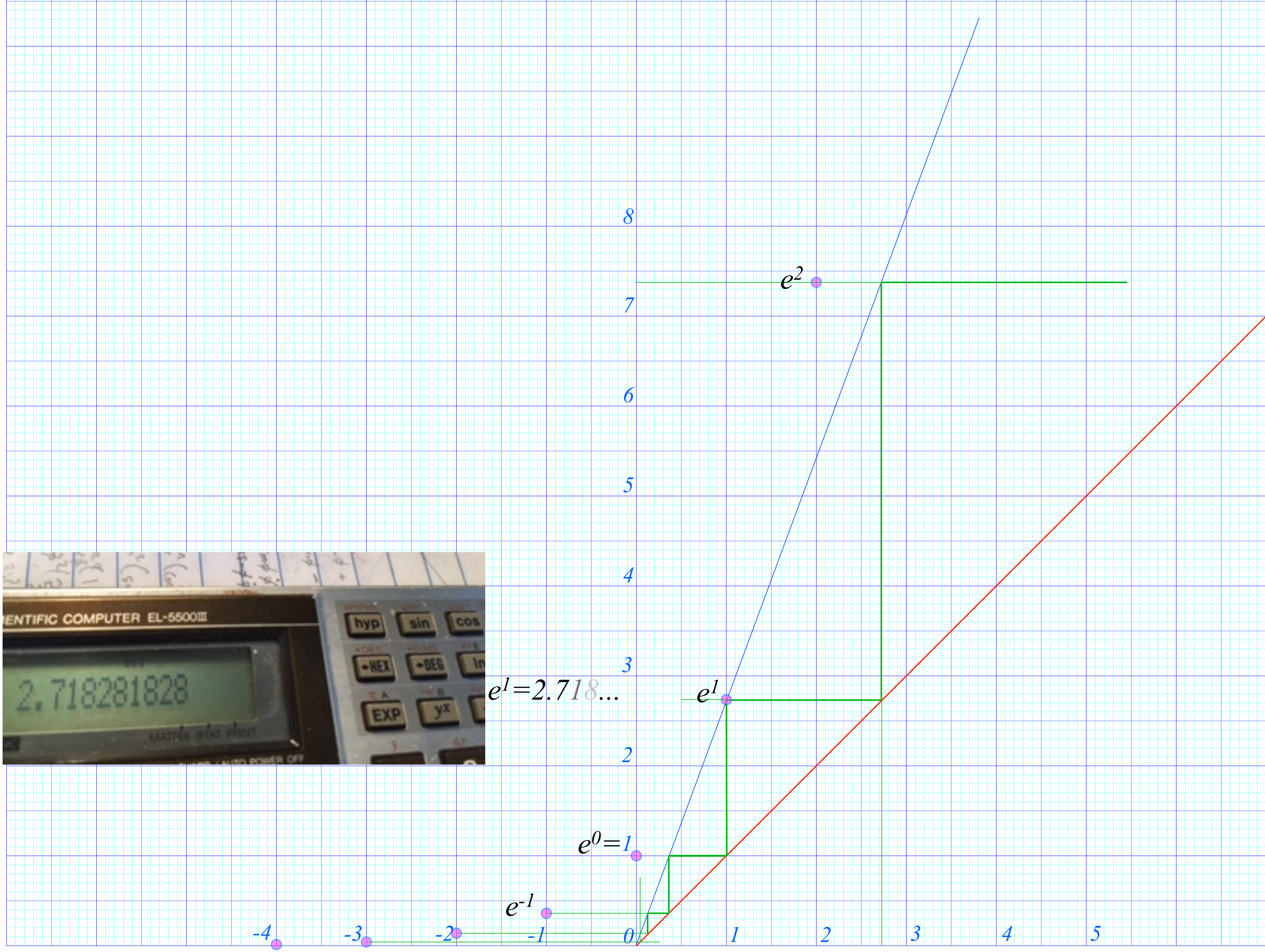
So far we mostly use Toolbox (a-b)

What follows uses Toolbox (c) ...

...and Toolbox (d)



8
7
6
5
4
3
2
1
0
-4
-3
-2
-1
1
2
3
4
5
e^2
e^1
e^1=2.718...
e^0=1
e^-1



8
7
6
5
4
3
2
e^2
e^1
$e^1=2.718...$
$e^0=1$
e^{-1}
-4
-3
-2
-1
0
1
2
3
4
5
ENTIFIC COMPUTER EL-5500III
2.718281828
hyp
sin
cos
EXP
MATRIX STAT PRINT

Geometry of common power-law potentials

Geometric (Power) series

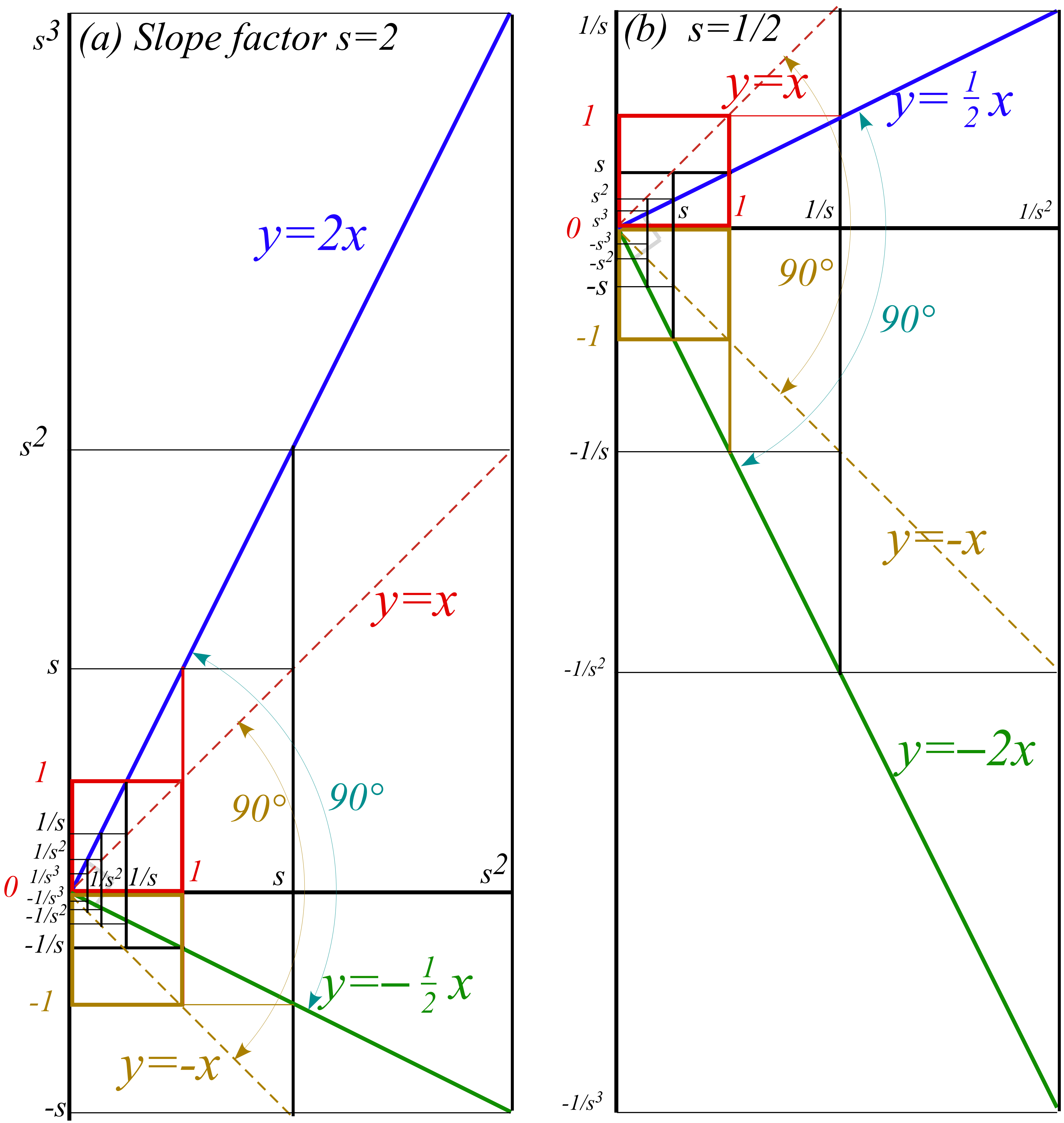
"Zig-Zag" exponential geometry

→ *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

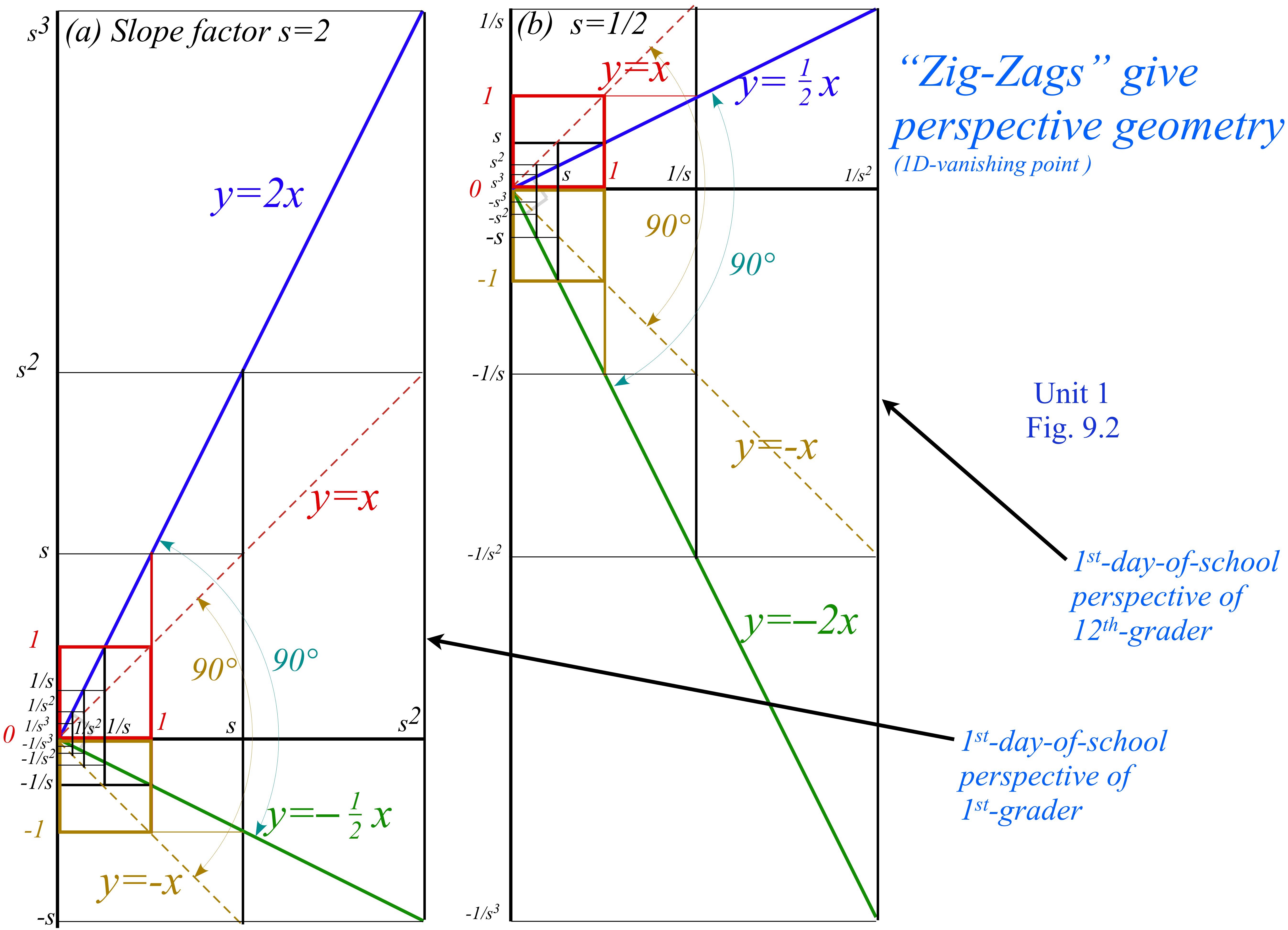
Compare mks units of Coulomb Electrostatic vs. Gravity



"Zig-Zags" give perspective geometry

(1D-vanishing point)

Unit 1
Fig. 9.2



(a) Slope factor s=2
y=2x
y=x
y=-x
y=−½x
90°
90°
(b) s=1/2
y=x
y=½x
y=-x
y=−2x
90°
90°
"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

Geometry of common power-law potentials

Geometric (Power) series

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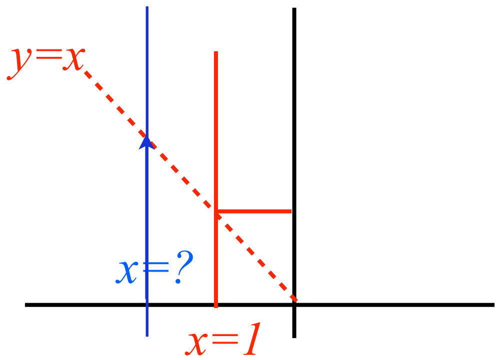
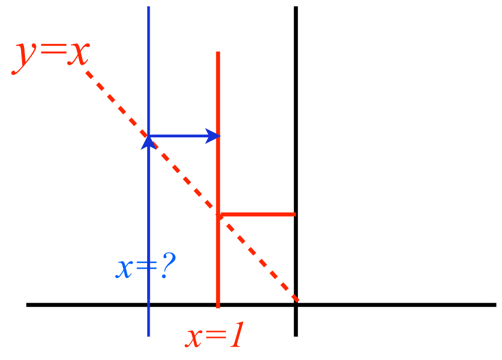
Compare mks units of Coulomb Electrostatic vs. Gravity

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

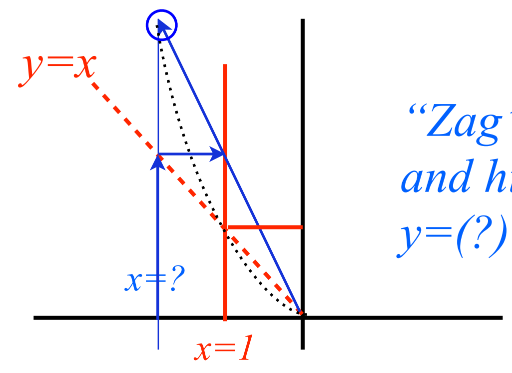
1. Pick an (x=?)-line



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



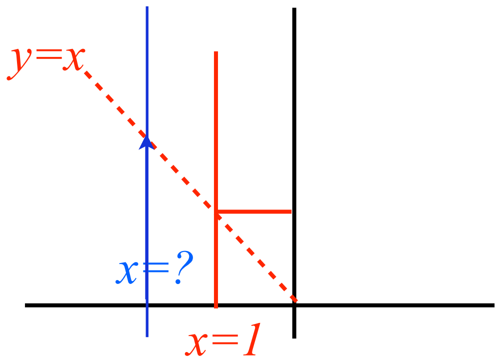
3. "Zag" from origin back to (x=?)-line



"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



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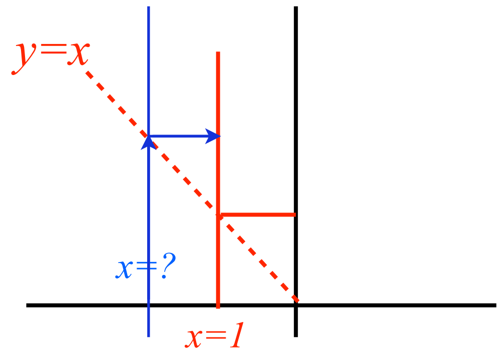

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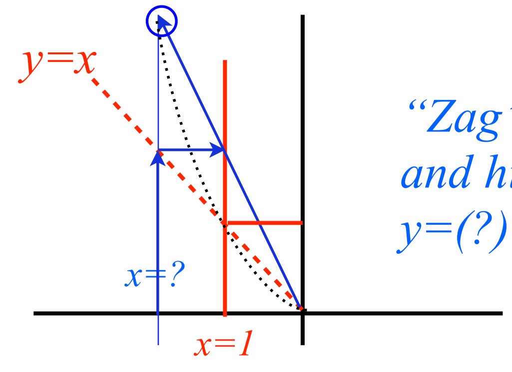
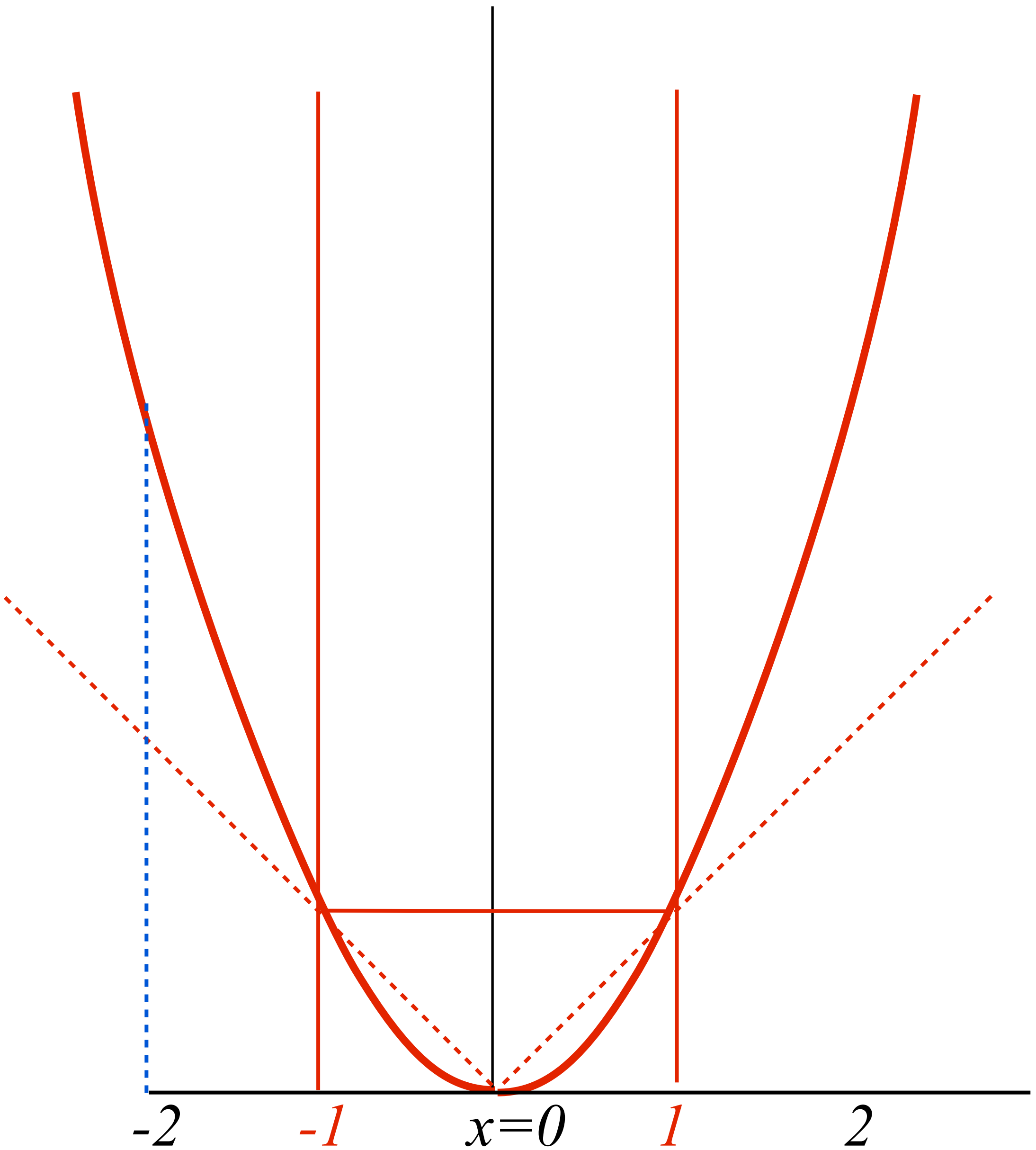


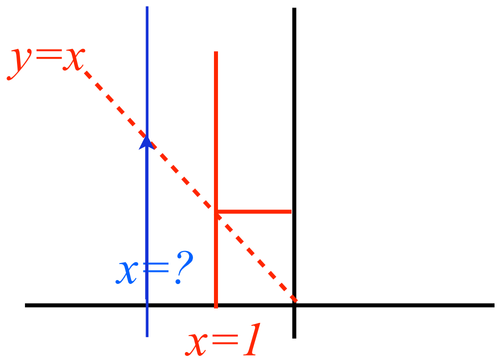
"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



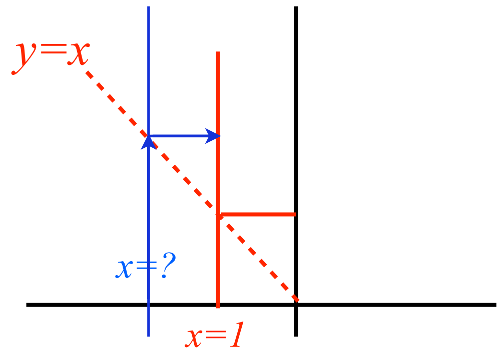
Unit 1
Fig. 9.1

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

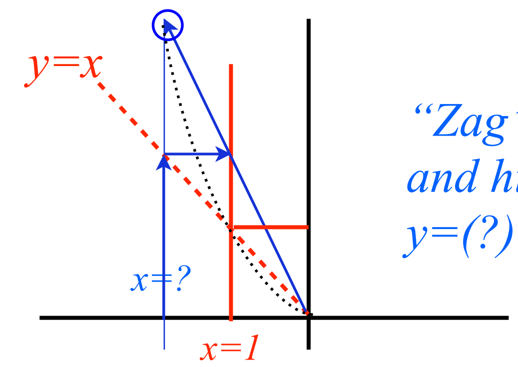
1. Pick an (x=?)-line



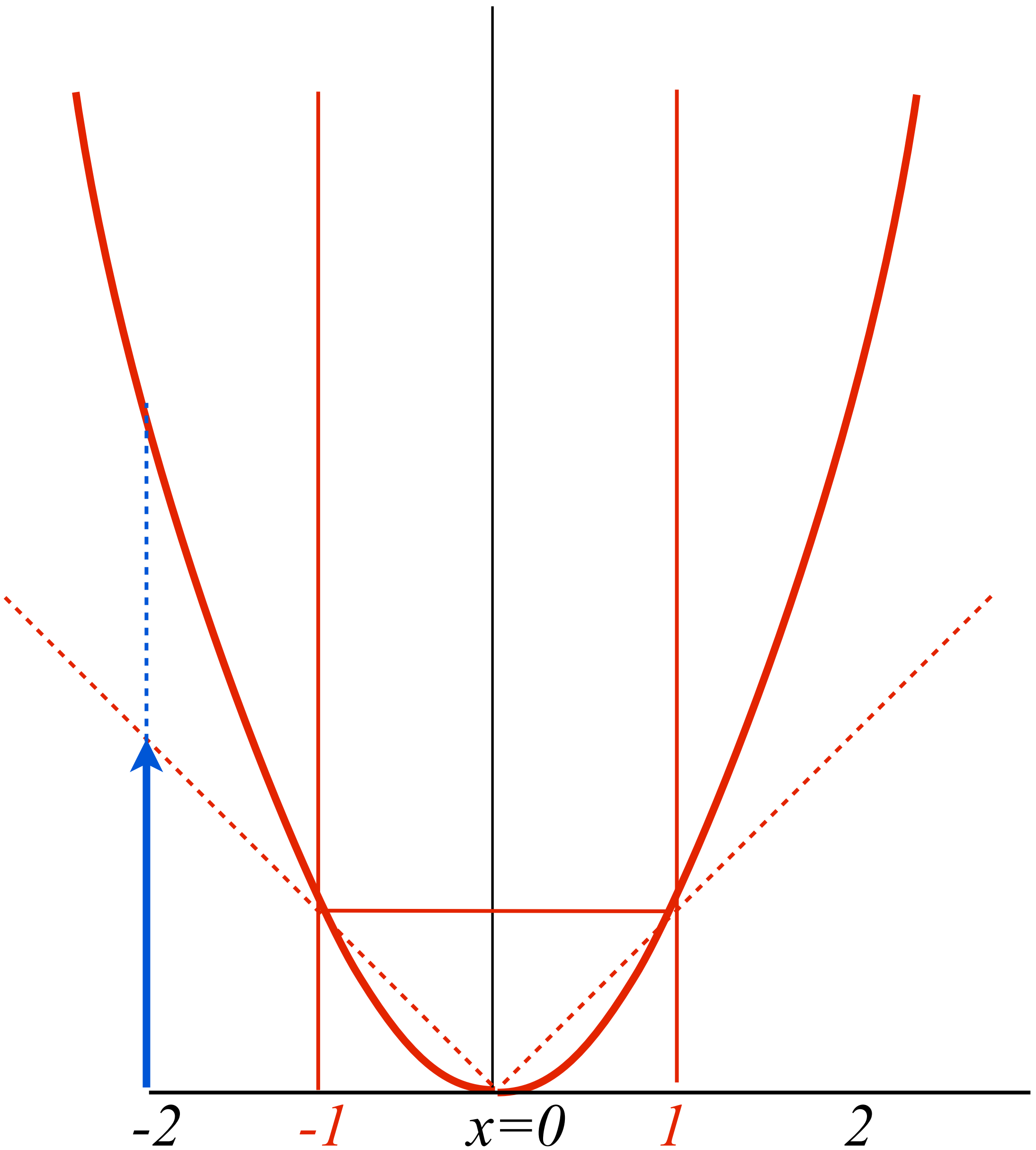
2. "Zig" from its y=x intersection to x=1 line



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



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



Unit 1
Fig. 9.1

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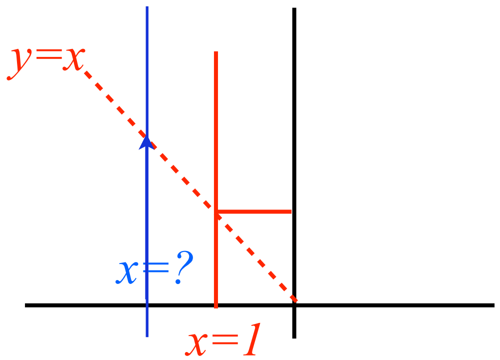

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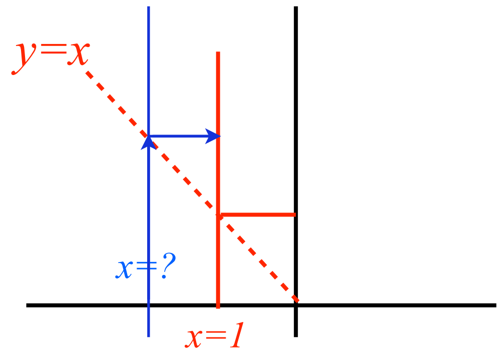

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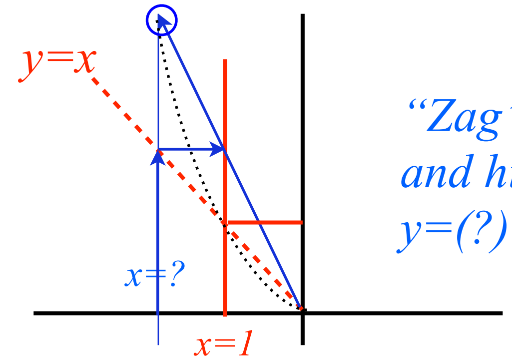

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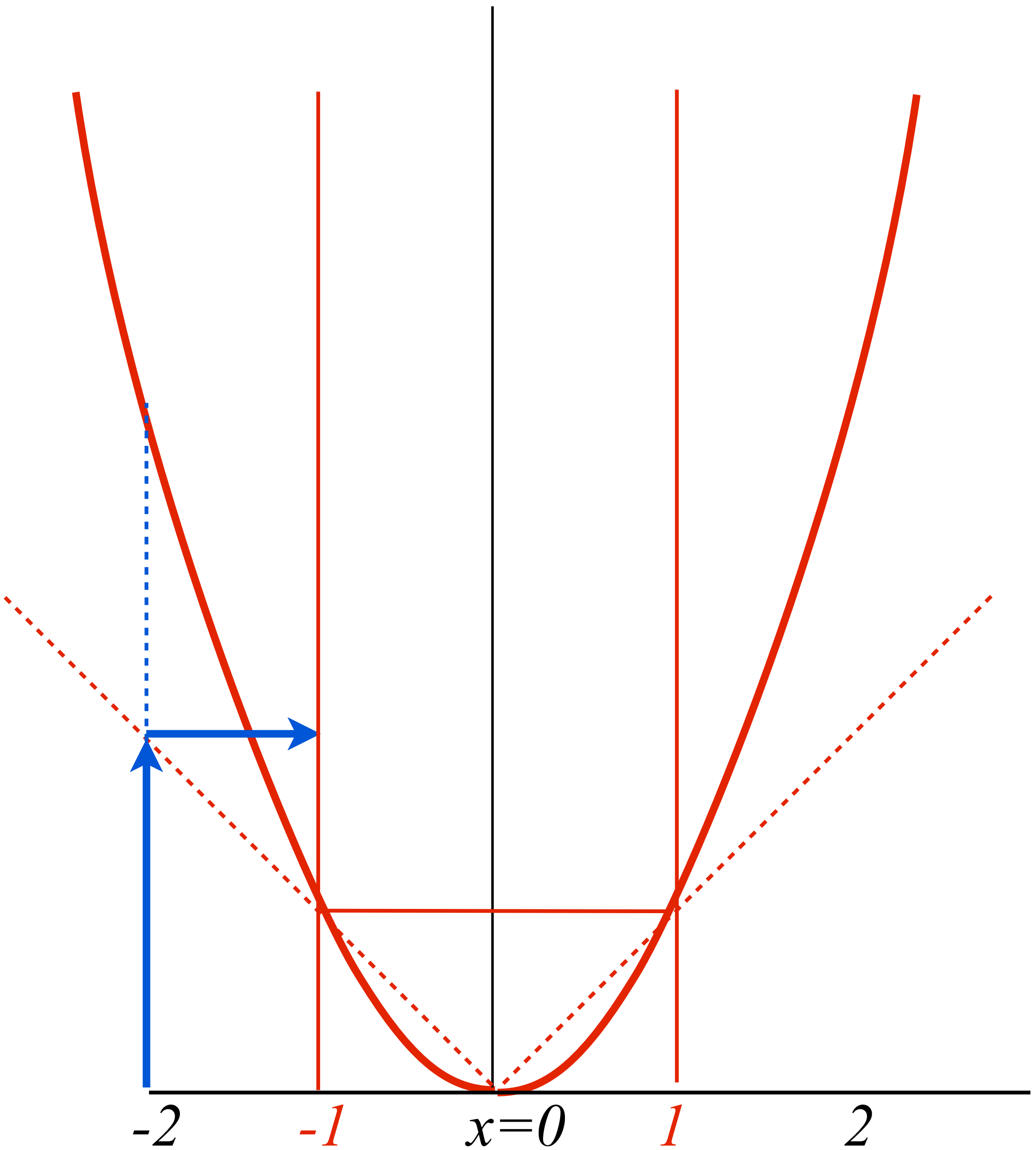

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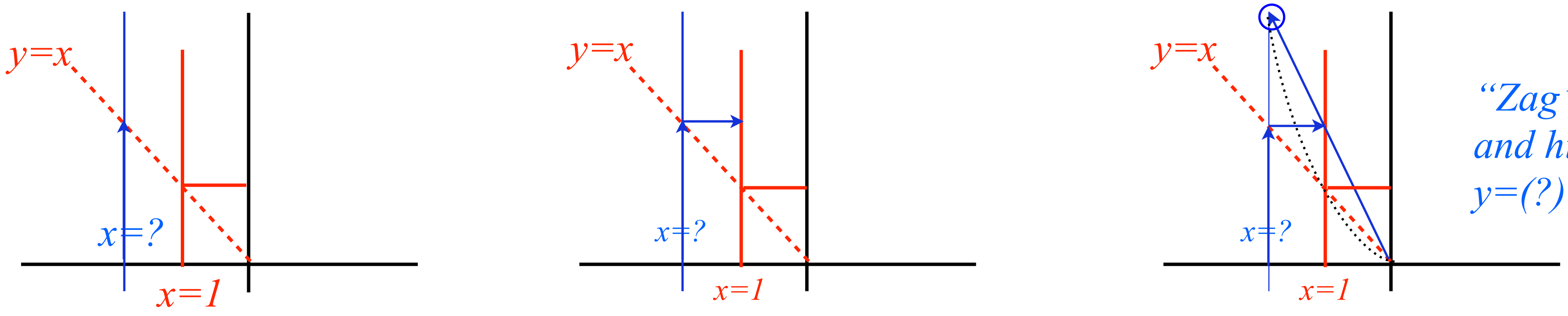
Each $y=x^2$ parabola point found by just one "Zig-Zag"

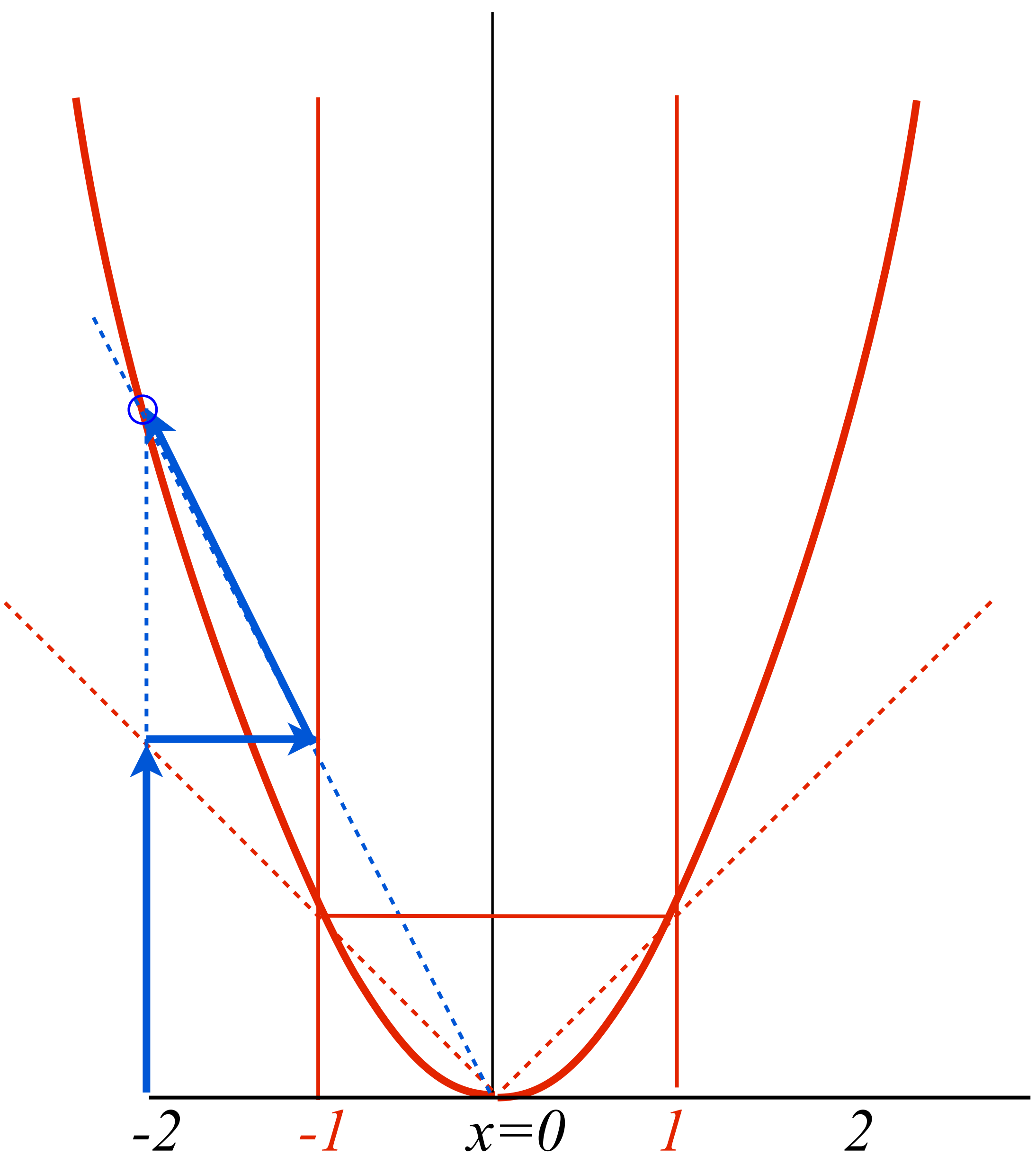
1. Pick an (x=?)-line

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

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



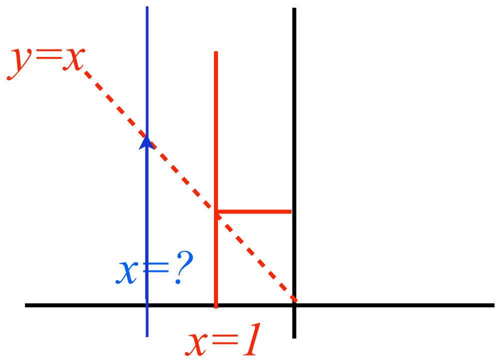
"Zag" line is y=(?)·x and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



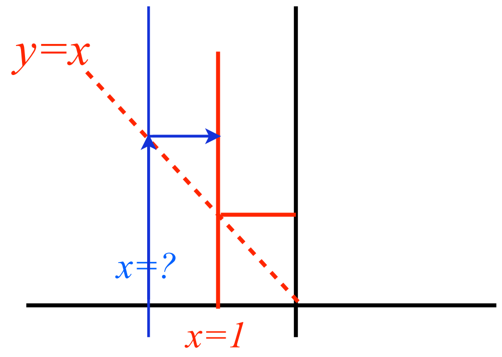
Unit 1
Fig. 9.1

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

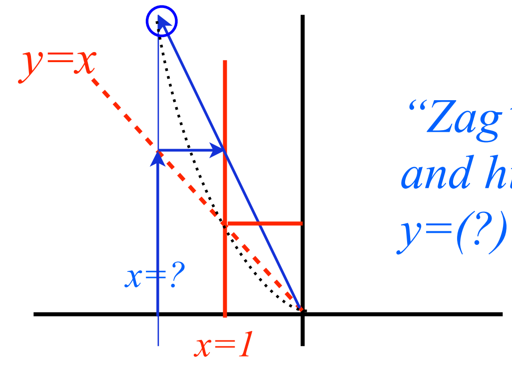
1. Pick an (x=?)-line



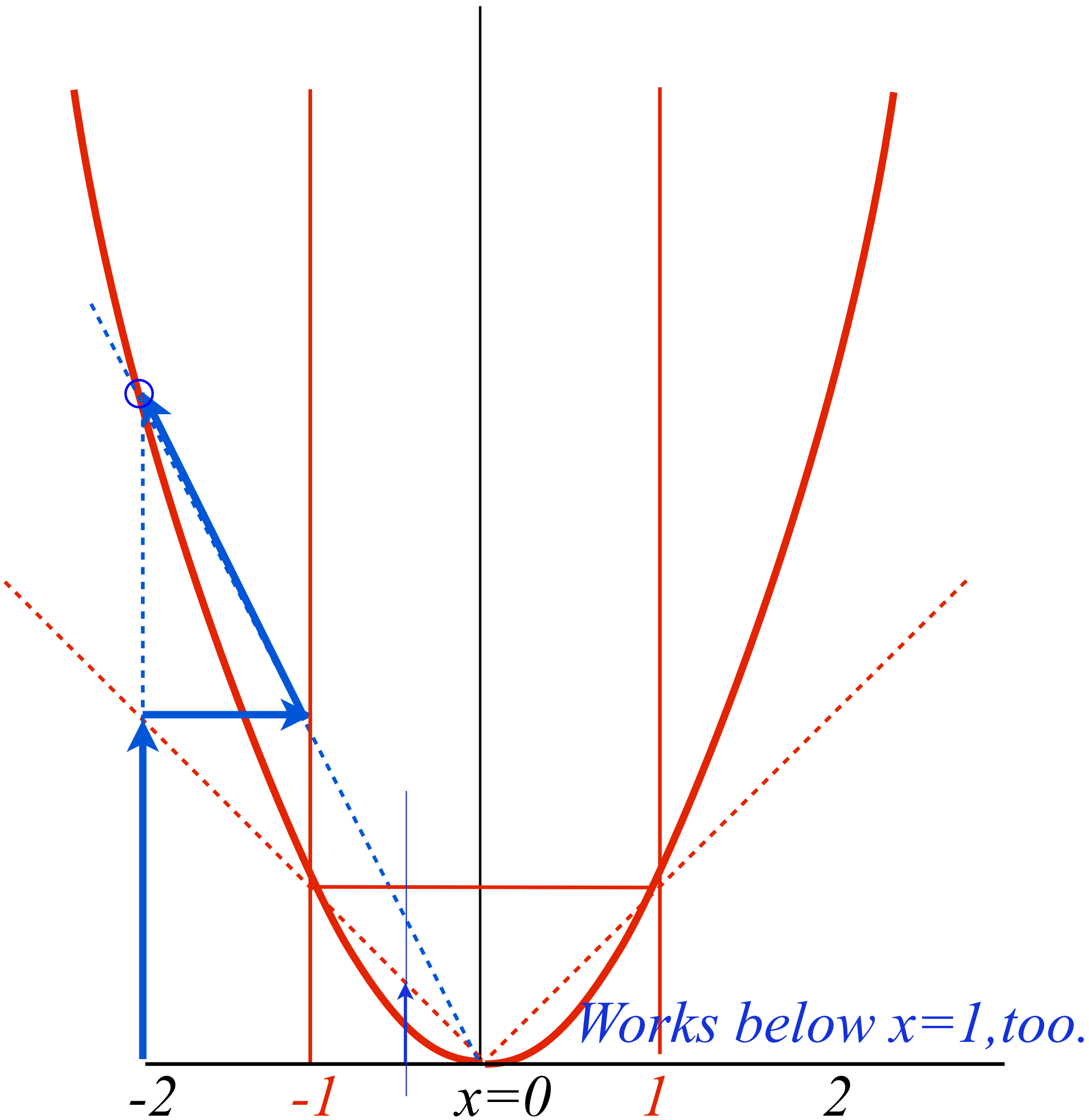
2. "Zig" from its y=x intersection to x=1 line



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



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



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

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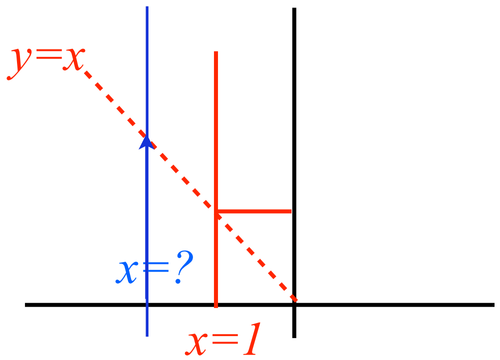
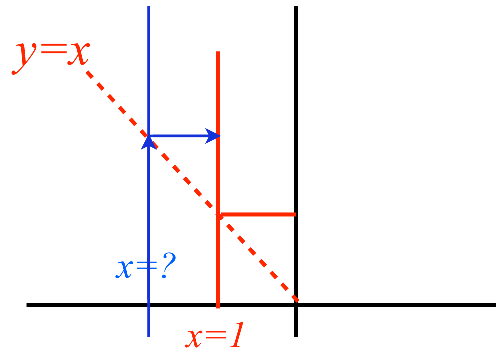
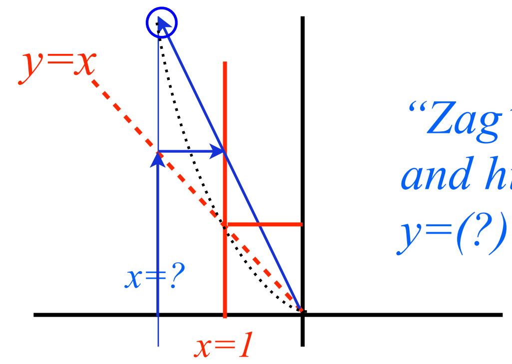
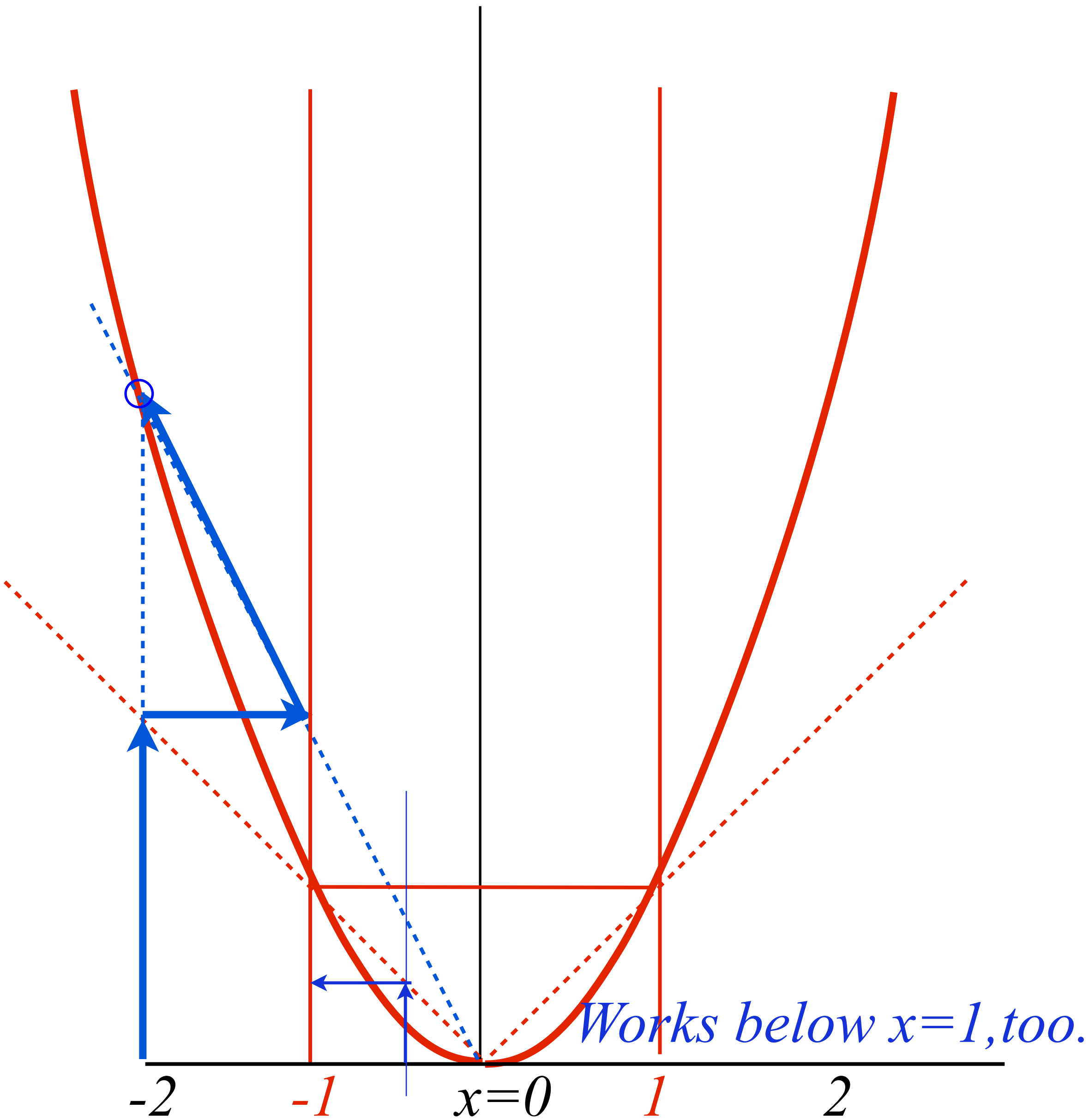






"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$

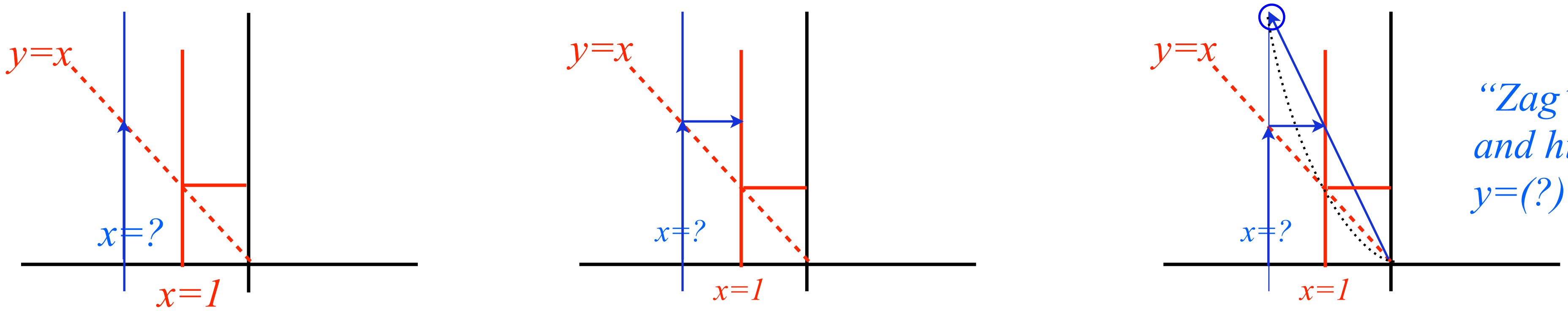


Each $y=x^2$ parabola point found by just one "Zig-Zag"

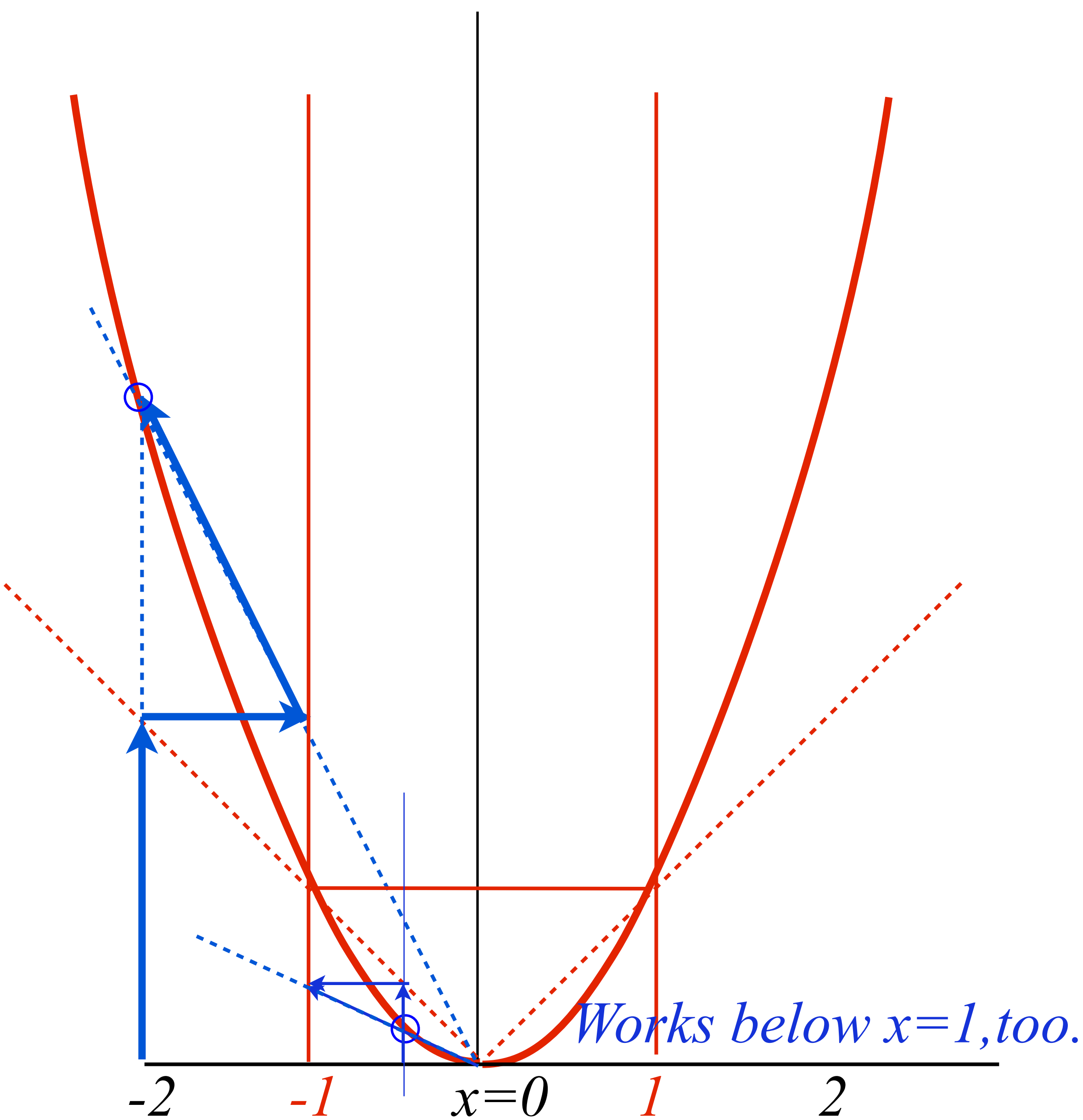
1. Pick an (x=?)-line

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
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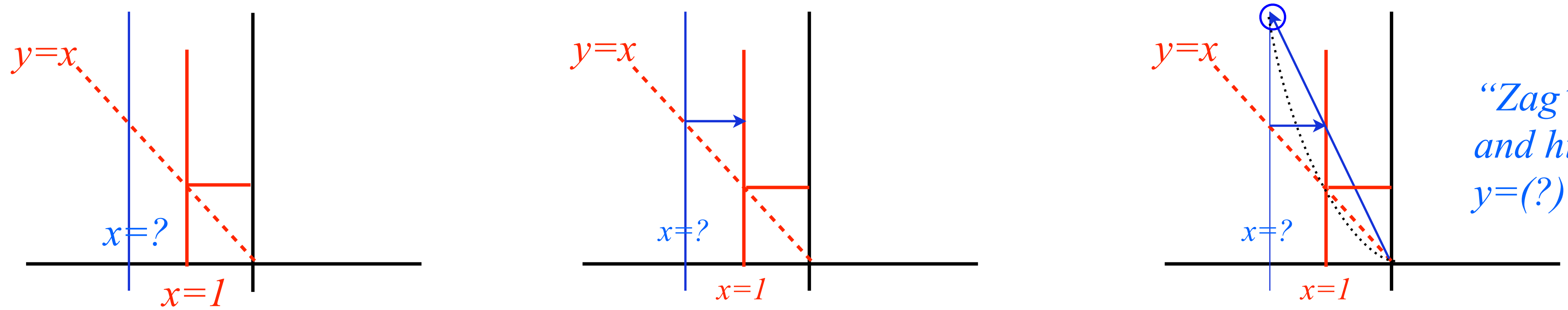
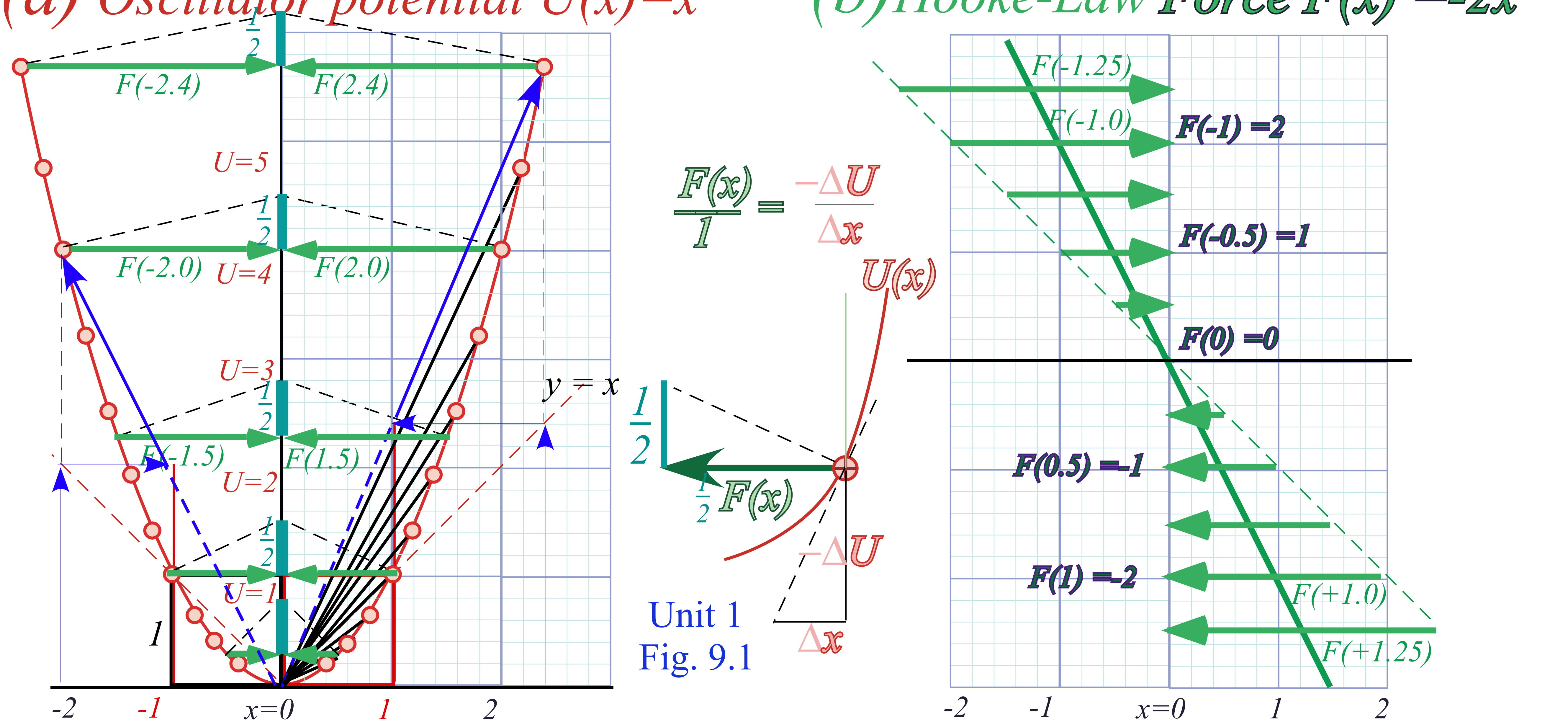


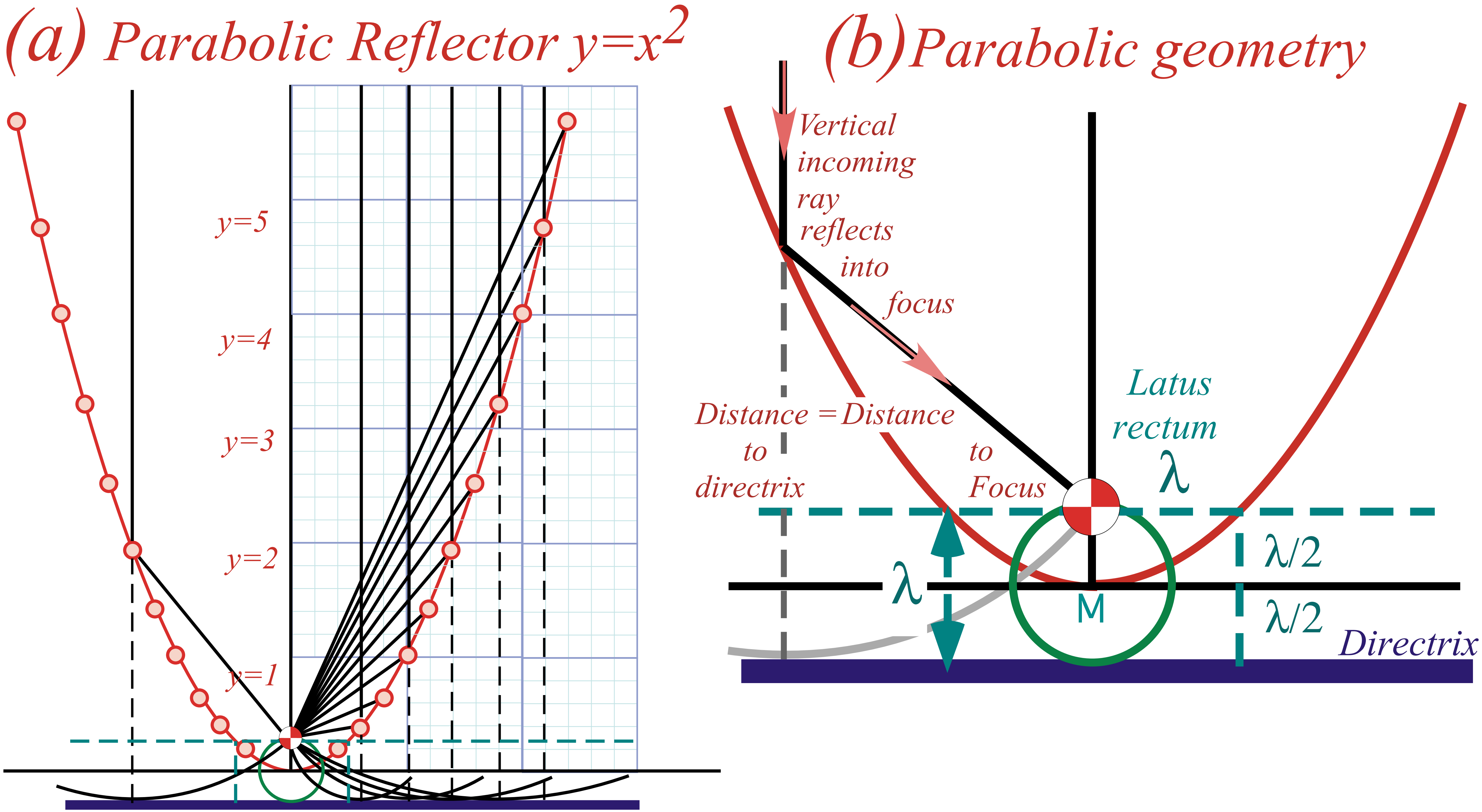
"Zag" line is $y=(?)\cdot x$ and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$

(a) Oscillator potential $U(x)=x^2$ (b) Hooke-Law **Force $F(x)=-2x$**



Unit 1
Fig. 9.1

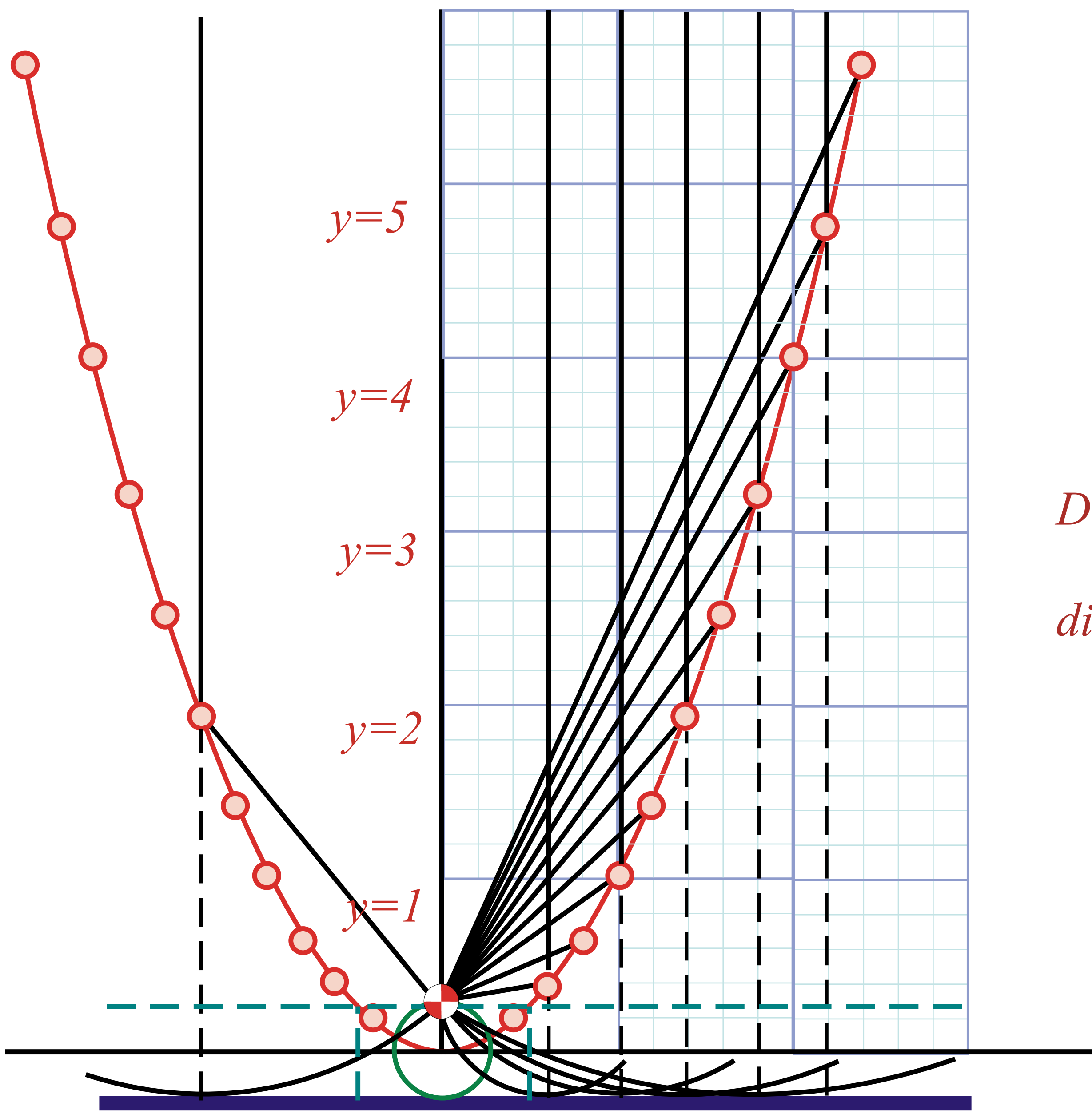
A more conventional parabolic geometry…(uses focal point)



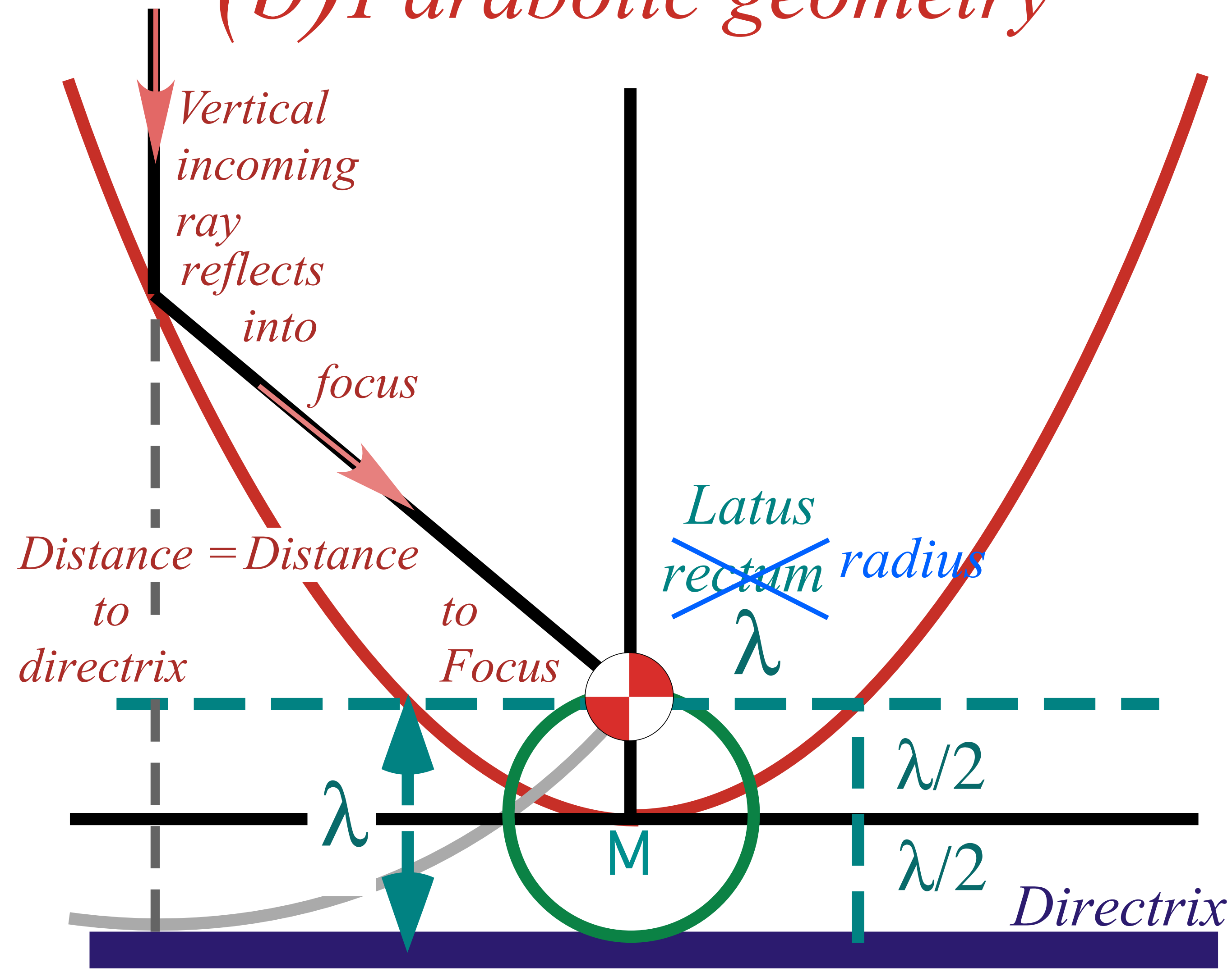
Unit 1
Fig. 9.3

A more conventional parabolic geometry...

(a) Parabolic Reflector $y=x^2$



(b) Parabolic geometry

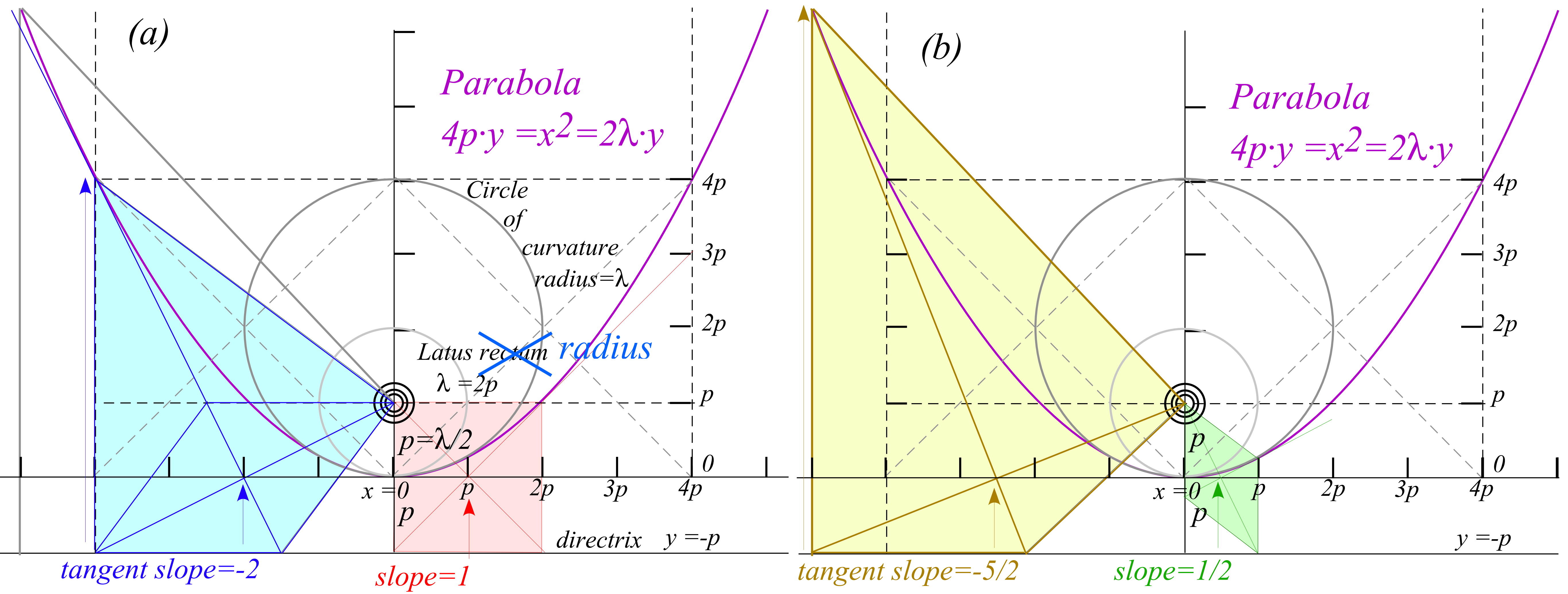


Better name† for λ : *latus radius*

†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

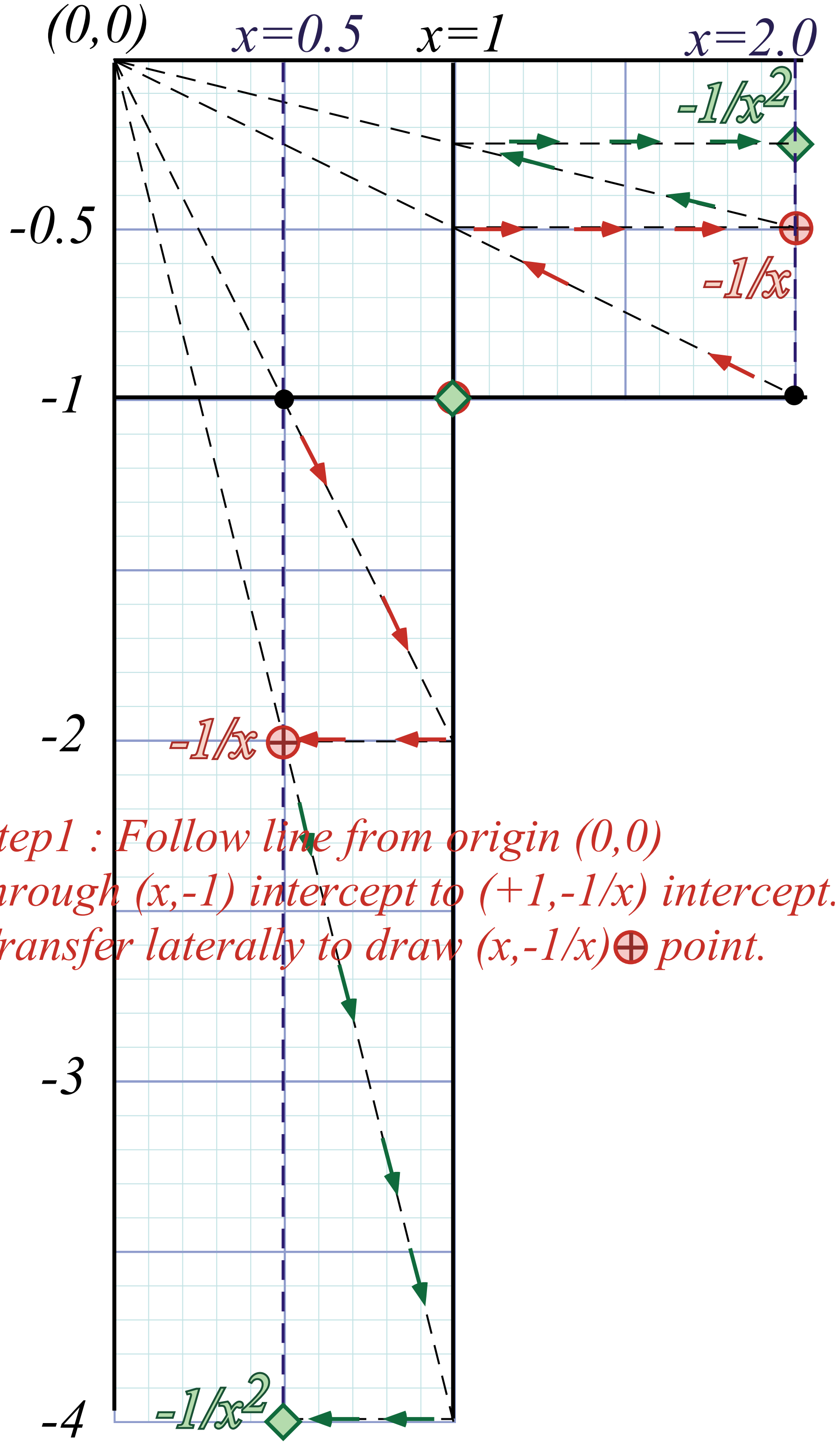
Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

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

Compare mks units of Coulomb Electrostatic vs. Gravity

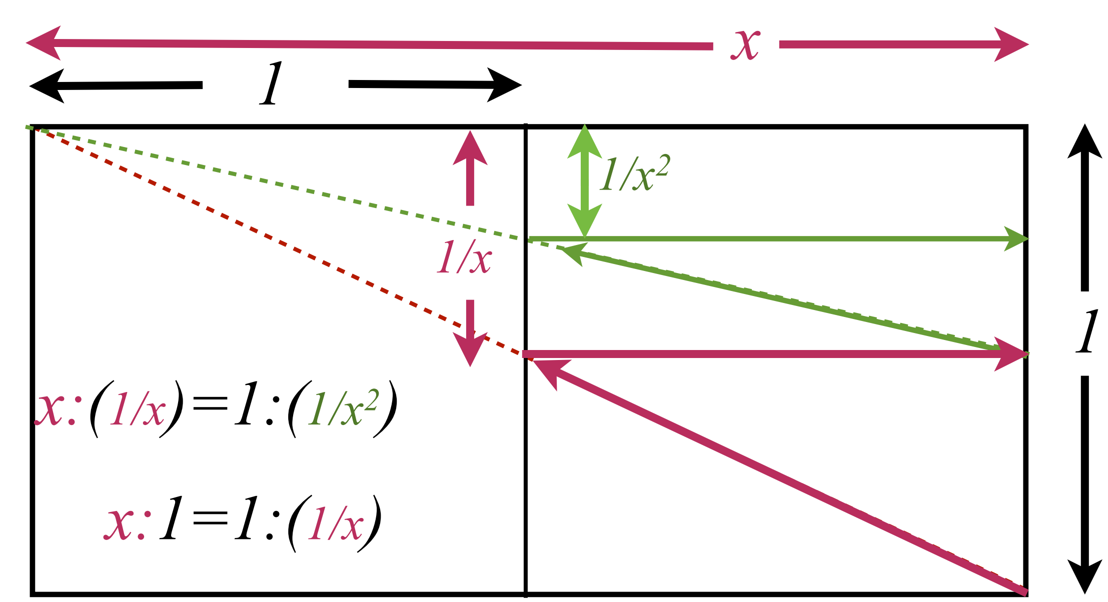
Unit 1
Fig. 9.4

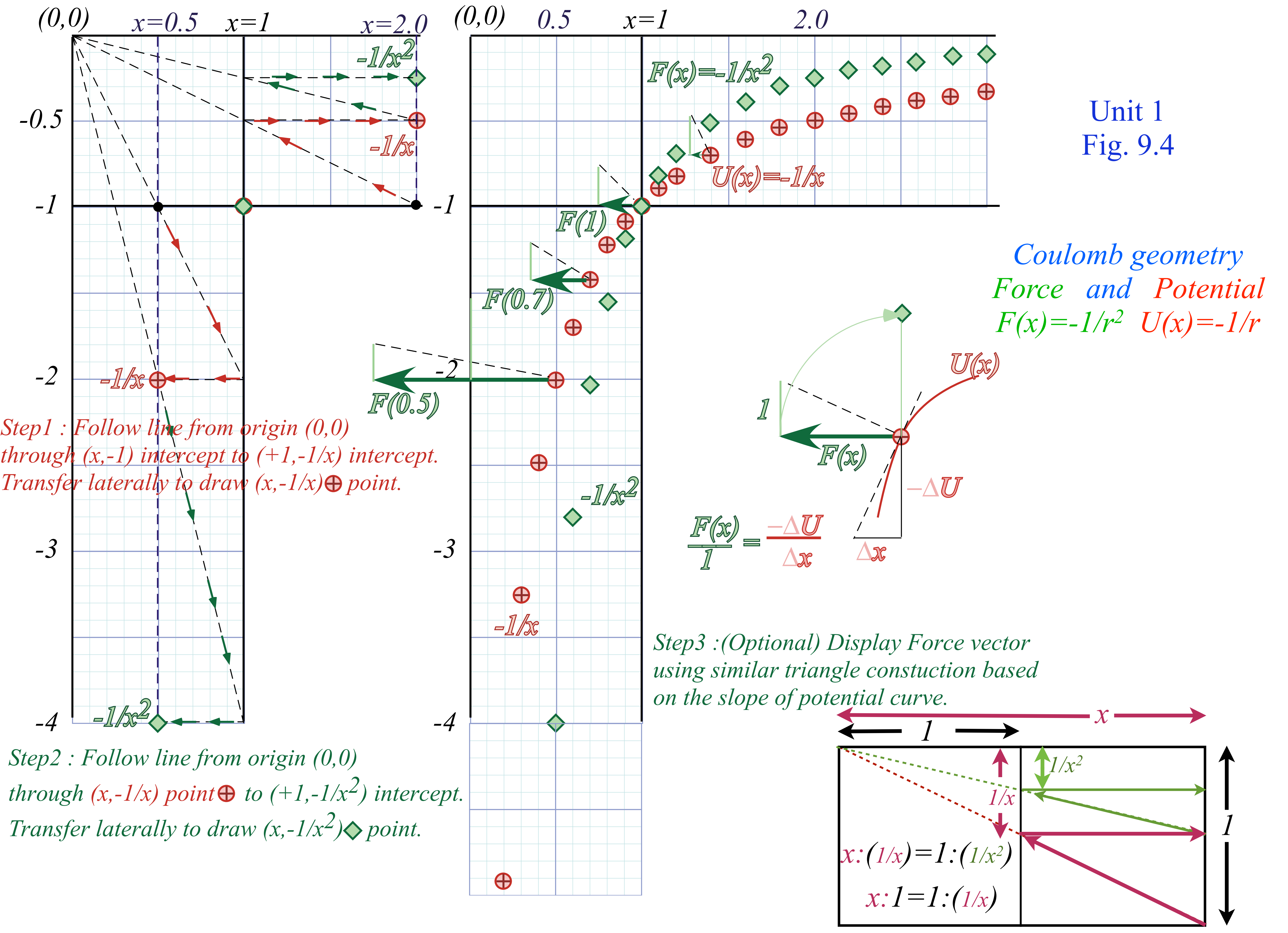
Coulomb geometry
Force and Potential
$F(x)=-1/r^2$ $U(x)=-1/r$

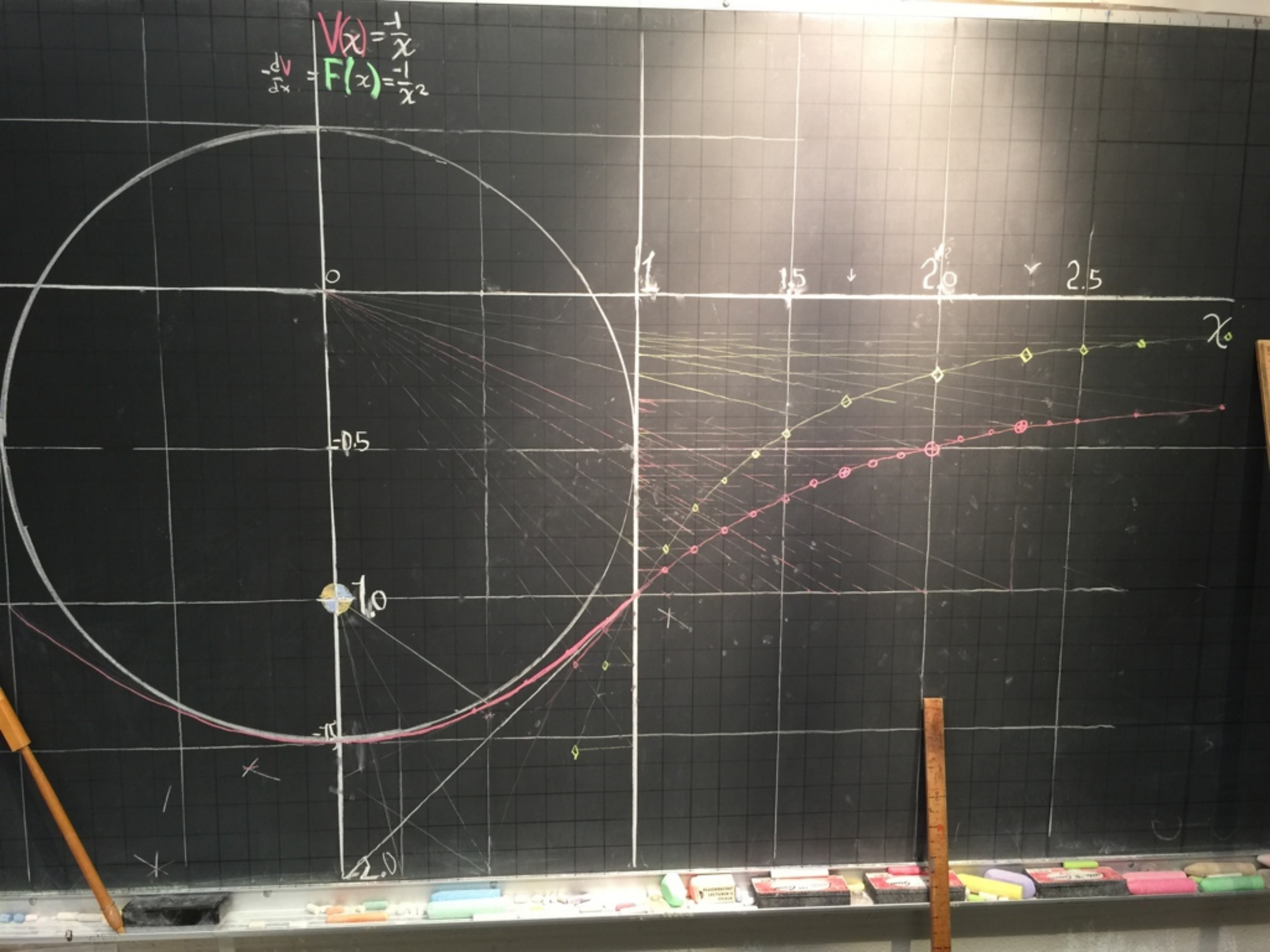


Step1 : Follow line from origin (0,0) through (x,-1) intercept to (+1,-1/x) intercept. Transfer laterally to draw (x,-1/x)⊕ point.

Step2 : Follow line from origin (0,0) through (x,-1/x) point⊕ to $(+1,-1/x^2)$ intercept. Transfer laterally to draw $(x,-1/x^2)$◇ point.




Unit 1
Fig. 9.4
Coulomb geometry
Force and Potential
F(x)=-1/r2 U(x)=-1/r
(0,0)
x=0.5
x=1
x=2.0
-0.5
-1
-2
-3
-4
-1/x2
-1/x
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.
0.5
2.0
F(x)=-1/x2
U(x)=-1/x
F(1)
F(0.7)
F(0.5)
U(x)
1
F(x)
−ΔU
F(x)/1 = −ΔU/Δx
Δx
Step3 :(Optional) Display Force vector
using similar triangle constuction based
on the slope of potential curve.
x
1
1/x2
1/x
x:(1/x)=1:(1/x2)
x:1=1:(1/x)



V(x) = -1/x
-dV/dx = F(x) = -1/x²
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}

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

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~9E9~10^{10}

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

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

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

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

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↑

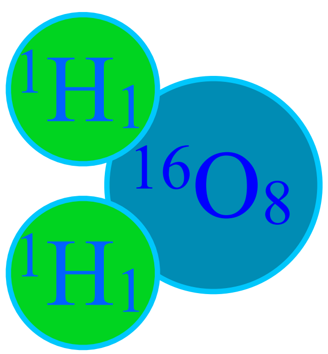
Repulsive (+)(+) or (-)(-)
Attractive (+)(-) or (-)(+)

...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) $6 \cdot 10^{23}$ molecules — *Avogodro's Number*

$\sim 0.3 \cdot 10^{23}$

H_2O Molecular weight~18



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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*

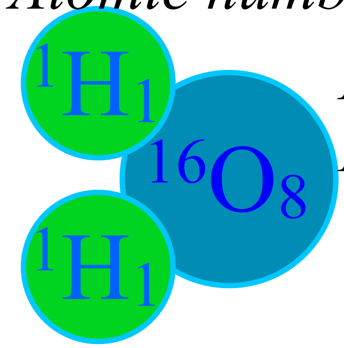
↑

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* $\sim 3 \cdot 10^{23}$ *electrons*
$\sim 0.3 \cdot 10^{23}$ *and* $\sim 3 \cdot 10^{23}$ *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*

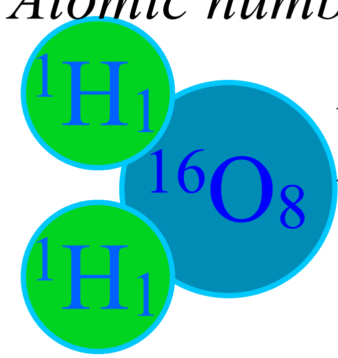
↑

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)* $6\cdot10^{23}$ *molecules or ~* $3\cdot10^{23}$ *electrons*
$\sim 0.3\cdot10^{23}$ *and ~* $3\cdot10^{23}$ *protrons.*

H_2O Molecular weight~18
Atomic number = 10



10 electrons *That is ~* $-3\cdot10^{23}\, 1.6022\cdot10^{-19}$ *Coulomb or about* $-0.5\cdot10^{+5}$ *C or − 50,000 Coulomb*
10 protons *plus ~* $+3\cdot10^{23}\, 1.6022\cdot10^{-19}$ *Coulomb or about* $+0.5\cdot10^{+5}$ *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 : $1/4\pi\varepsilon_0 = 8.987{,}551 \cdot 10^9 Nm^2/C^2$ $\sim 9\cdot 10^9 \sim 10^{10}$

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.)

$$F^{grav.}(r) = -G\frac{mM}{r^2} \quad where: G = \boxed{?.?\cdot 10^?} \frac{Newtons \cdot meter \cdot square}{per\ square\ Coulomb}$$

Compare mks units for Coulomb fields

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

~9E9~10^{10}

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

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

↓

↕ COMPARE! ↕

BIG
vs
small

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

$\sim {}^2/_3 10^{-10} \sim 10^{-10}$

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

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

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.)

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

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

!!!!

Compare mks units for Coulomb fields

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

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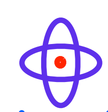
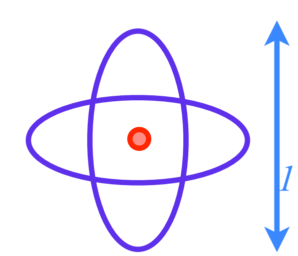
$\sim 9E9 \sim 10^{10}$!!!!



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

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



Compare mks units for Coulomb fields

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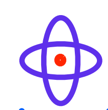
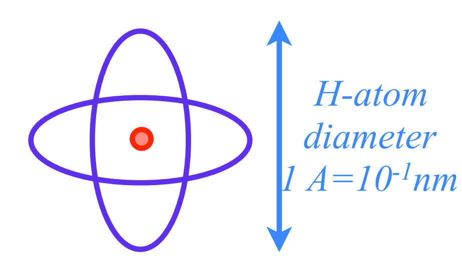


Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

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

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



Compare mks units for Coulomb fields

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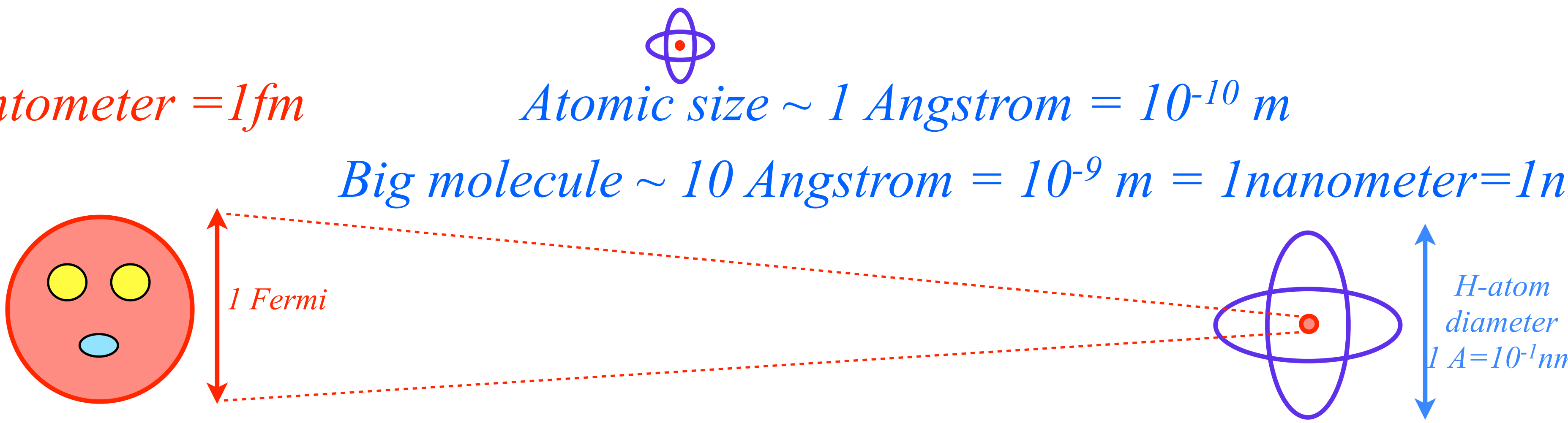
Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

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

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

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



Compare mks units for Coulomb fields

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

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

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

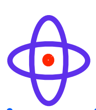
quantum of charge: $|e| = 1.6022 \cdot 10^{-19}$ Coulomb

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

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

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

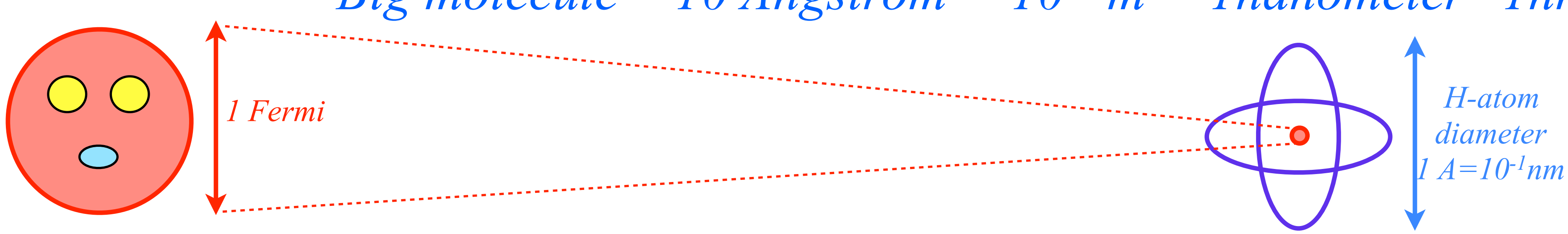
Nuclear size ~ 10^{-15} m = 1 femtometer =1fm



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

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

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



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 **bigger** that of atomic/chemical...*

Geometry of idealized "Sophomore-physics Earth"

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

Contact-geometry of potential curve(s)

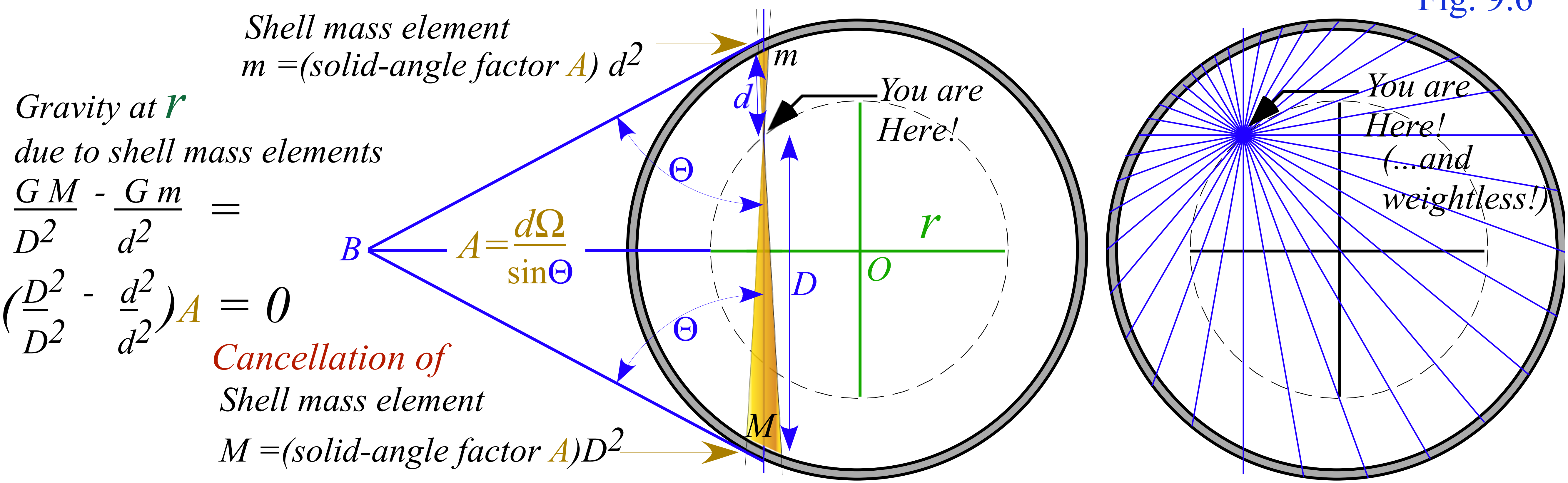
"Crushed-Earth" models: 3 key energy "steps" and 4 key energy "levels"

Earth matter vs nuclear matter:

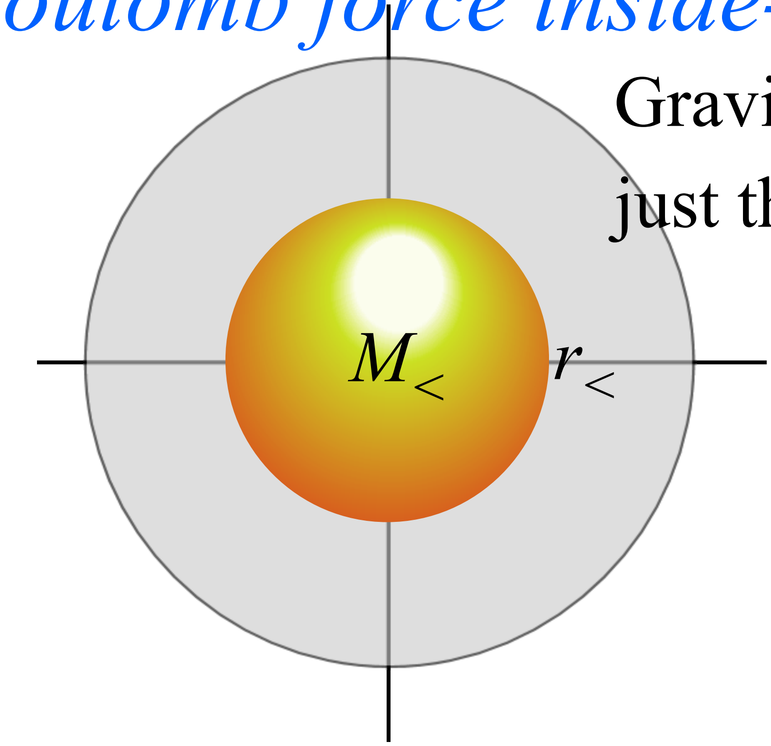
*Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

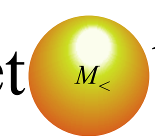
Coulomb force vanishes inside-spherical shell (Gauss-law)

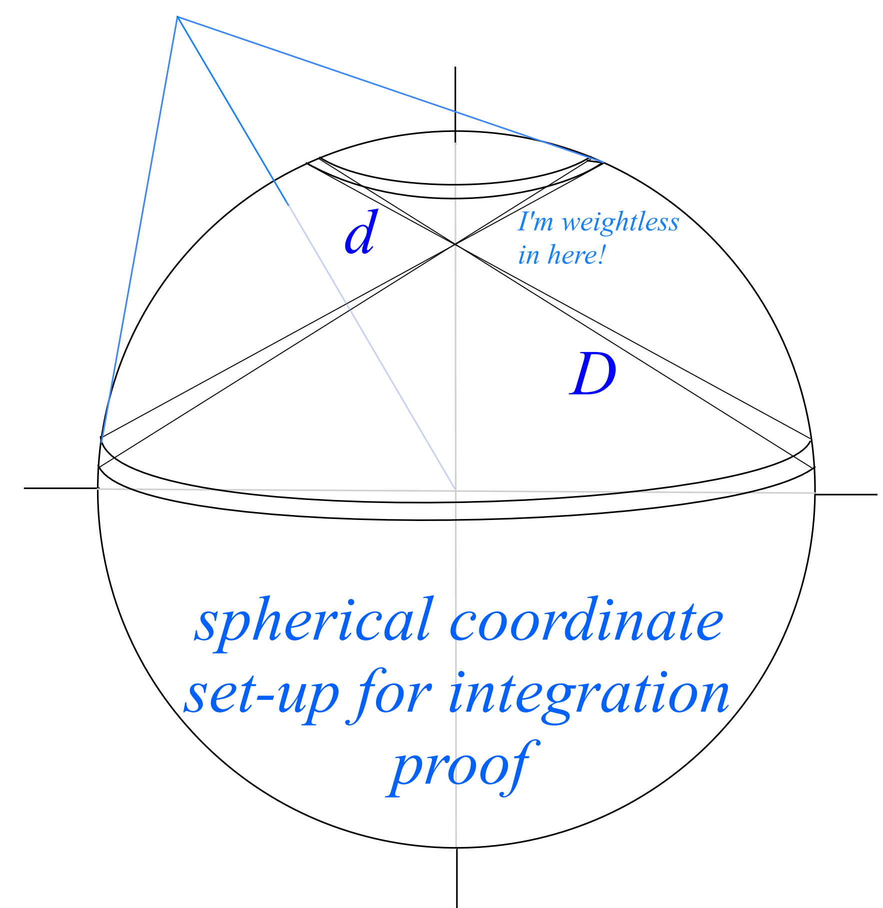
Unit 1
Fig. 9.6



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)

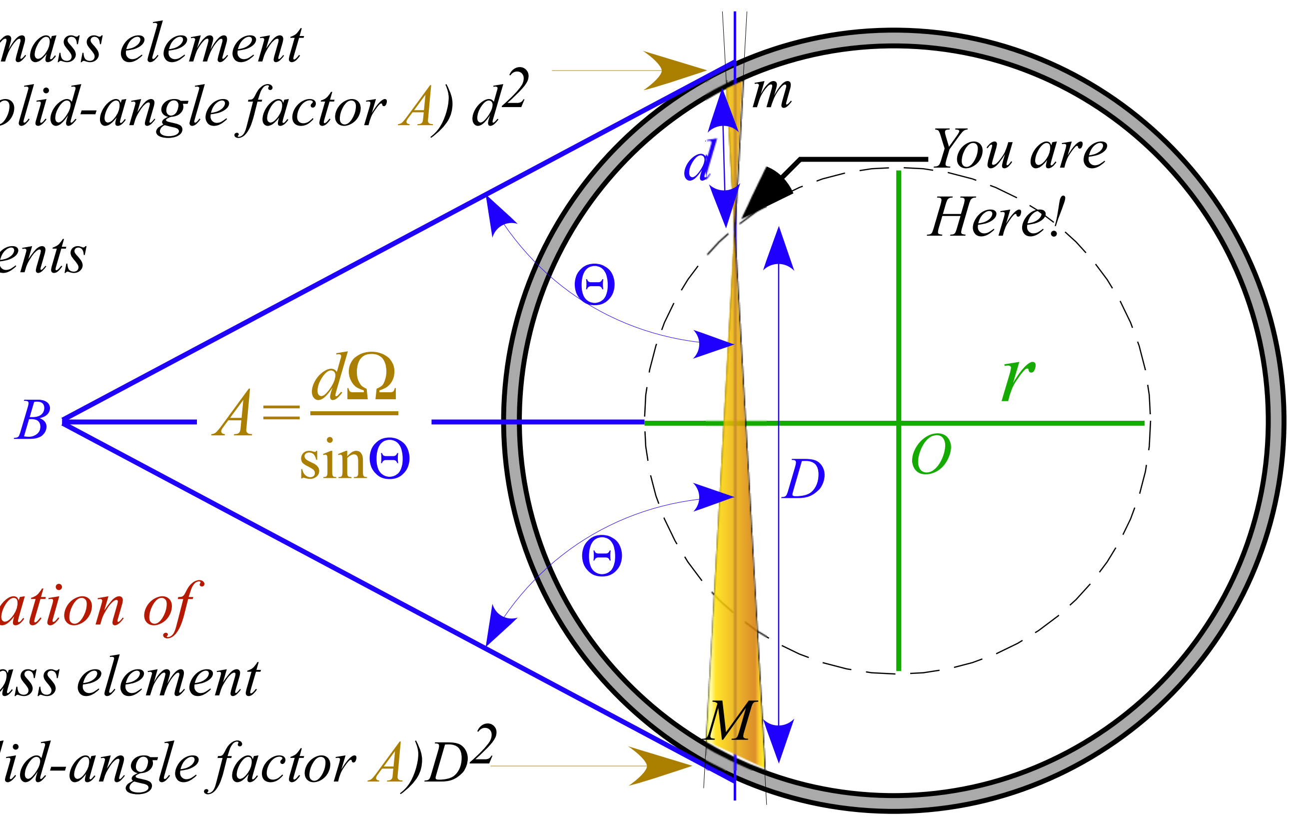
Shell mass element
$m = (\text{solid-angle factor } A)\, d^2$

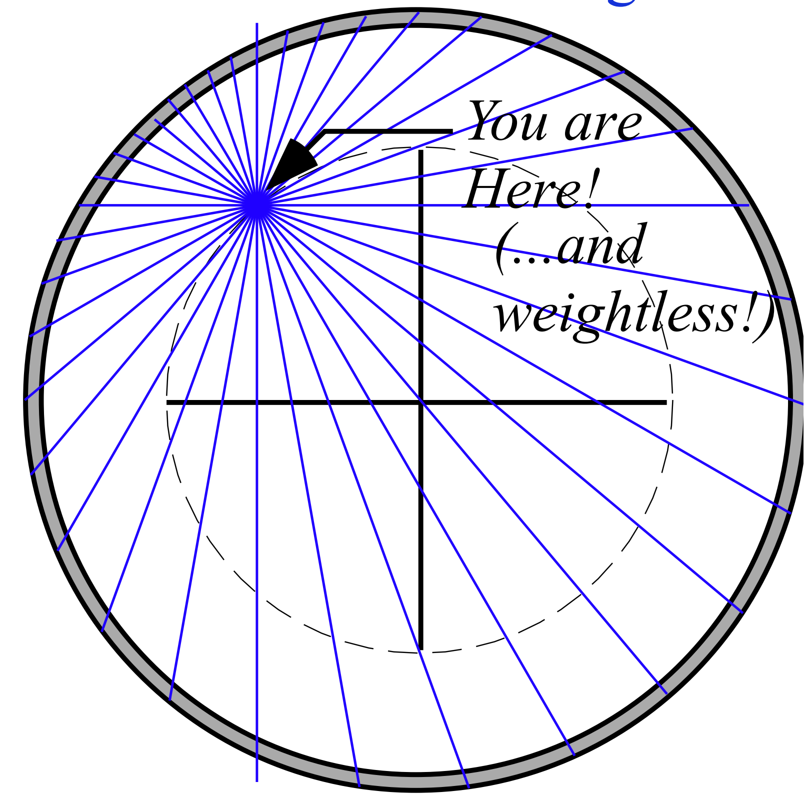
Gravity at r
due to shell mass elements

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

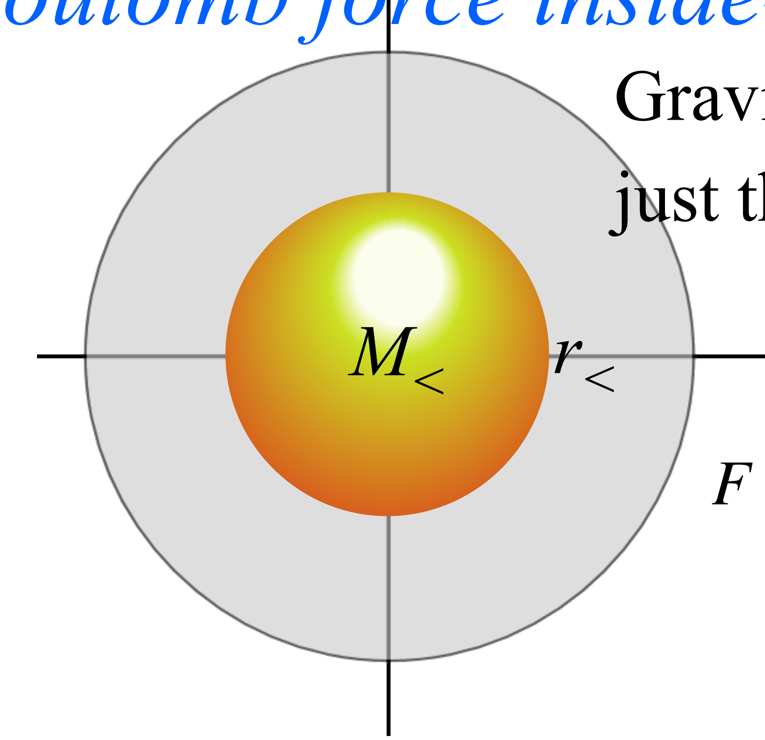
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$

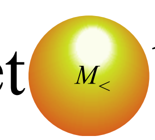
Cancellation of
Shell mass element
$M = (\text{solid-angle factor } A)\, D^2$





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

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

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

Unit 1
Fig. 9.6

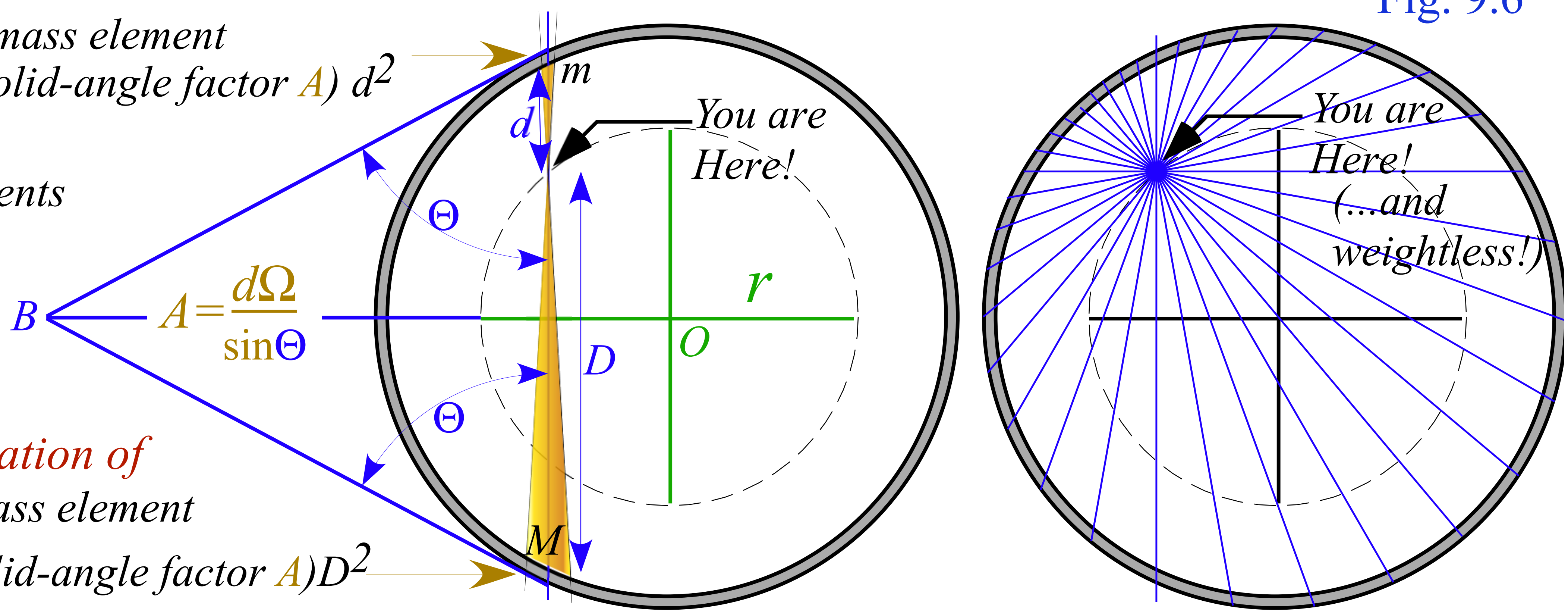
Shell mass element
m =(solid-angle factor A) d^2

Gravity at r
due to shell mass elements

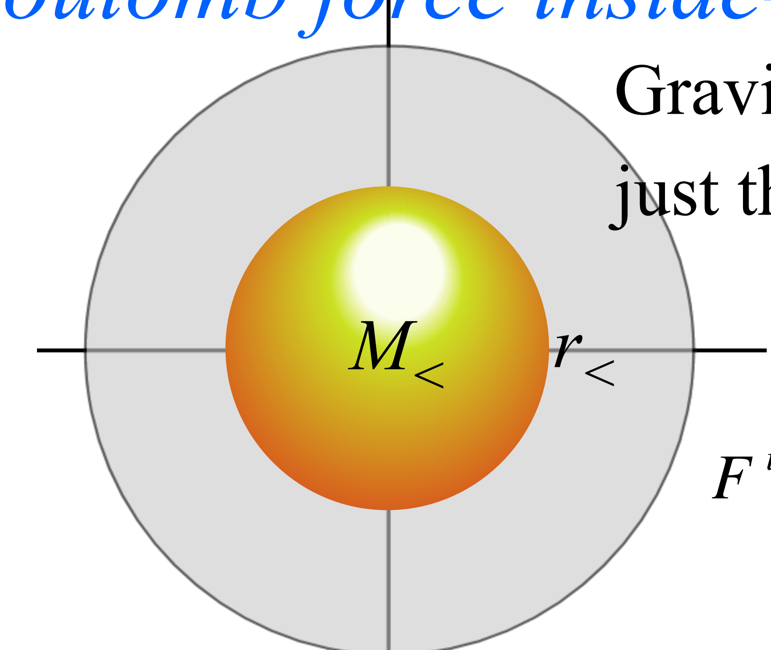
$$\frac{G\,M}{D^2} - \frac{G\,m}{d^2} =$$

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

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 $M_<$ 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

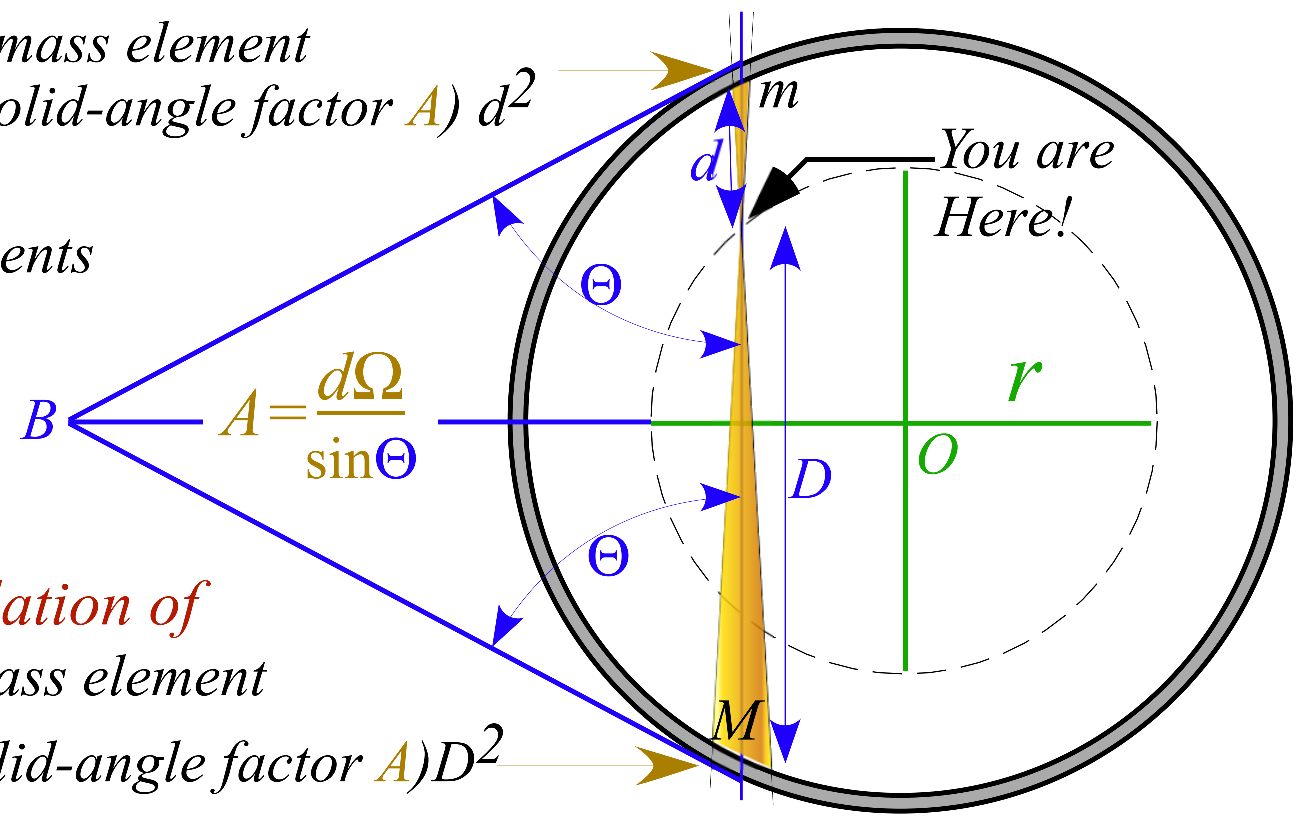
Shell mass element
m =(solid-angle factor A) d^2

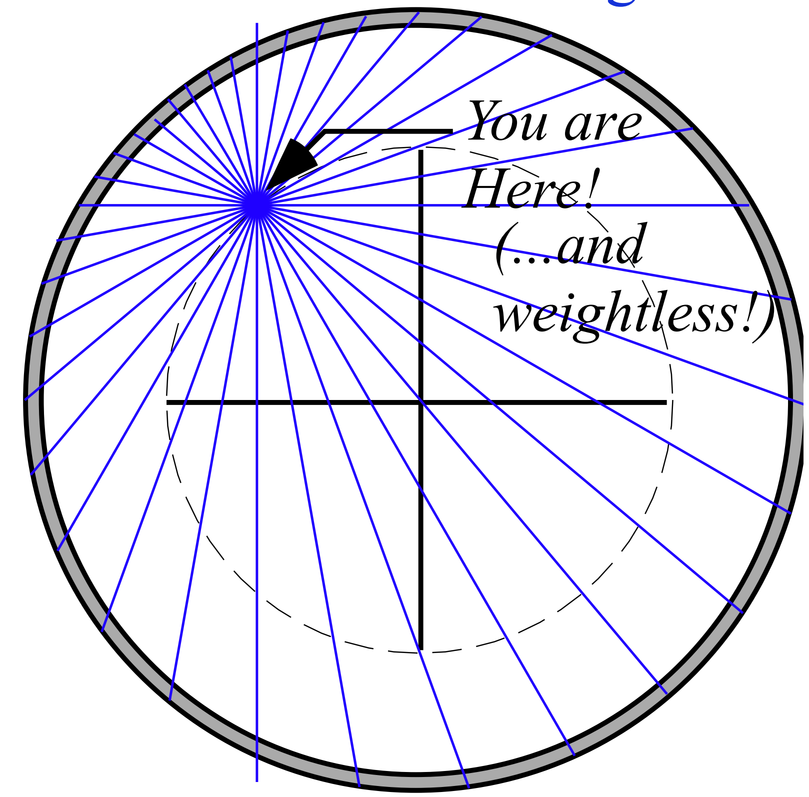
Gravity at r
due to shell mass elements

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

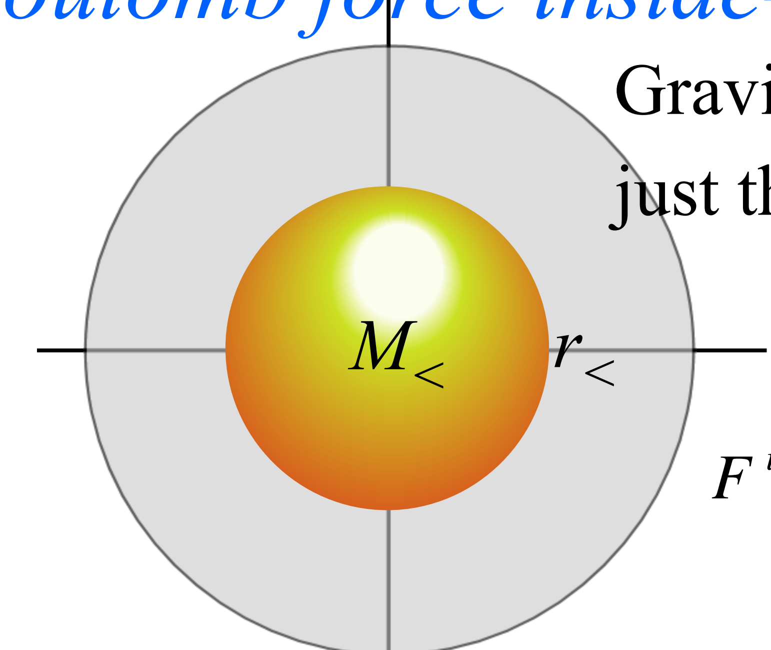
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$

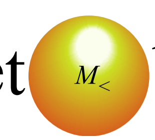
Cancellation of
Shell mass element
M =(solid-angle factor A)D^2





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

G=6.67384(80)·$10^{-11}$$Nm^2/C^2$ ~(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 <u>outside</u> *Isotropic Harmonic Oscillator (IHO) field <u>inside</u>*

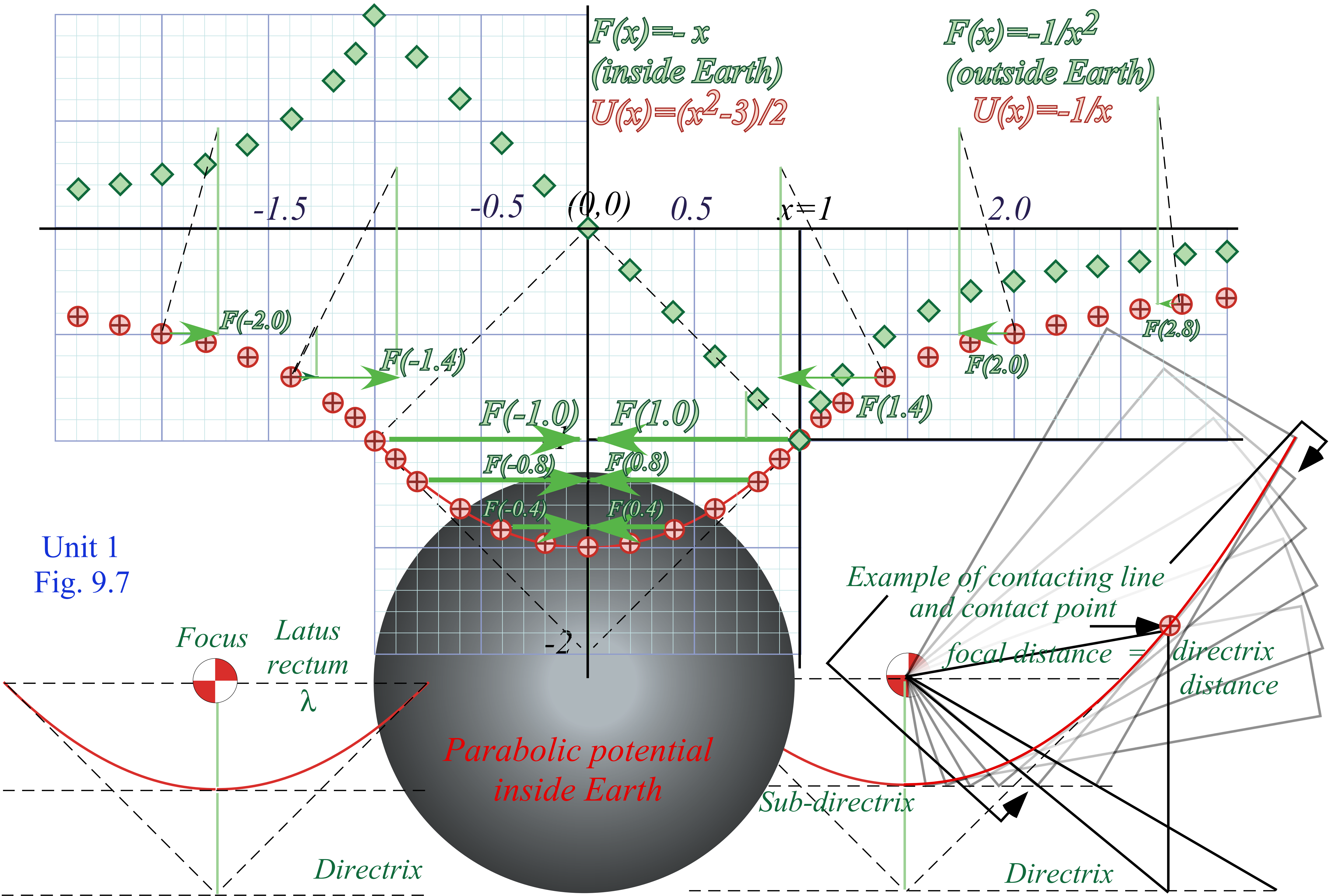
→ *Contact-geometry of potential curve(s)*

"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***"*

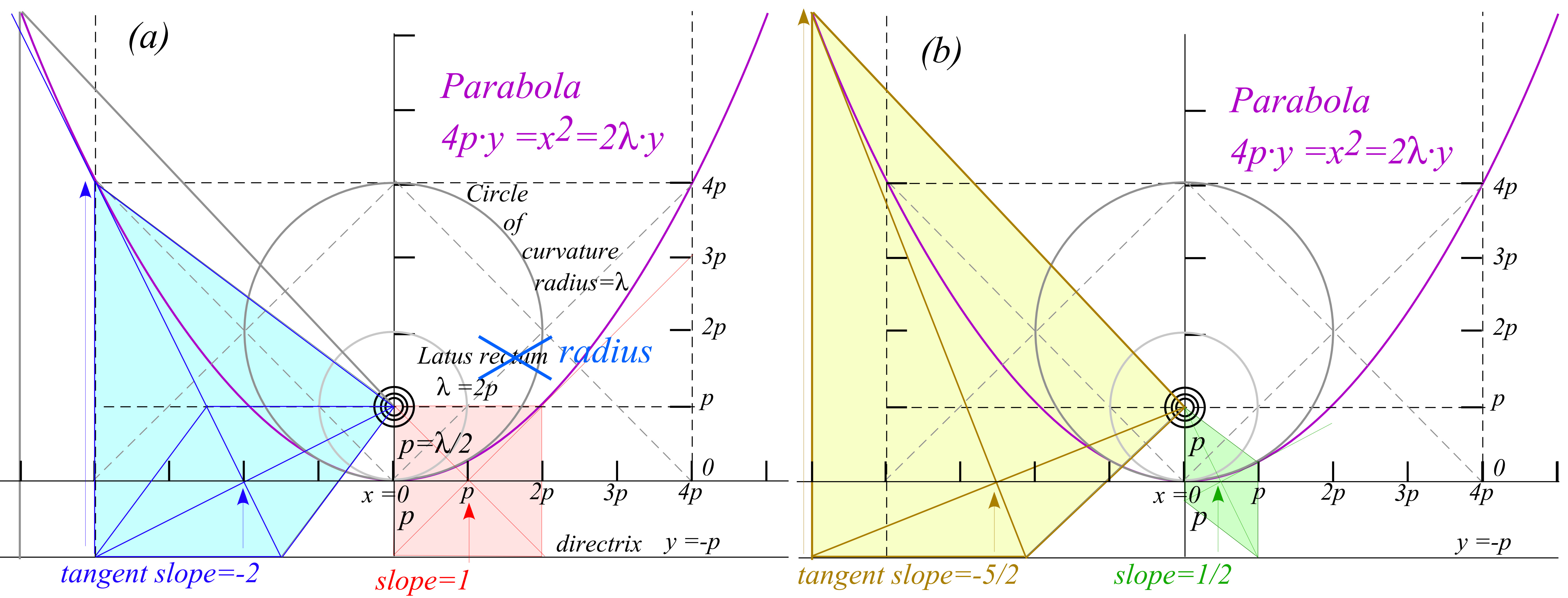
The ideal "Sophomore-Physics-Earth" model of geo-gravity



Unit 1
Fig. 9.7

...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*

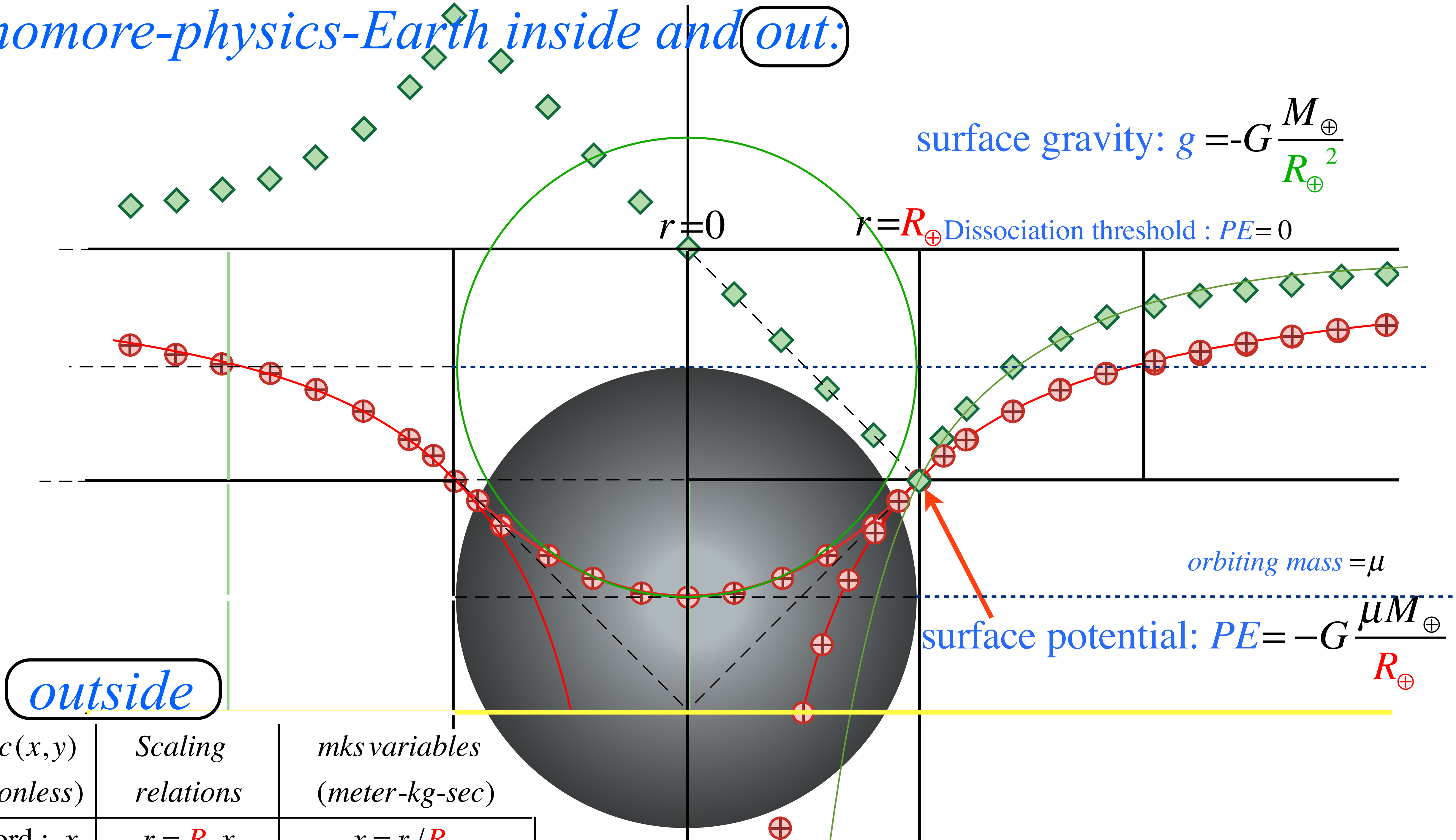
Contact-geometry of potential curve(s)

→ *"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***"*

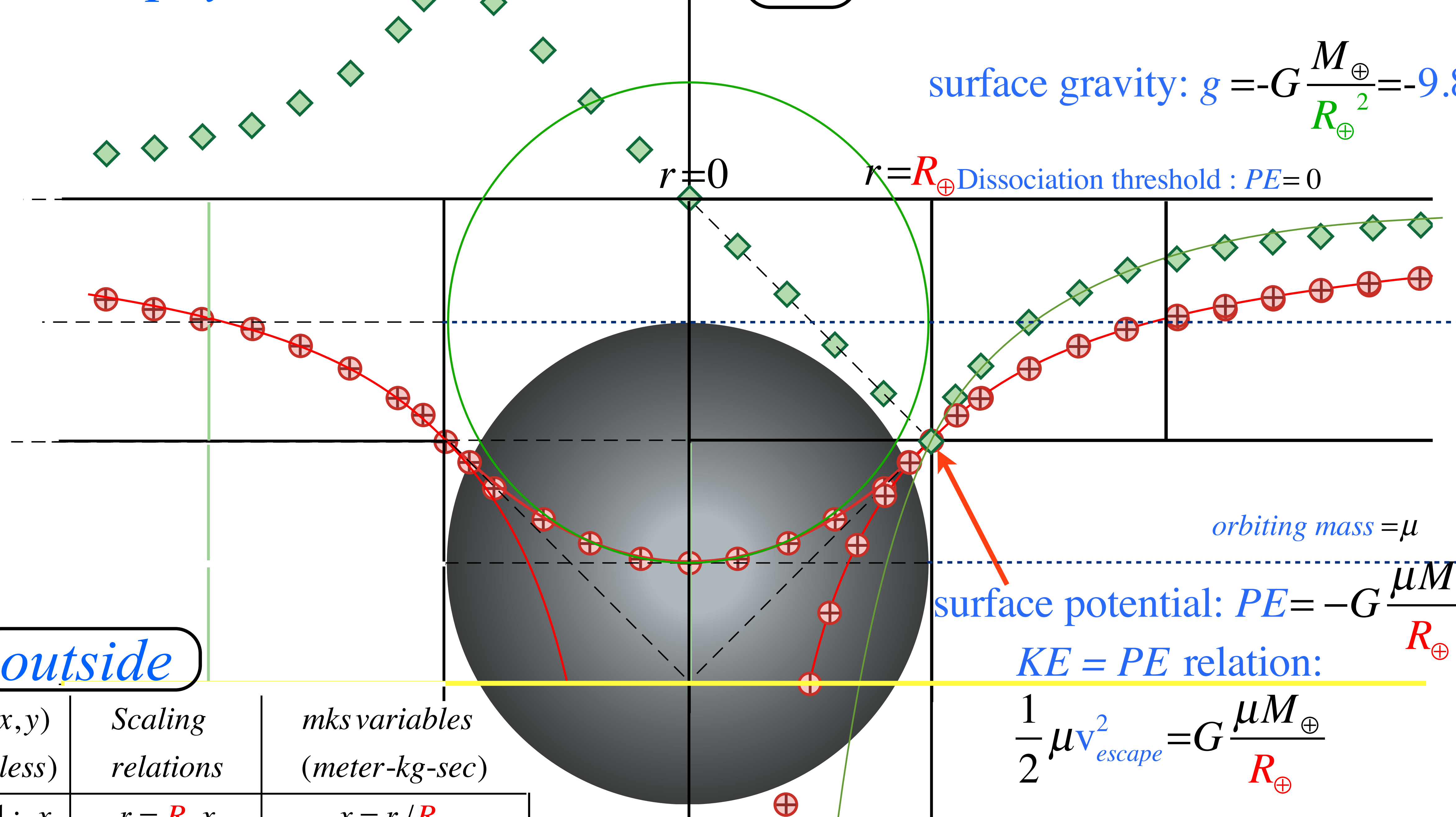
Sophomore-physics-Earth inside and out:



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:

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



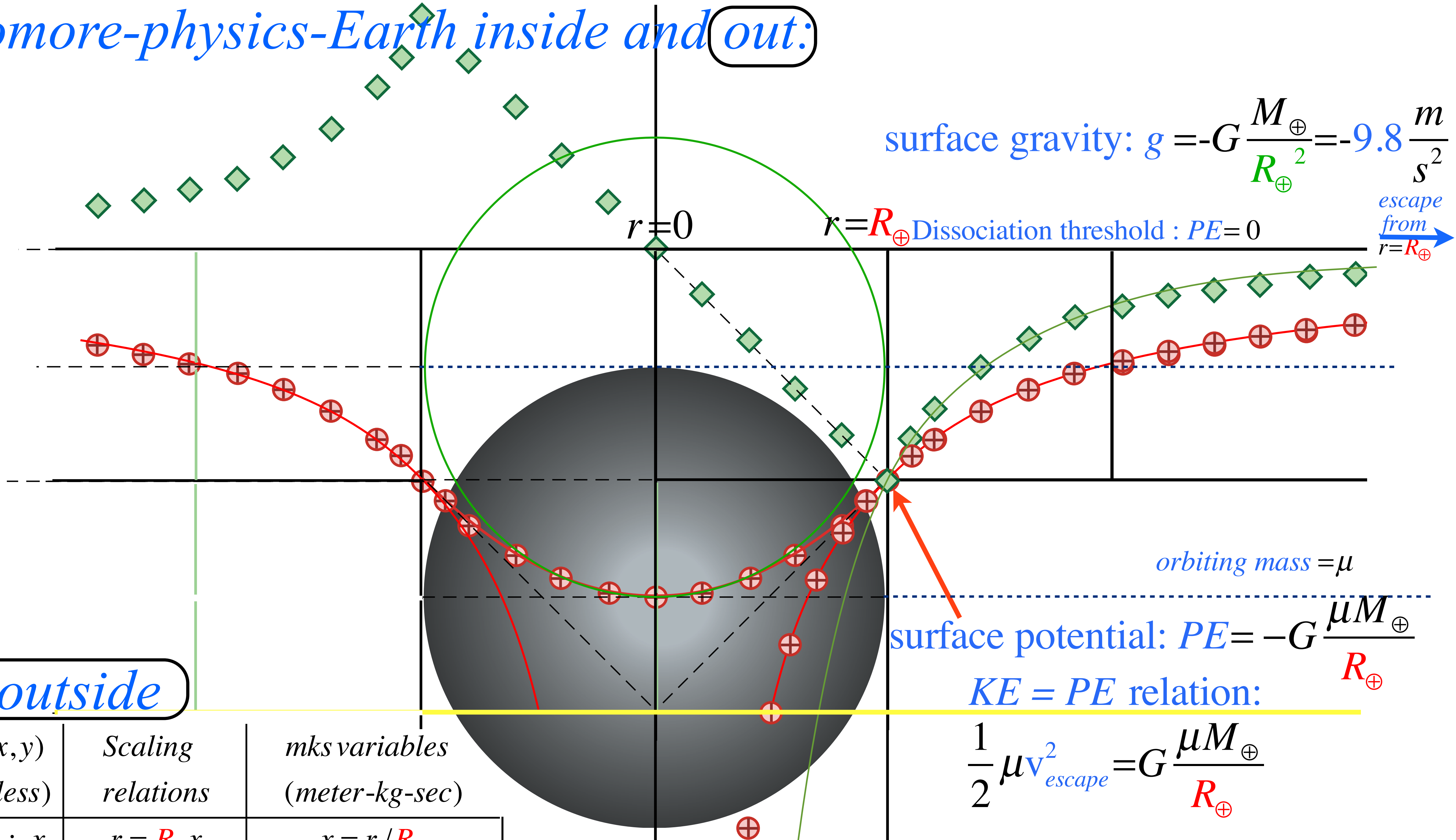
surface potential: $PE = -G\dfrac{\mu M_\oplus}{R_\oplus}$

KE = PE relation:

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

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

KE = PE relation:

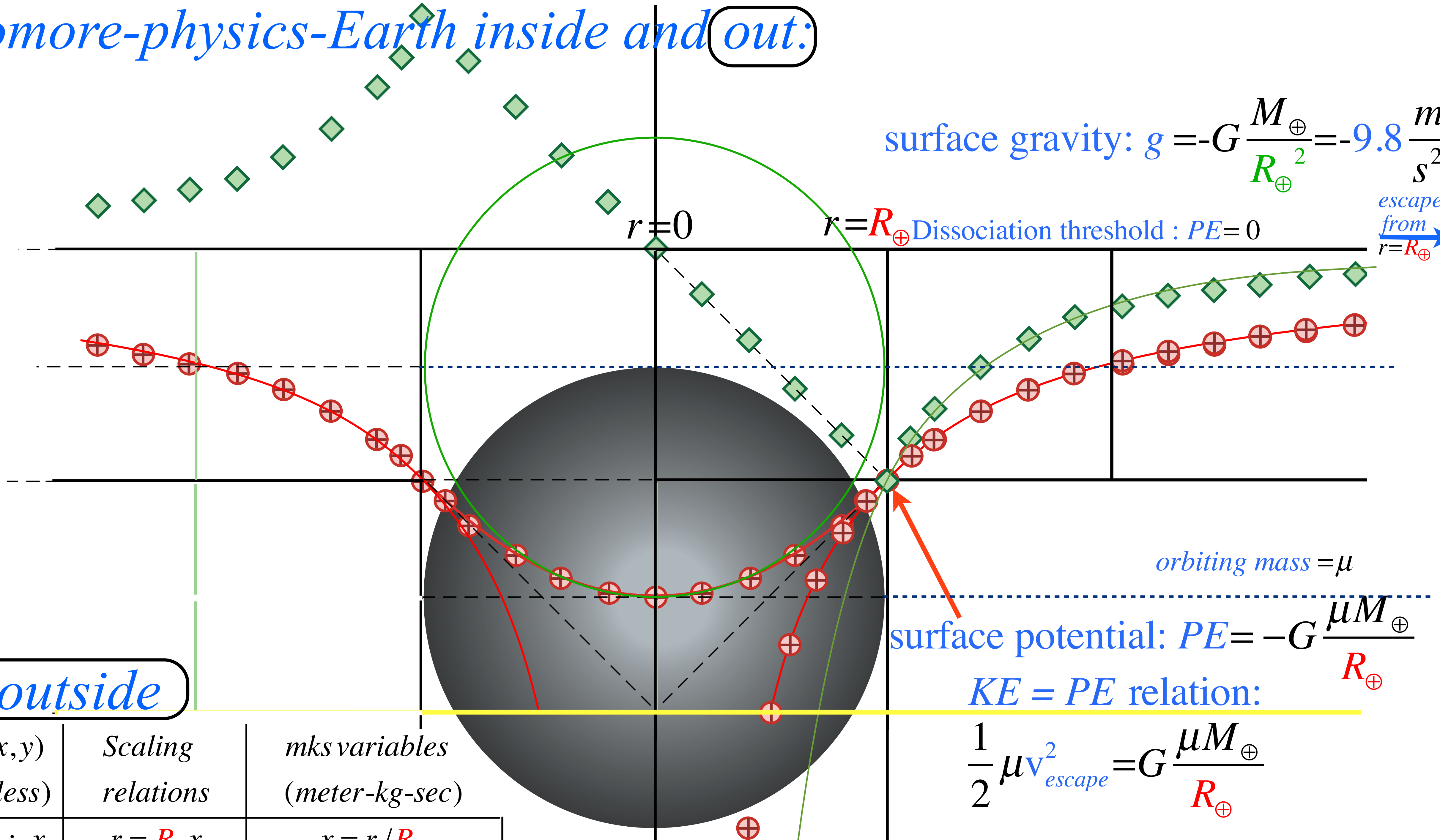
$$\frac{1}{2}\mu v_{escape}^2 = G\frac{\mu M_\oplus}{R_\oplus}$$

$R_\oplus$-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 $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$

Sophomore-physics-Earth inside and out:



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

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

KE = PE relation:

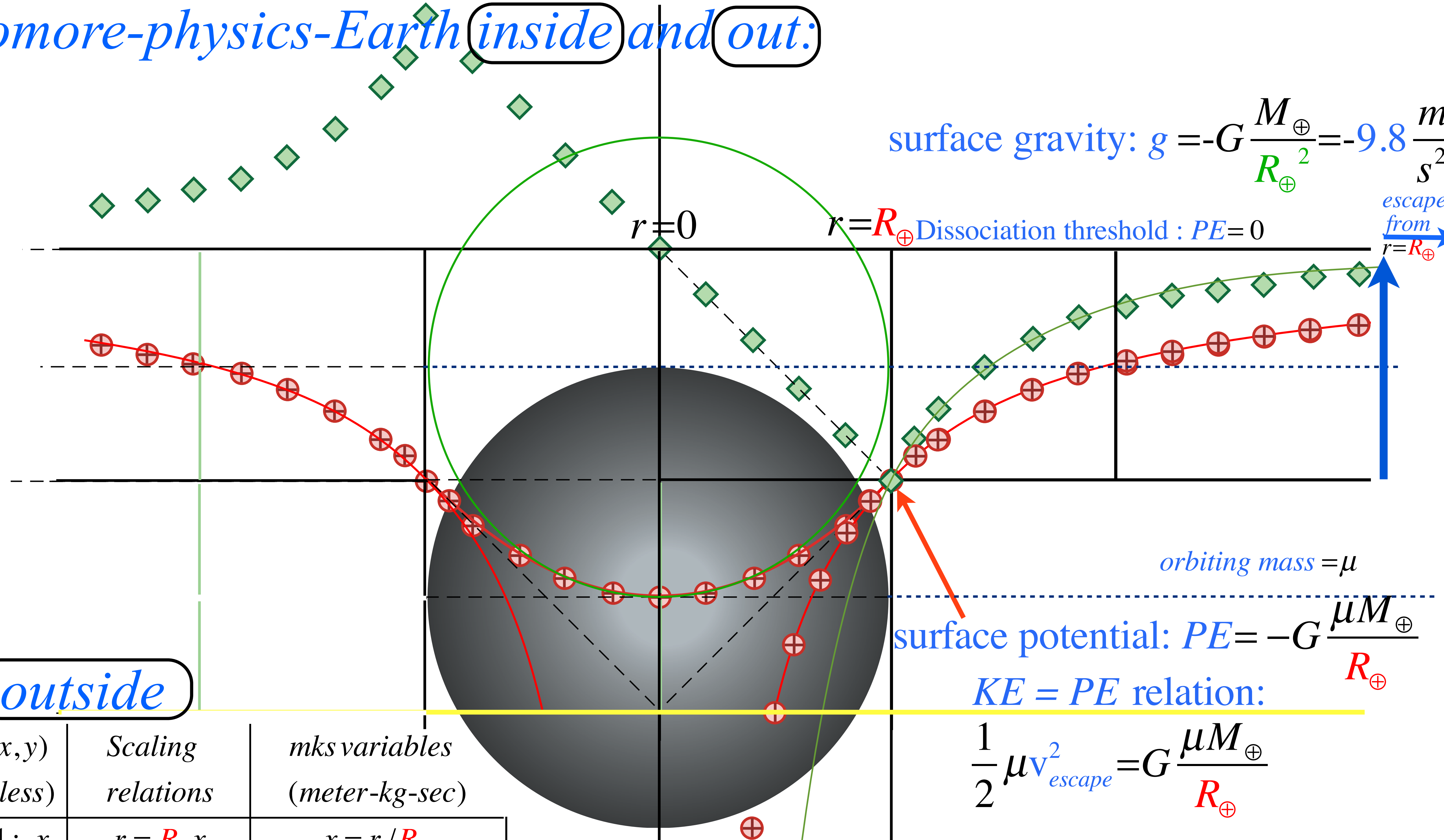
$$\frac{1}{2}\mu v_{escape}^2 = G\frac{\mu M_\oplus}{R_\oplus}$$

$R_\oplus$-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 $\lvert x\rvert \geq 1$: $y^{PE} = \frac{-1}{x}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\frac{GM\mu}{r} = -\frac{GM\mu}{R_\oplus}\frac{1}{x}$
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:



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 $\lvert x\rvert \geq 1$: $y^{Force} = \frac{-1}{x^2}$	$F^{mks}(r) = \frac{GM\mu}{R_\oplus^2} y^{Force}$	$F^{mks}(r) = -\frac{GM\mu}{r^2} = -\frac{GM\mu}{R_\oplus^2}\frac{1}{x^2}$

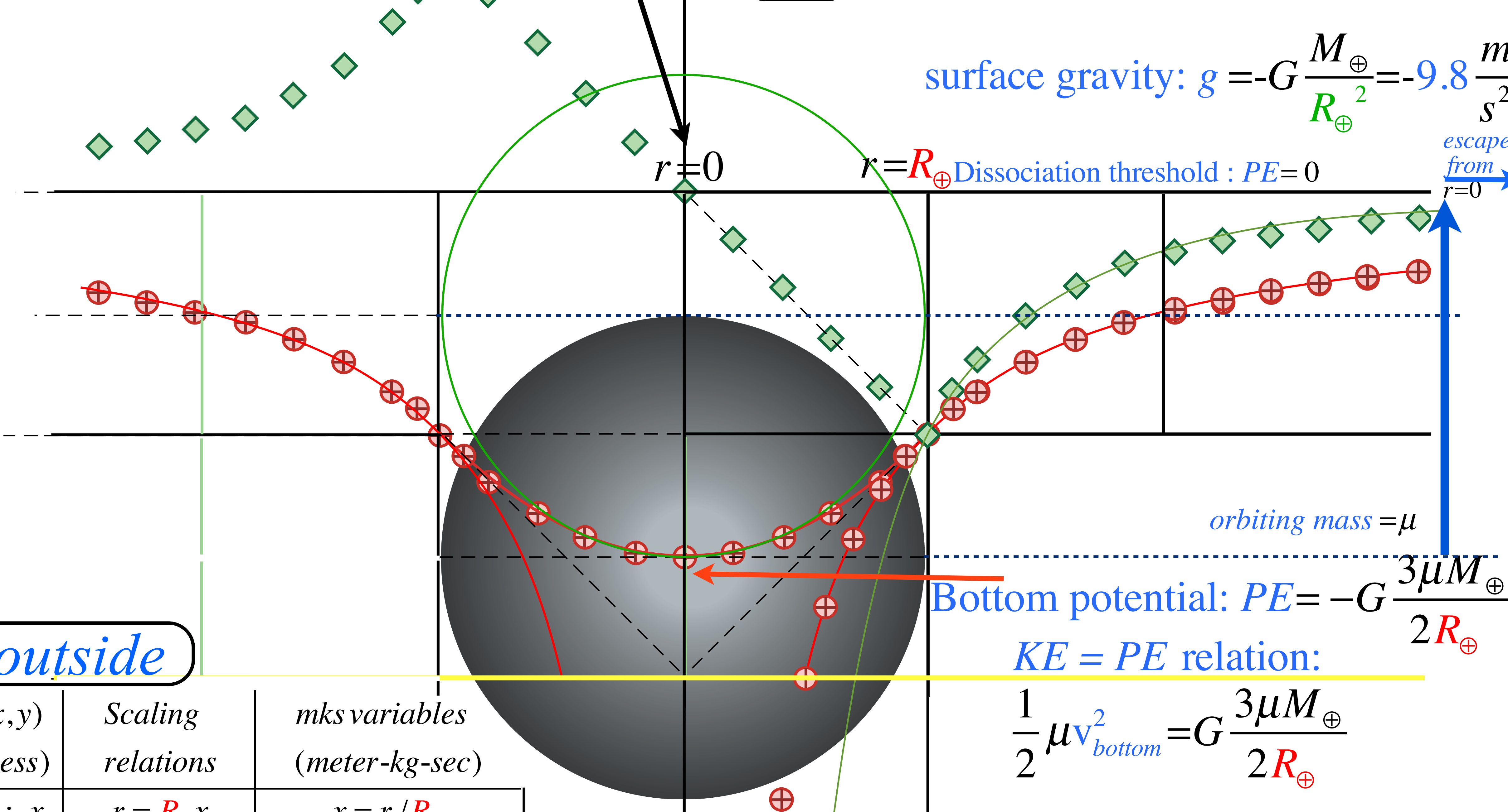
PE for $\lvert x\rvert < 1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
$Force$ for $\lvert x\rvert < 1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$R_\oplus$-escape-velocity

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

11.1km/sec

Sophomore-physics-Earth inside and out:



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

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

KE = PE relation:

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

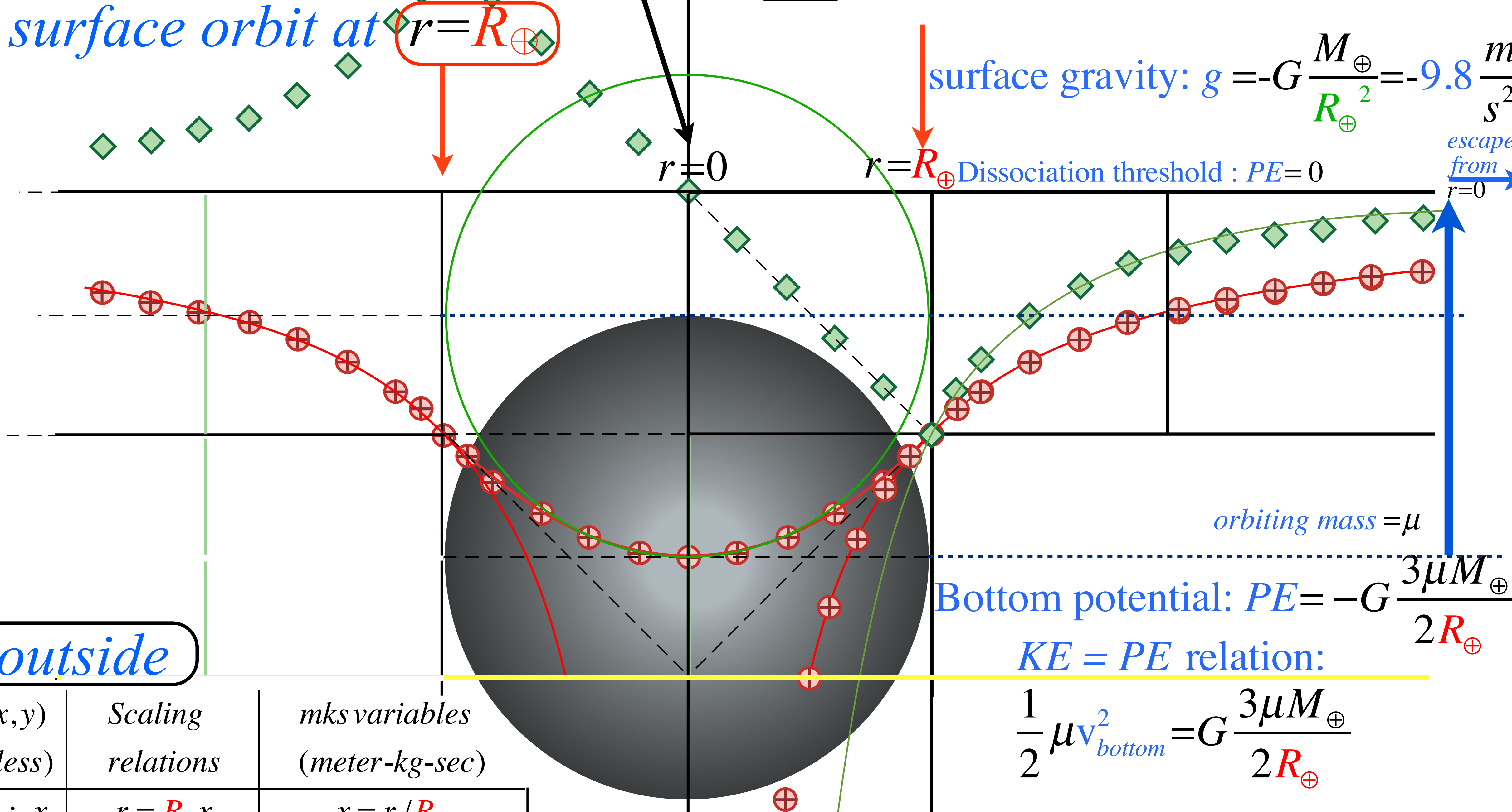
(r=0)-escape-velocity

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

13.7km/sec

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

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



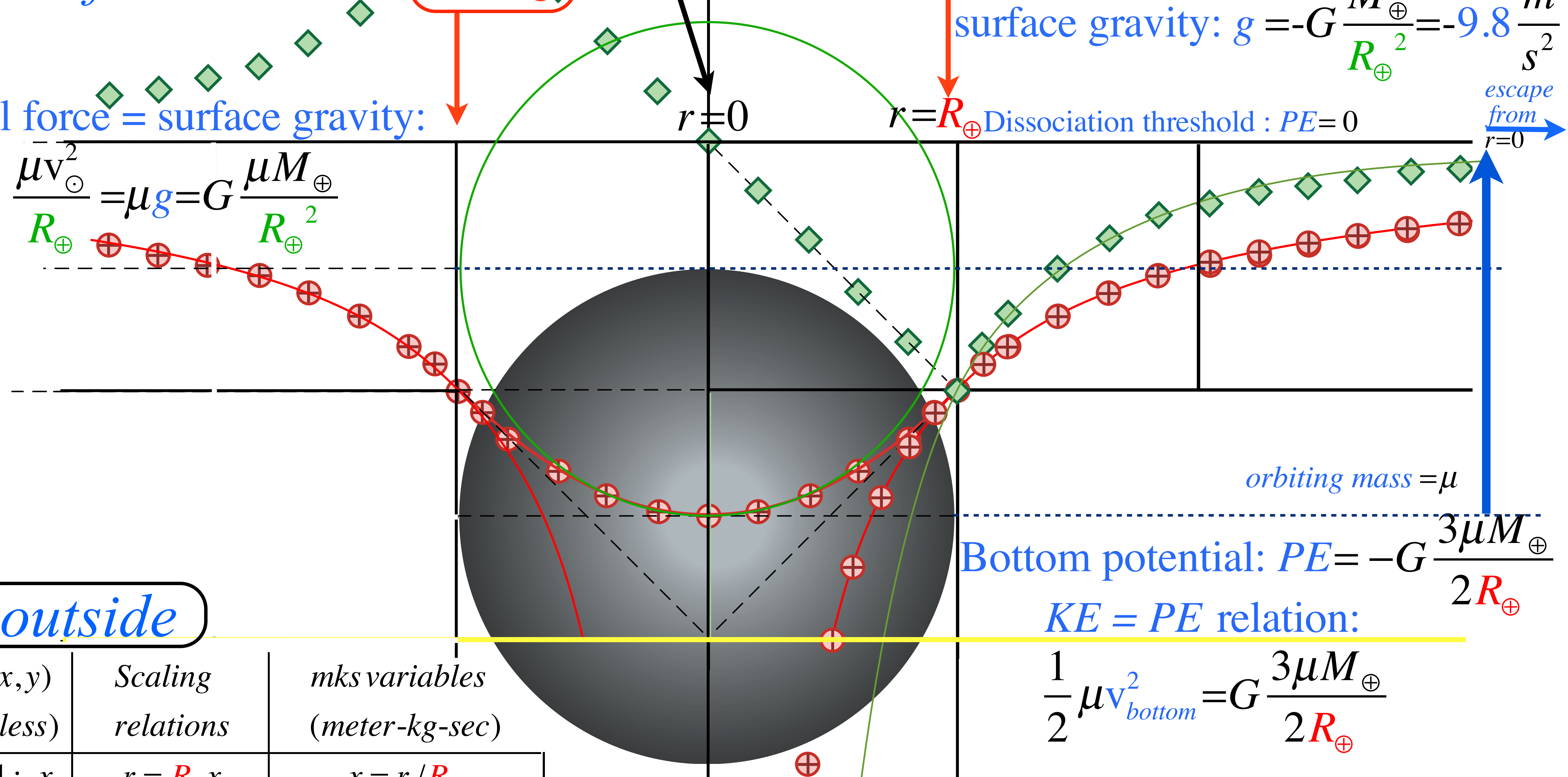
Geometric (x,y) (Dimensionless)	Scaling relations	mks variables (meter-kg-sec)		inside
space coord.: x	$r = R_\oplus x$	$x = r/R_\oplus$		
PE for $\lvert x\rvert \geq 1$: $y^{PE} = \dfrac{-1}{x}$	$PE^{mks}(r) = \dfrac{GM\mu}{R_\oplus} y^{PE}$	$PE^{mks}(r) = -\dfrac{GM\mu}{r} = -\dfrac{GM\mu}{R_\oplus}\dfrac{1}{x}$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

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

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)		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

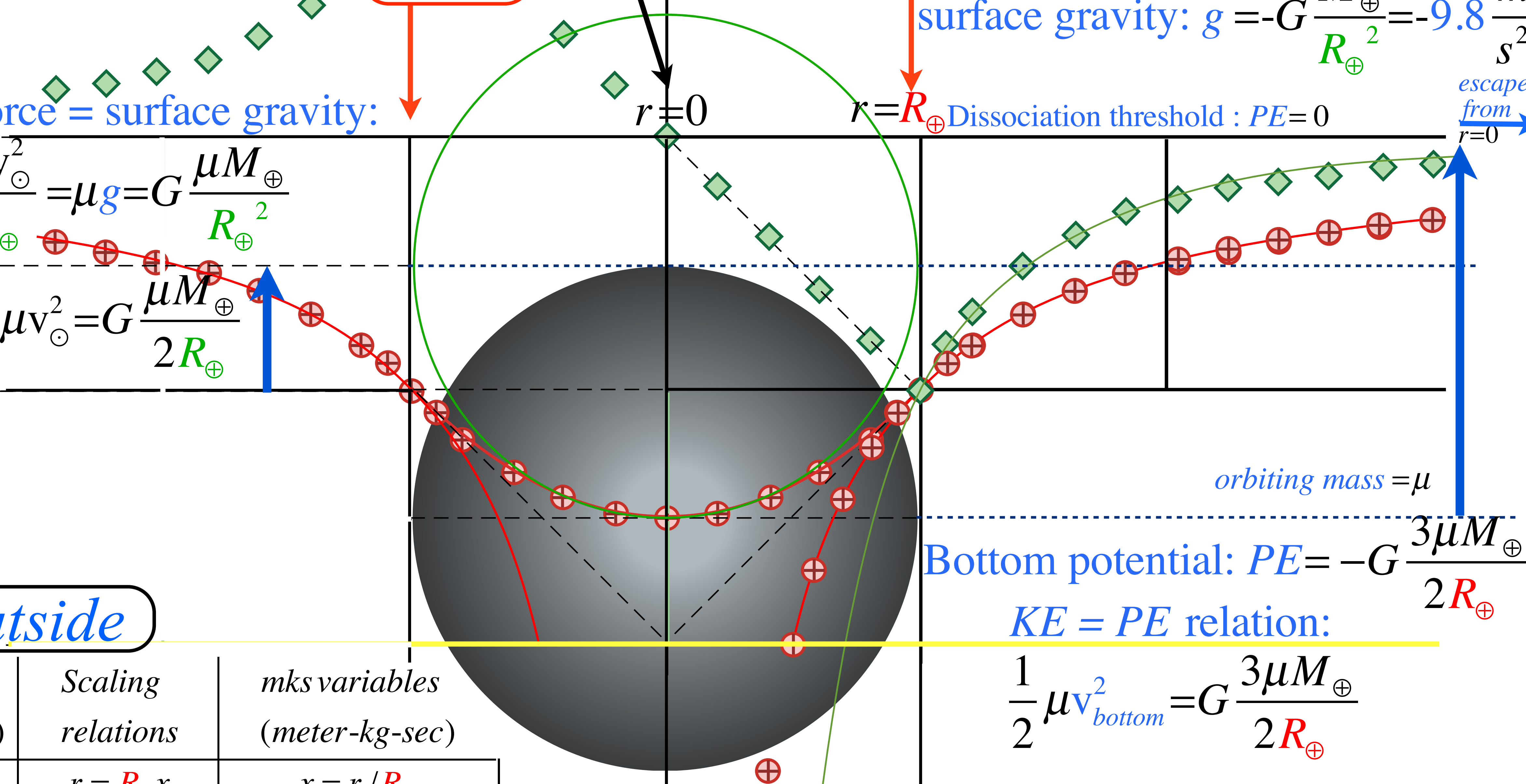
Sophomore-physics-Earth inside and out:
...and surface orbit at $r=R_\oplus$

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



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)
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

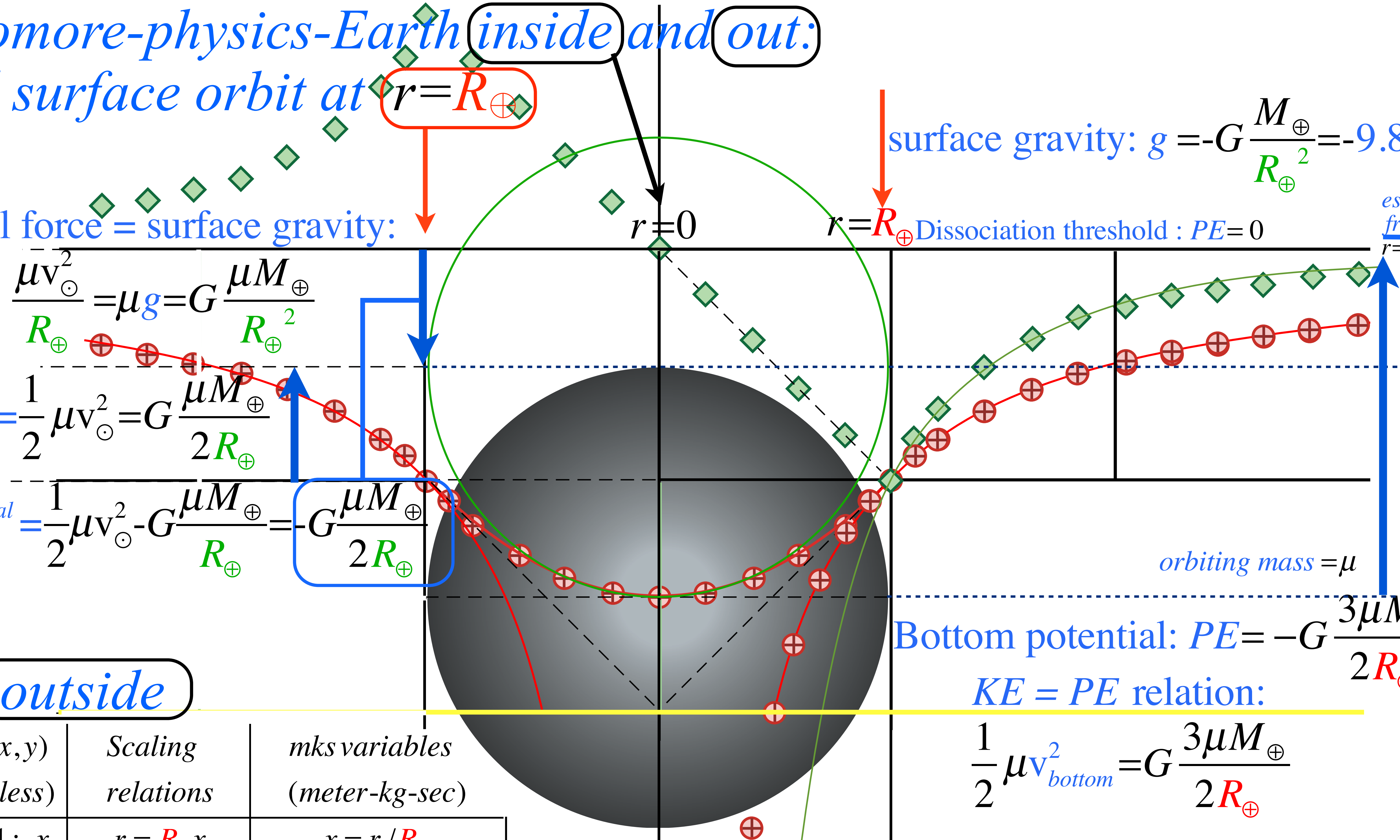
PE for $\lvert x\rvert<1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
Force for $\lvert x\rvert<1$: $y^{Force} = -x$	$F^{mks}(r) = -\frac{GM\mu}{R_\oplus^3} r$

$(r=0)$-escape-velocity

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

13.7km/sec

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



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

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

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

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

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

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

13.7km/sec

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

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

Centifugal force = surface gravity:

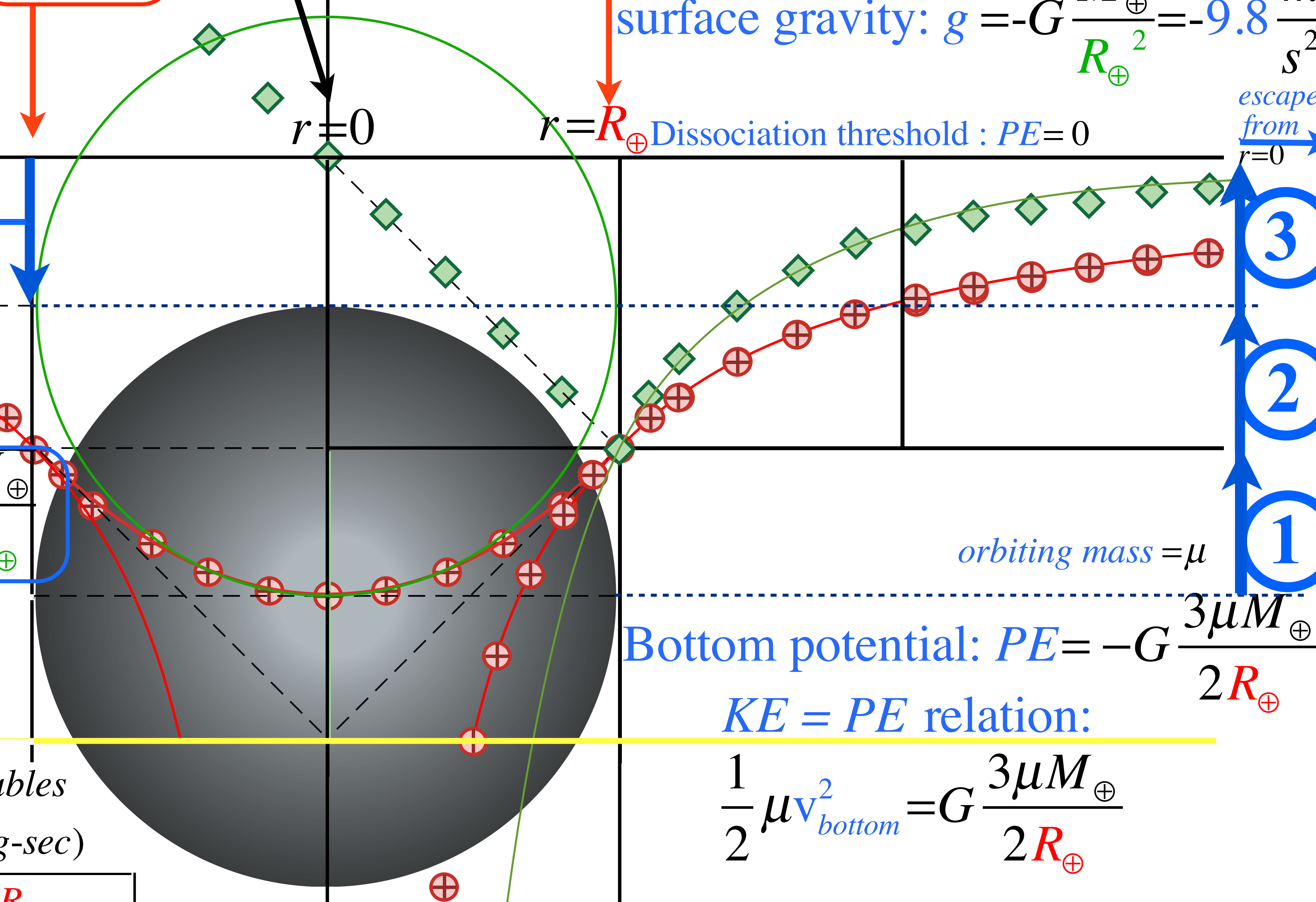
$$\frac{\mu v_\odot^2}{R_\oplus} = \mu g = G\frac{\mu M_\oplus}{R_\oplus^{2}}$$

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:

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



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

13.7km/sec

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 $\lvert x\rvert<1$: $y^{PE} = \frac{x^2}{2} - \frac{3}{2}$	$PE^{mks}(r) = \frac{GM\mu}{R_\oplus}\left(\frac{r^2}{2R_\oplus^2} - \frac{3}{2}\right)$
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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: $g=-G\frac{M_\oplus}{R_\oplus^2}=-9.8\frac{m}{s^2}$

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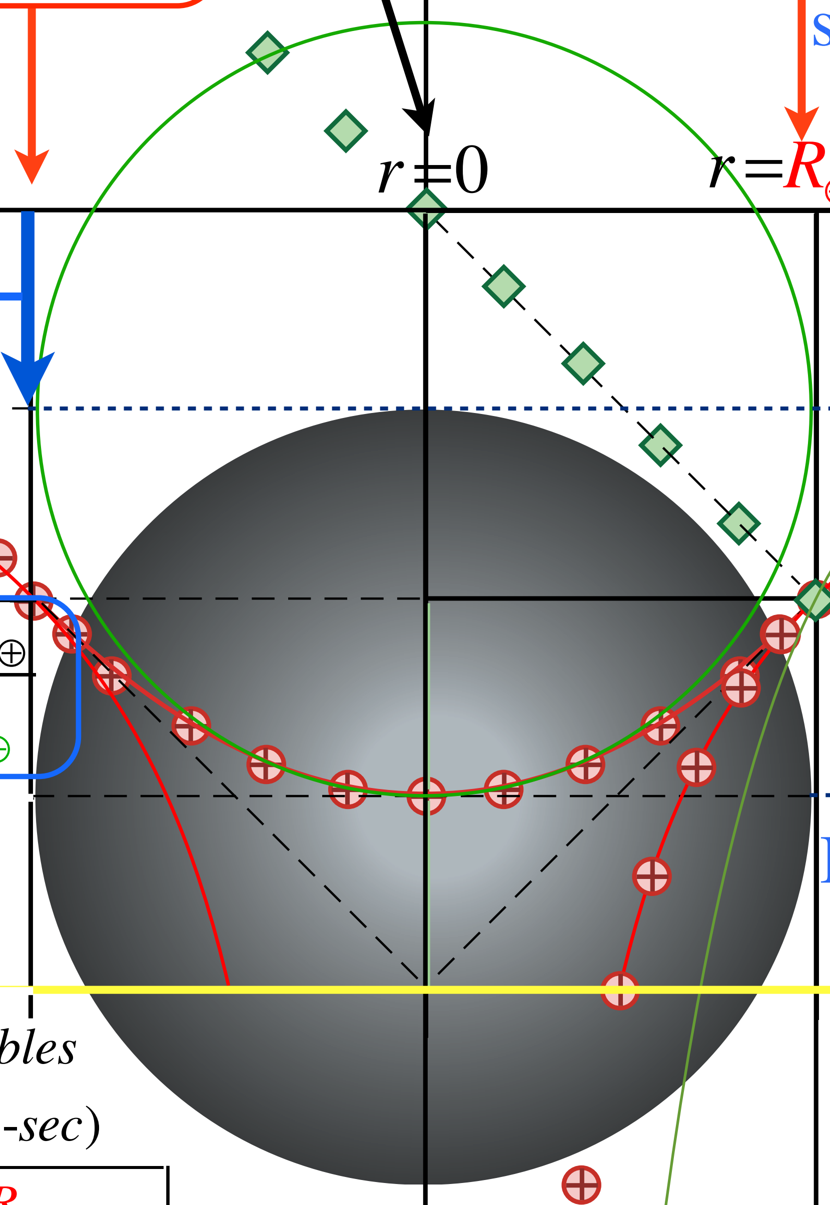
Orbit $E_\odot^{Total}=\frac{1}{2}\mu v_\odot^2-G\frac{\mu M_\oplus}{R_\oplus}=-G\frac{\mu M_\oplus}{2R_\oplus}$

$(r=R_\oplus)$-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: $PE=-G\frac{3\mu M_\oplus}{2R_\oplus}$

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Geometric (x,y) (Dimensionless)	Scaling relations	mks variables (meter-kg-sec)
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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

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

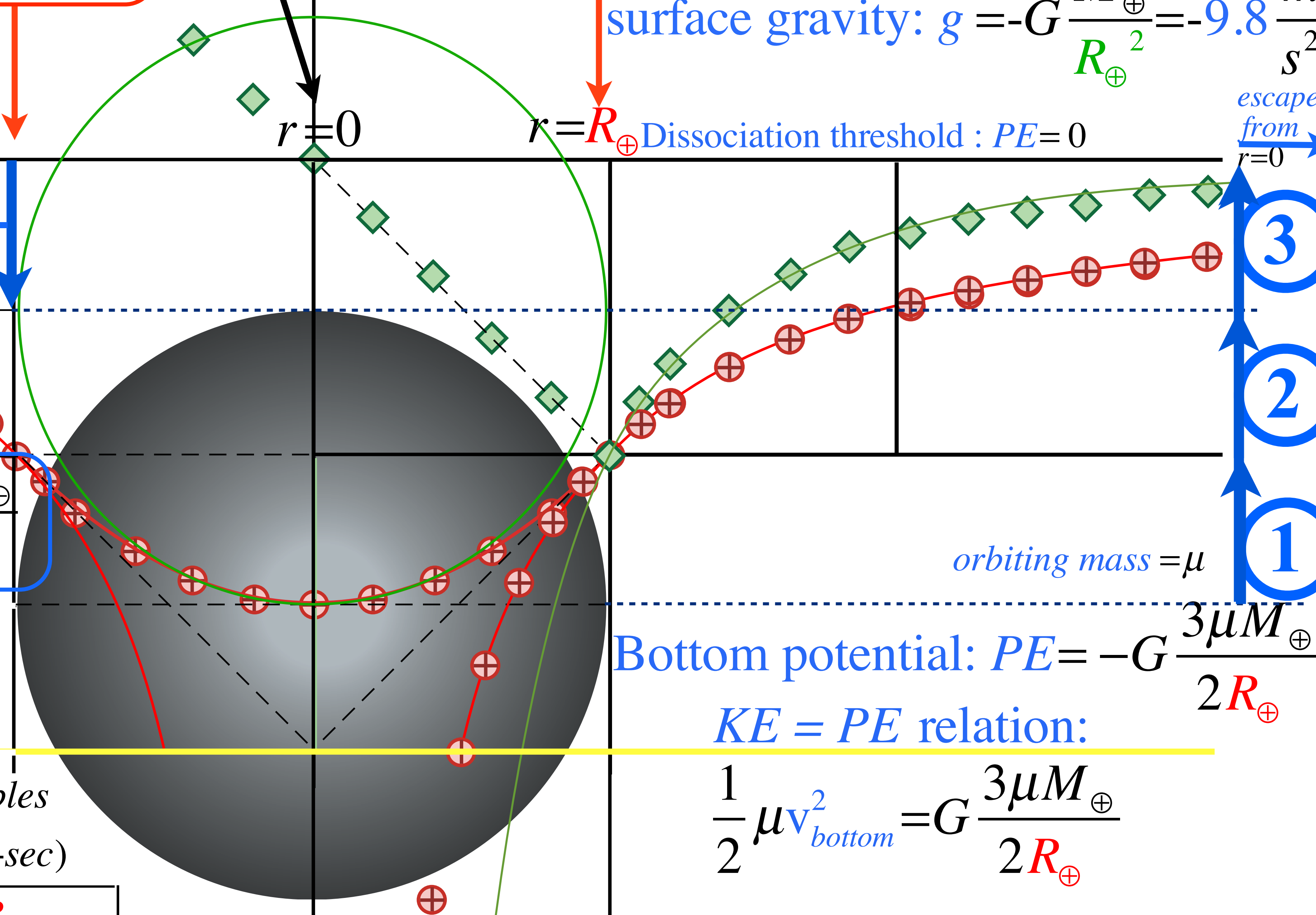
13.7km/sec

$(r=R_\oplus)$-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: $g = -G\dfrac{M_\oplus}{R_\oplus^2} = -9.8\dfrac{m}{s^2}$

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inside

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$(r=0)$-escape-velocity

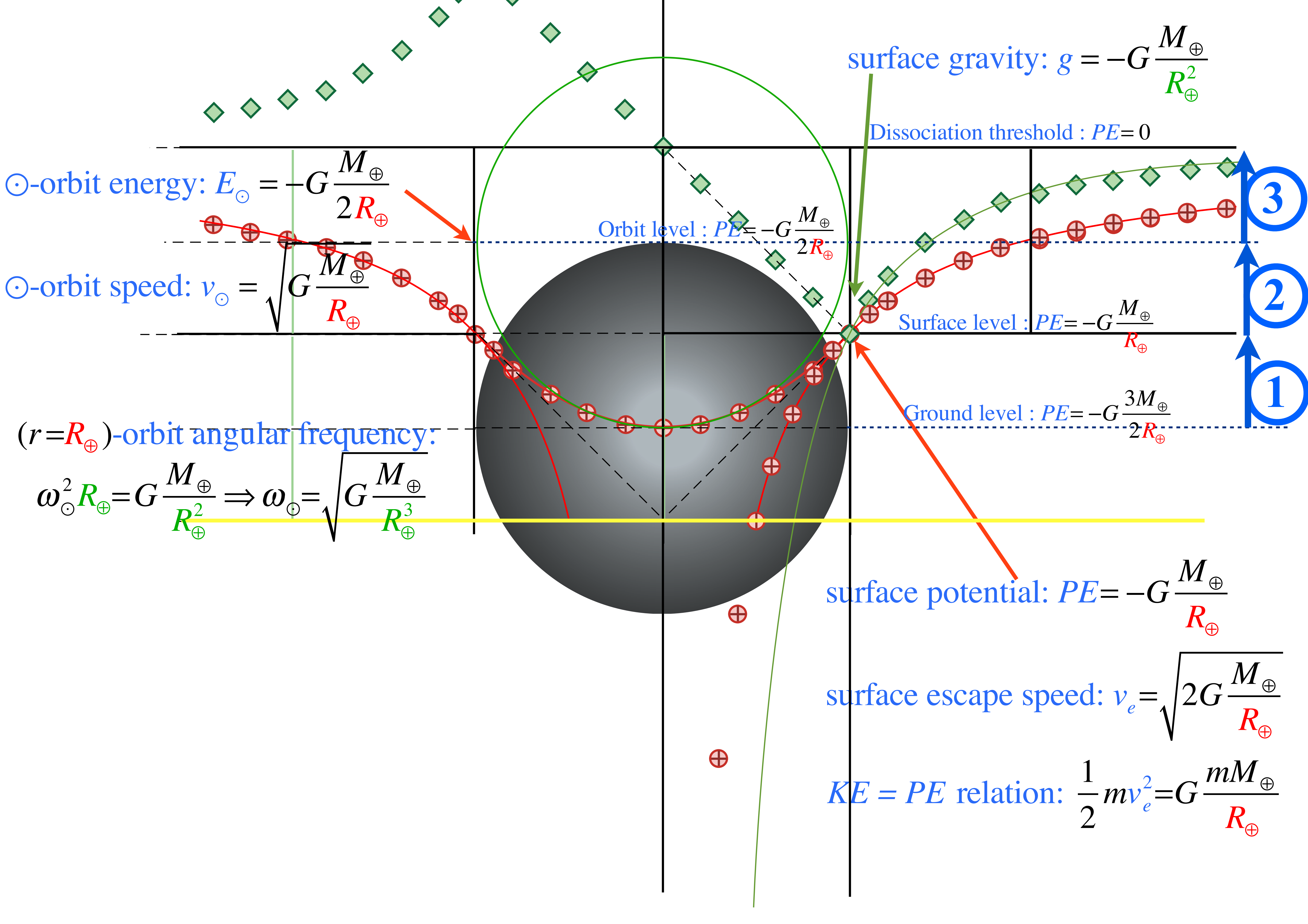
$$v_{bottom} = \sqrt{3G\frac{M_\oplus}{R_\oplus}}$$

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

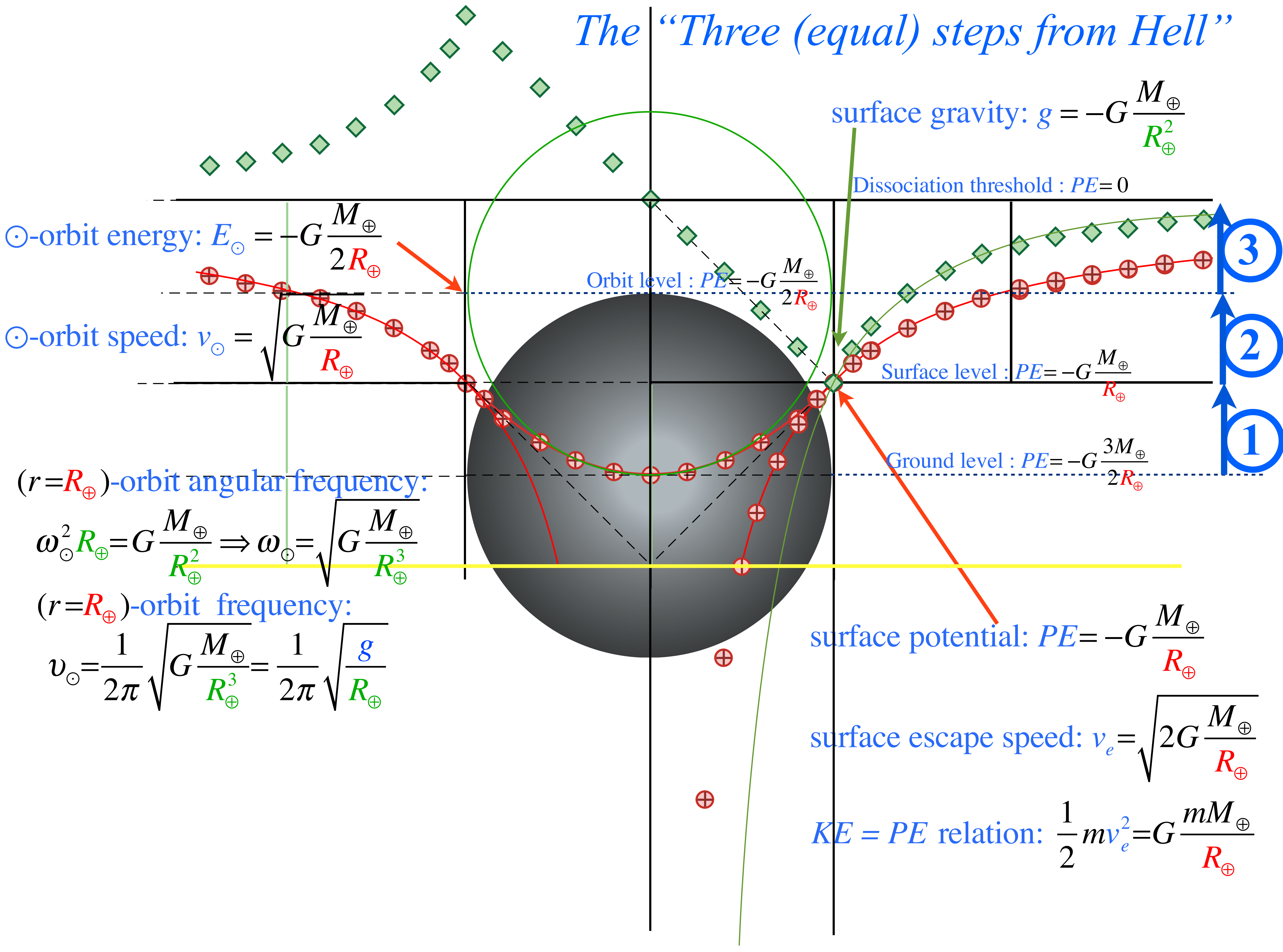
$$v_{escape} = \sqrt{2G\frac{M_\oplus}{R_\oplus}}$$

11.1km/sec

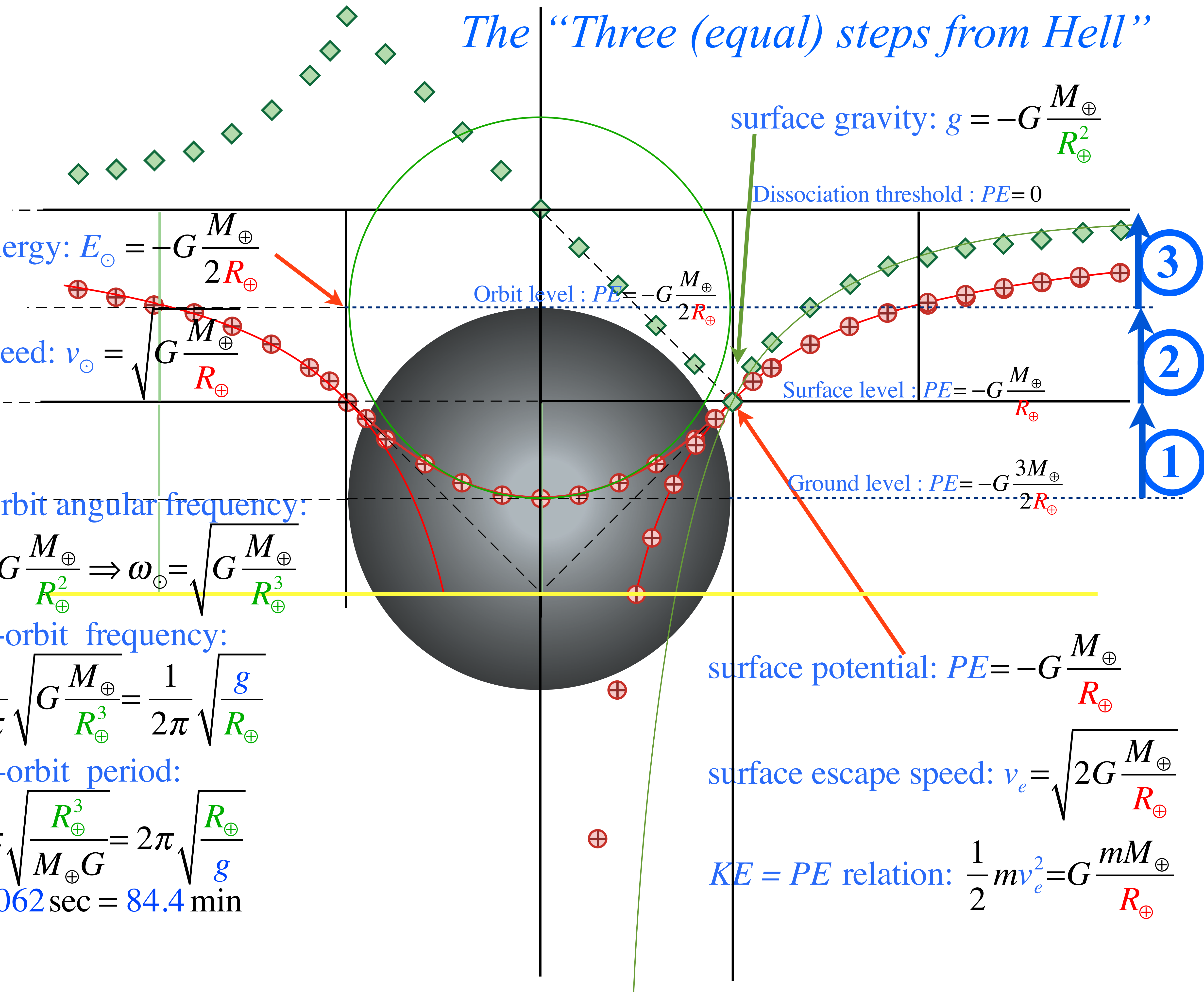
The "Three (equal) steps from Hell"



The "Three (equal) steps from Hell"



The "Three (equal) steps from Hell"



$\odot$-orbit energy: $E_\odot = -G\frac{M_\oplus}{2R_\oplus}$

$\odot$-orbit speed: $v_\odot = \sqrt{G\frac{M_\oplus}{R_\oplus}}$

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

$(r=R_\oplus)$-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:

$$\upsilon_\odot = \frac{1}{2\pi}\sqrt{G\frac{M_\oplus}{R_\oplus^3}} = \frac{1}{2\pi}\sqrt{\frac{g}{R_\oplus}}$$

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

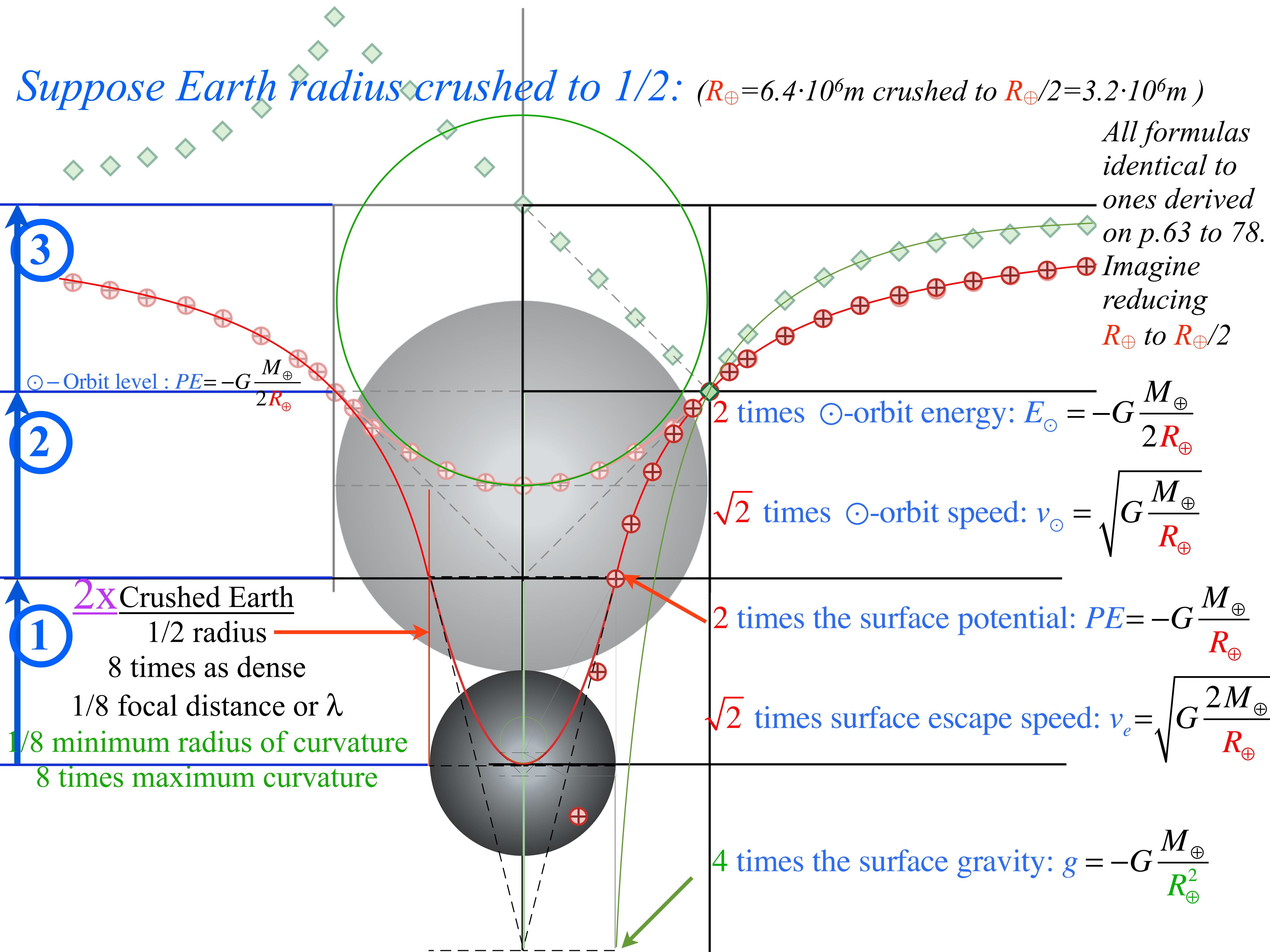
$$\upsilon_\odot = 2\pi\sqrt{\frac{R_\oplus^3}{M_\oplus G}} = 2\pi\sqrt{\frac{R_\oplus}{g}}$$

$= 5062\,\text{sec} = 84.4\,\text{min}$

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: ($R_\oplus$=6.4·10^{6}m crushed to $R_\oplus$/2=3.2·10^{6}m)
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 $\rho_{\oplus} = ??$

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

$(6.4)^3 \sim 262$ 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 $\rho_{\oplus} \sim 6.0 \cdot 10^{24-21} \sim 6 \cdot 10^{3} kg/m^{3}$

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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

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

Earth matter

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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 $2 \cdot 10^{-27} kg$.

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$^{4\pi}/_{3}3^{3} = 36\pi = 113 \sim 10^{2}$

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 $10^{-43}\,m^{3}$.

$36\pi = 113 \sim 10^{2}$

Examples of "crushed" matter

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

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

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

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

Examples of "crushed" matter

Earth matter

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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 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"

Earth matter vs nuclear matter:

→ *Introducing the "neutron starlet"*

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

Examples of "crushed" matter

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

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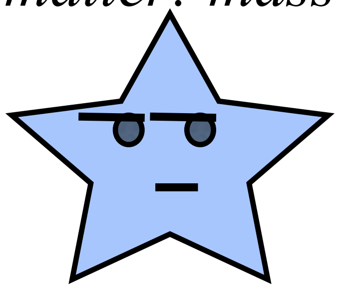
Introducing the "Neutron starlet"

$1\,cm^3$ *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"

Earth matter vs nuclear matter:

Introducing the "neutron starlet"

→ *Fantasizing a "***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 $\rho_{\oplus} \sim 6.0 \cdot 10^{24-21} \sim 6 \cdot 10^{3} kg/m^{3}$

Earth radius : $R_{\oplus} = 6.371 \cdot 10^{6} m \simeq 6.4 \cdot 10^{6} m$ *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 $2 \cdot 10^{-27} kg$.

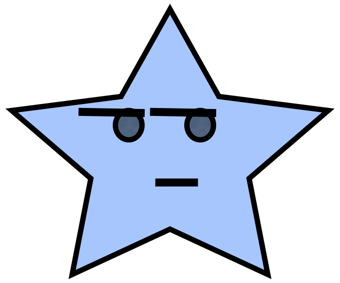
That's $100 \cdot 10^{-27} = 10^{-25}$ *kg* packed into a volume of $\frac{4\pi}{3} r^{3} = \frac{4\pi}{3} (3 \cdot 10^{-15})^{3} m^{3}$ or about $10^{-43} m^{3}$.

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 $R_{crush\oplus} \simeq 300 m$ would approach neutron-star density.

Introducing the "Neutron starlet"

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



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

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

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

(from p. 65, 66,..,82)

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

(from p. 61)

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

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

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

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Nuclear matter

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

$^{4\pi}/_3 3^3 = 36\pi = 113 \sim 10^2$

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 $10^{-43}\ m^3$.

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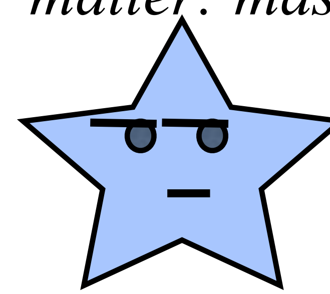

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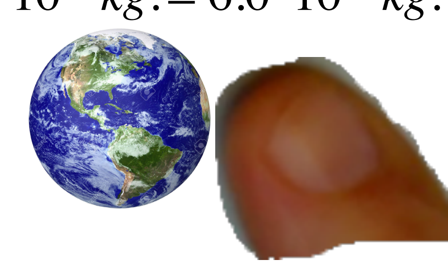
(from p. 61)

$R_\otimes = 2GM/c^2 = 8.9mm \sim 1cm$

(fingertip size!)



→ *Introducing 2D IHO orbits and phasor geometry*

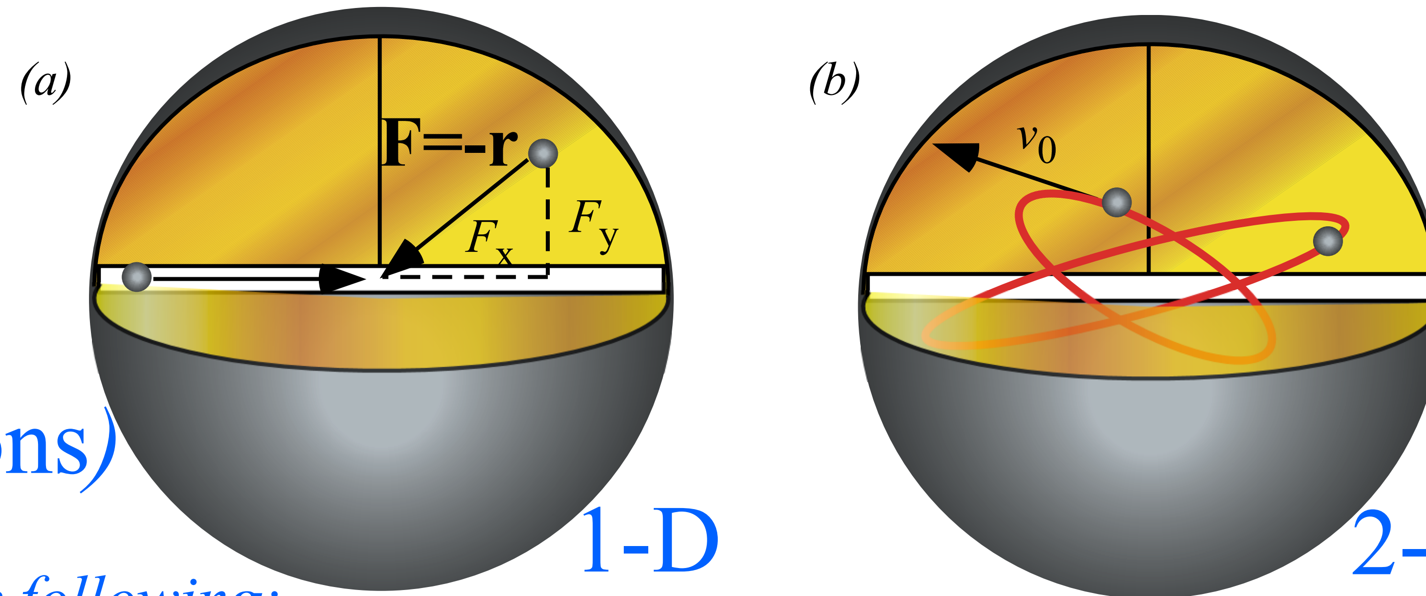
Phasor "clock" geometry

Isotropic Harmonic Oscillator phase dynamics in uniform-body

<u>*I.H.O. Force law*</u>

F =-x (1-Dimension)

F =-**r** (2 or 3-Dimensions)



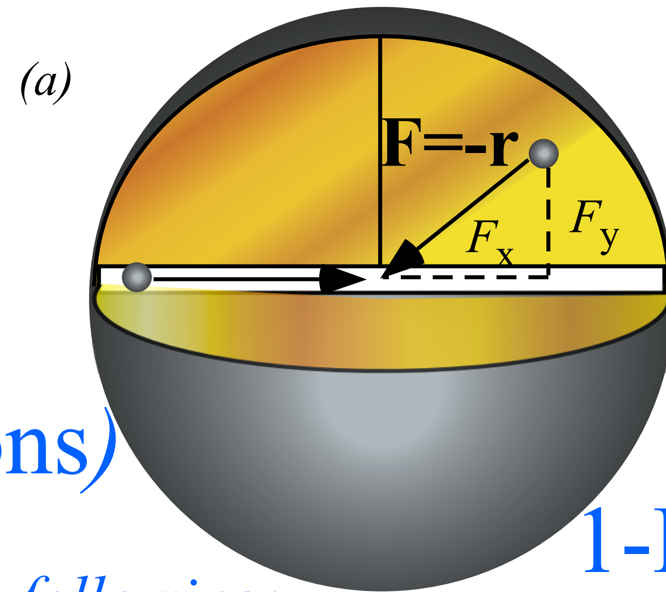
Unit 1
Fig. 9.10

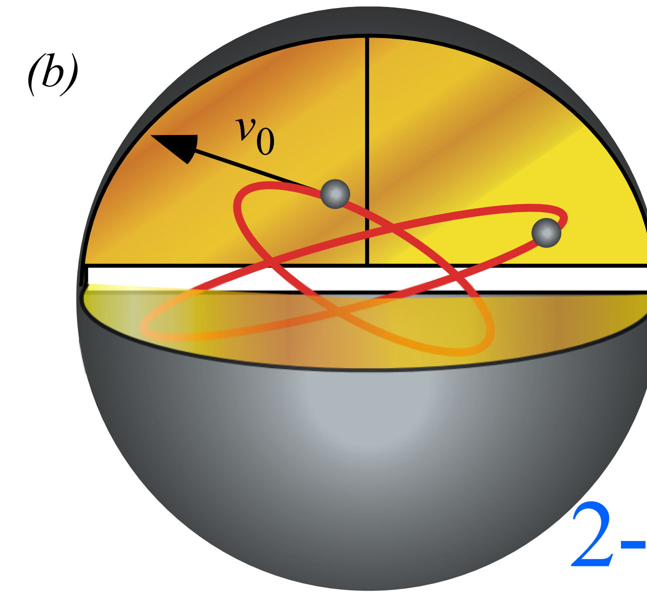
(Paths are *always* 2-D ellipses if viewed right!)

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

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

Isotropic Harmonic Oscillator phase dynamics in uniform-body





Unit 1
Fig. 9.10

I.H.O. Force law

F =-x (1-Dimension)

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1-D

2-D or 3-D

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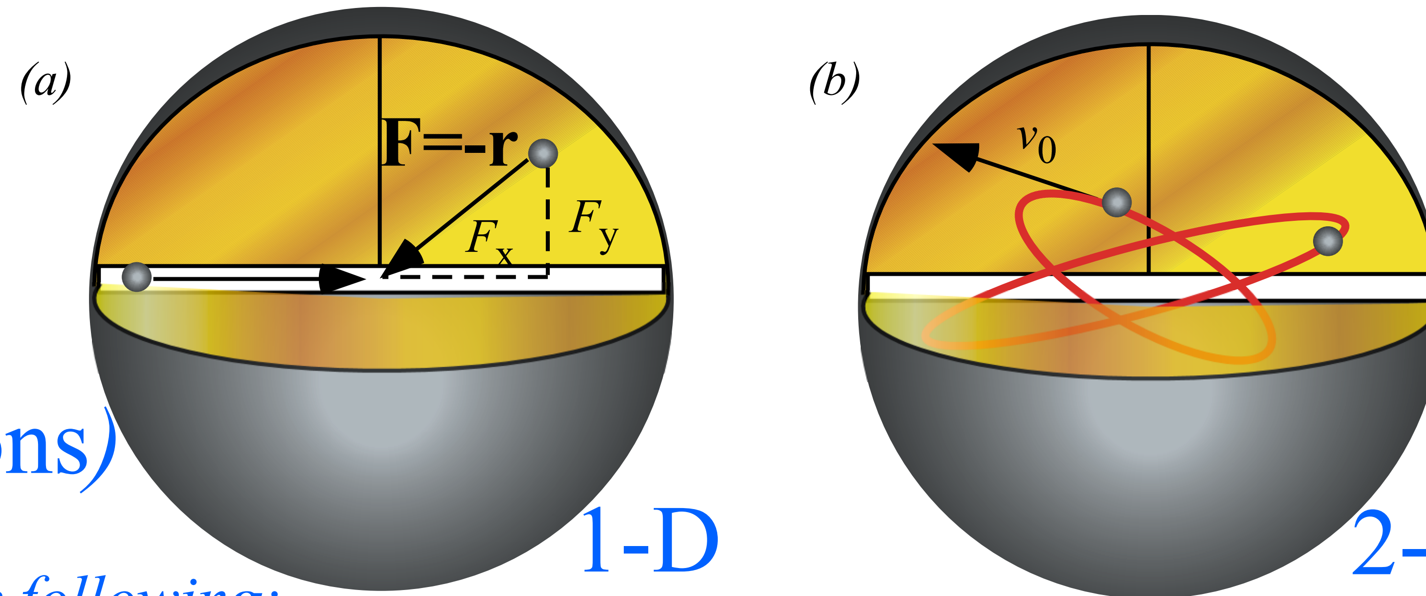

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Another example of the old "scale-a-circle" trick...

velocity: *position:*

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

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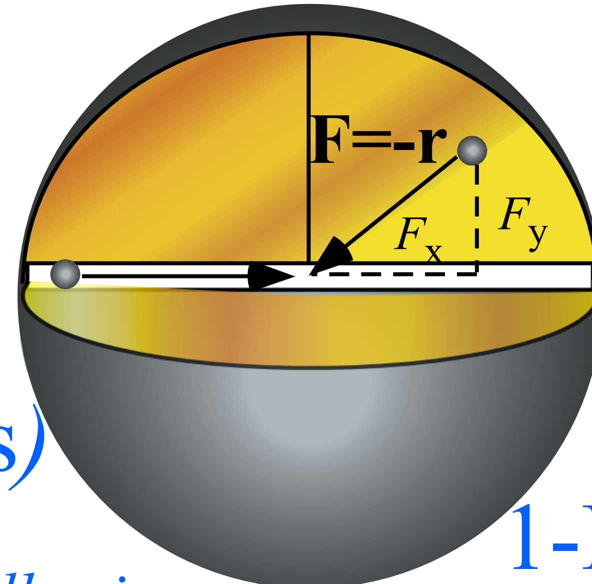
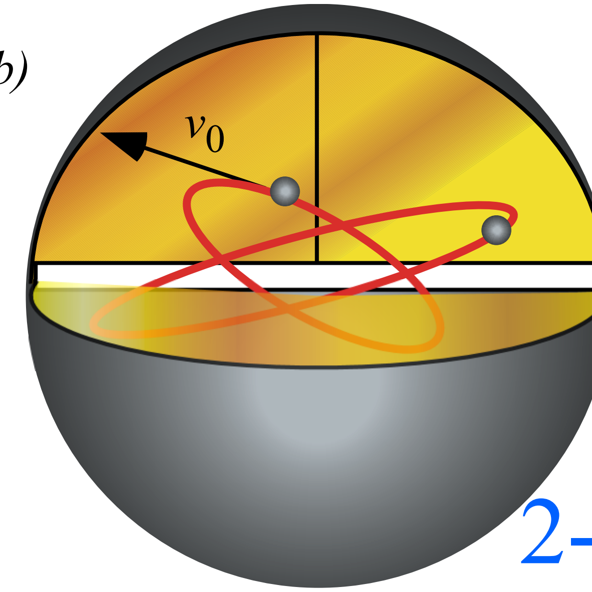


1-D



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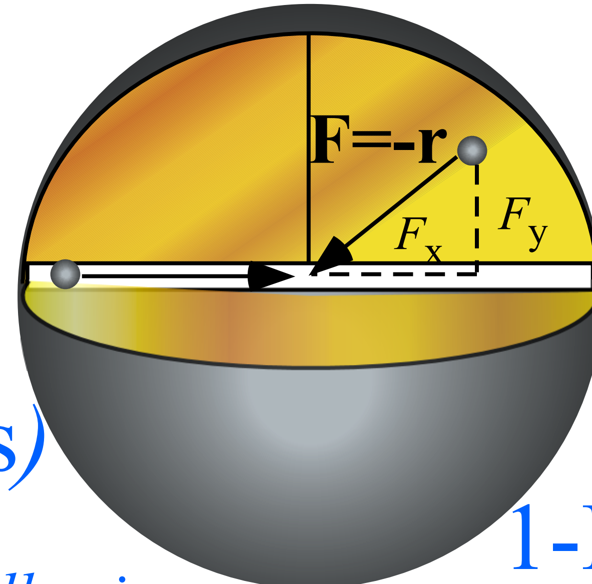
Isotropic Harmonic Oscillator phase dynamics in uniform-body



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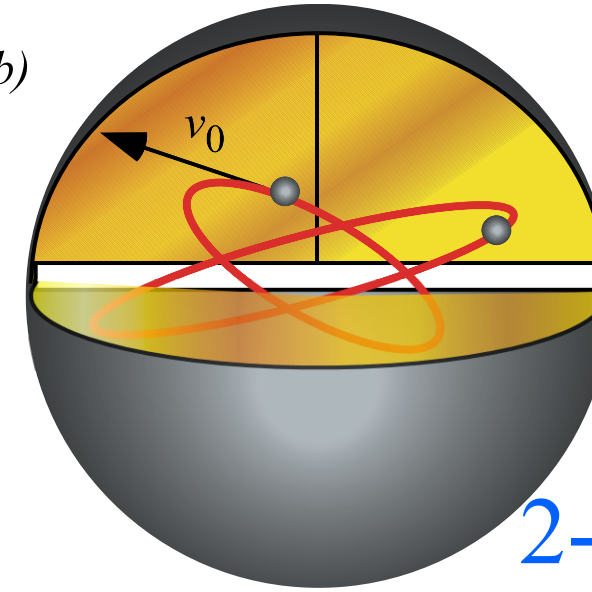

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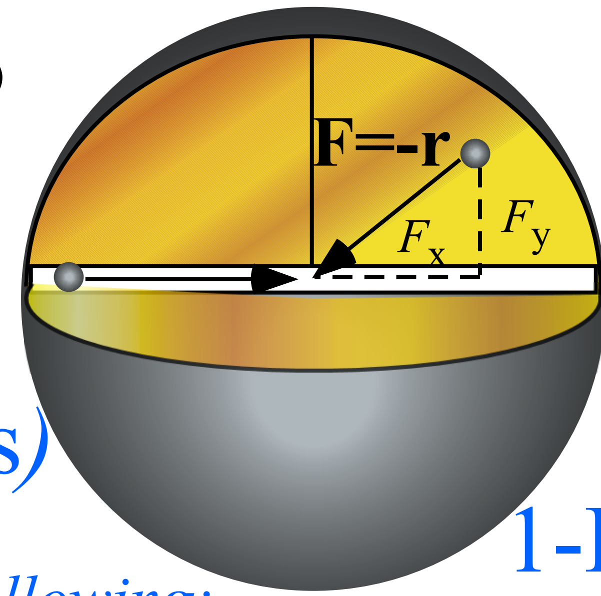
angular velocity: *def.* **(3)** $\omega = \frac{d\theta}{dt}$

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

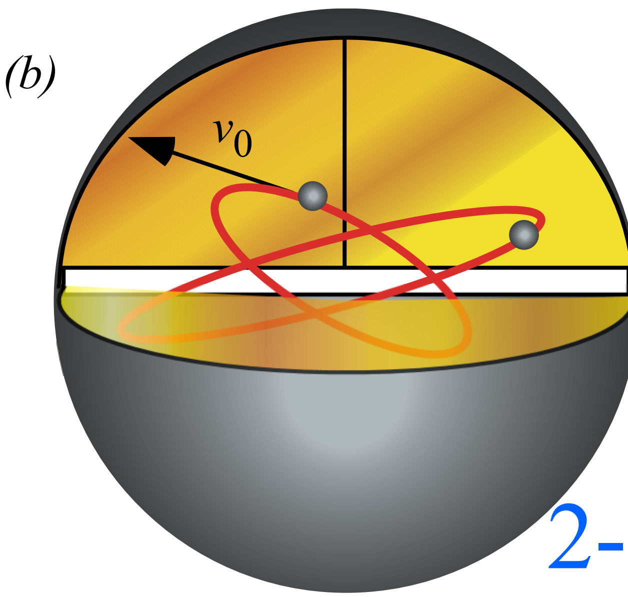
by **(1)**

Isotropic Harmonic Oscillator phase dynamics in uniform-body

(a)



(b)



Unit 1
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Isotropic Harmonic Oscillator phase dynamics in uniform-body

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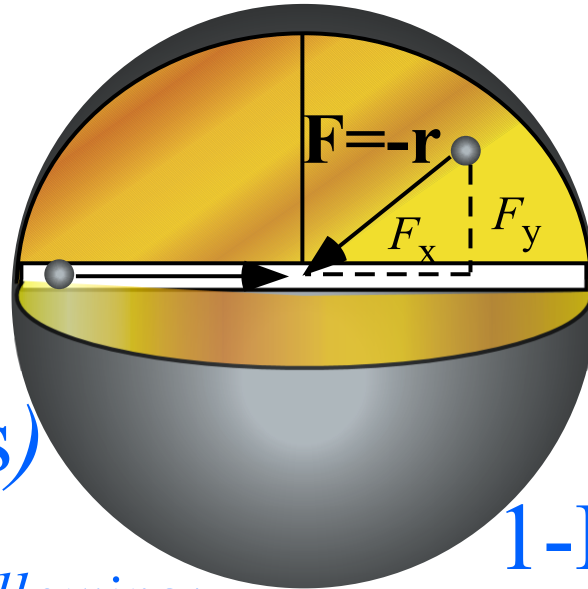
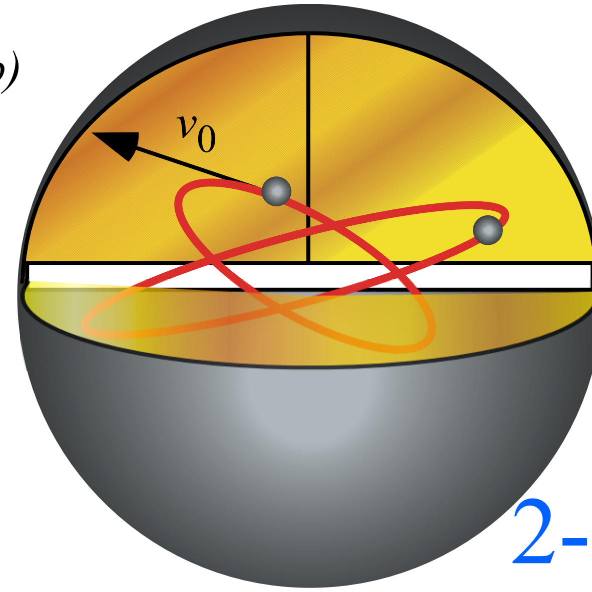


1-D

(b)



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

Isotropic Harmonic Oscillator phase dynamics in uniform-body

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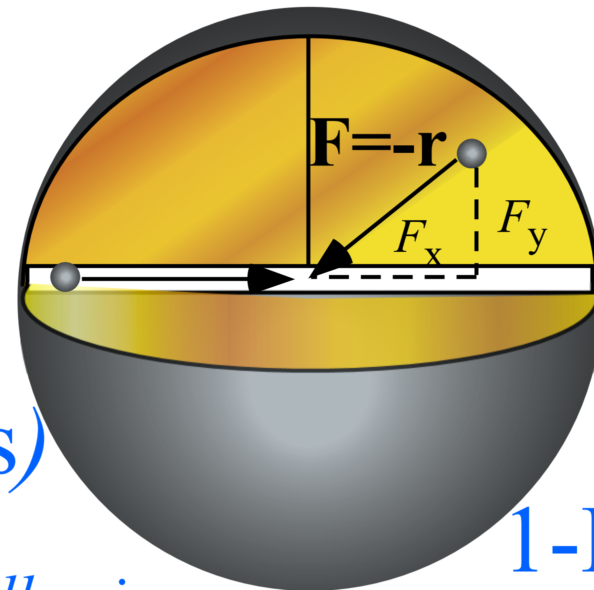

1-D

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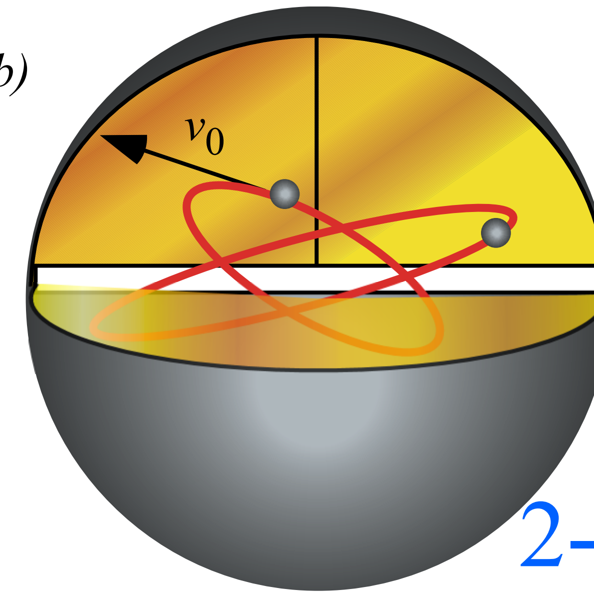

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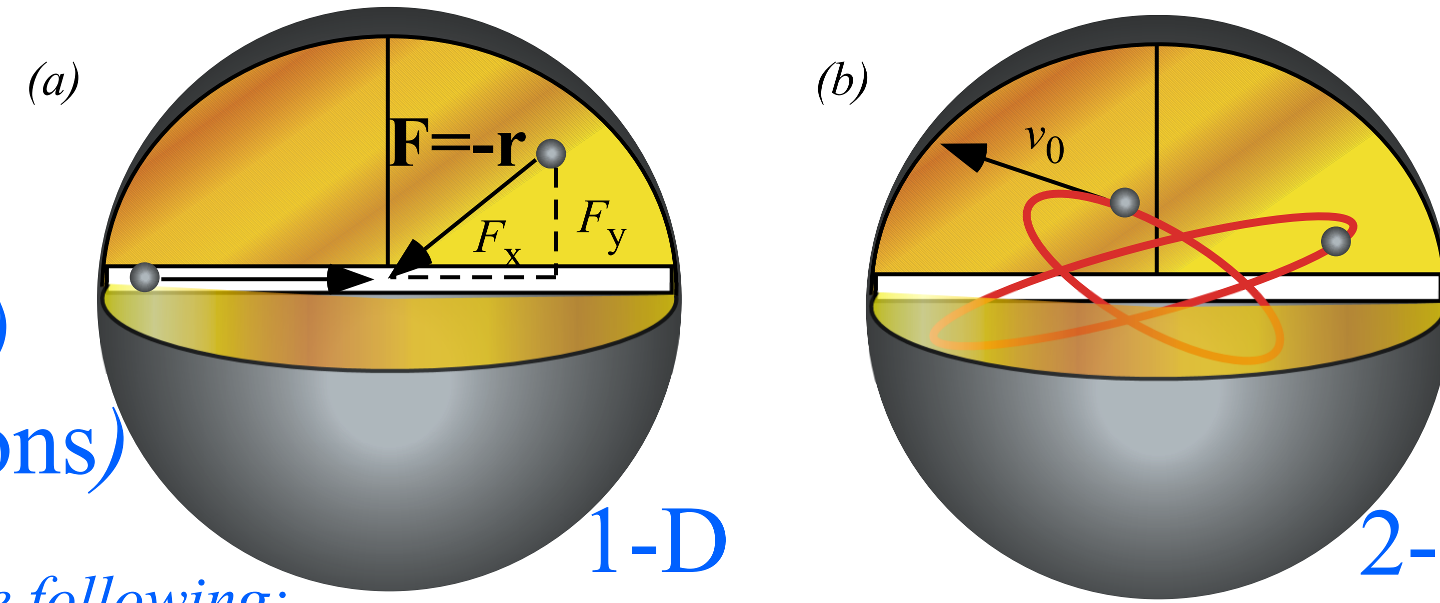
Isotropic Harmonic Oscillator phase dynamics in uniform-body



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Unit 1
Fig. 9.10

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

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by (1) — *by def.* (3) — *by* (2)

by def. (3)

$$\omega = \frac{d\theta}{dt}$$

Isotropic Harmonic Oscillator phase dynamics in uniform-body

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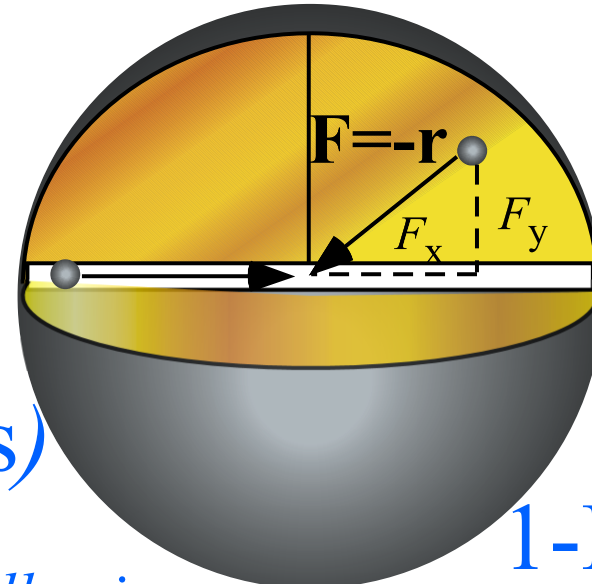
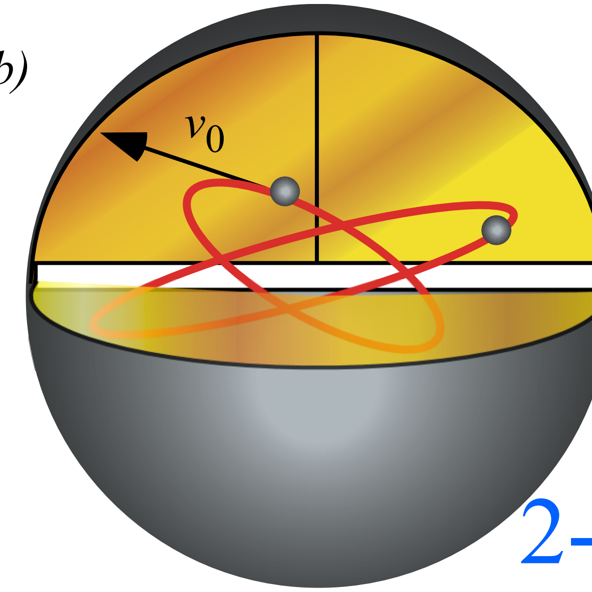


1-D

(b)



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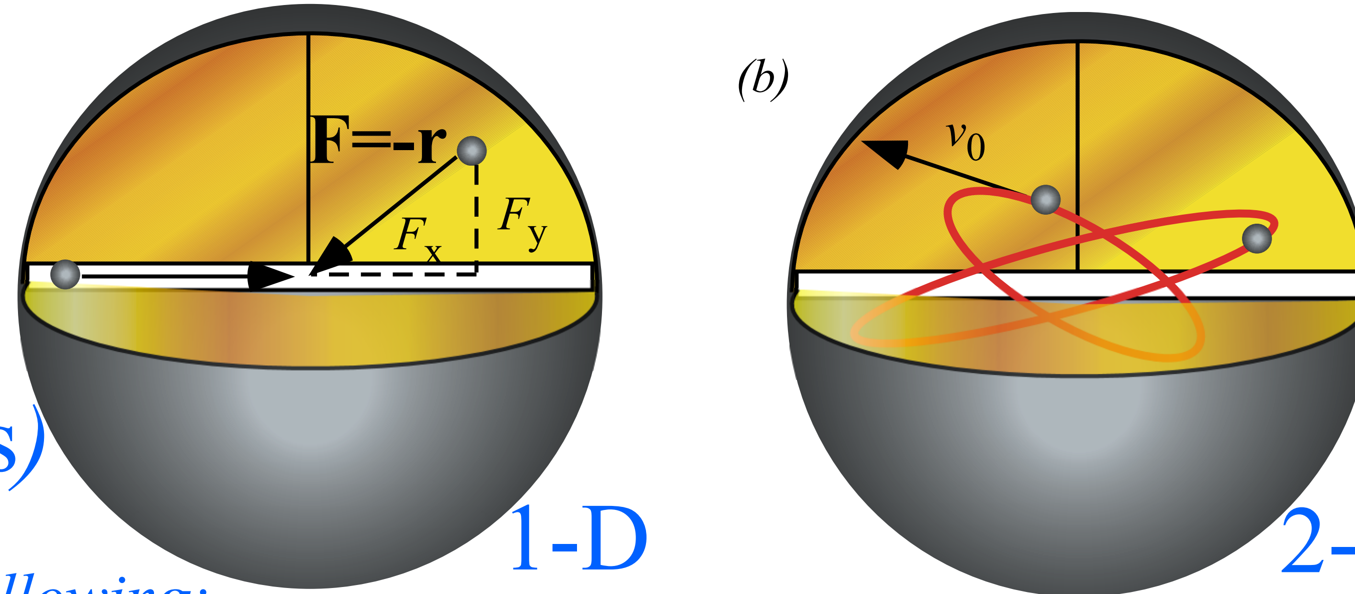
by **(1)** — *by def.* **(3)** — *by* **(2)**

by def. **(3)**

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

divide **(1)** — *by* **(2)** *derivative*

Isotropic Harmonic Oscillator phase dynamics in uniform-body



Unit 1
Fig. 9.10

I.H.O. Force law

$F = -x$ (1-Dimension)

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

1-D

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.

$$1 = \frac{mv^2}{2E} + \frac{kx^2}{2E} = \left(\frac{v}{\sqrt{2E/m}}\right)^2 + \left(\frac{x}{\sqrt{2E/k}}\right)^2$$

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

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

$$Let:\ \mathbf{(1)}\ v = \sqrt{2E/m}\cos\theta, \quad and:\ \mathbf{(2)}\ x = \sqrt{2E/k}\sin\theta \qquad def.\ \mathbf{(3)}\ \omega = \frac{d\theta}{dt}$$

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

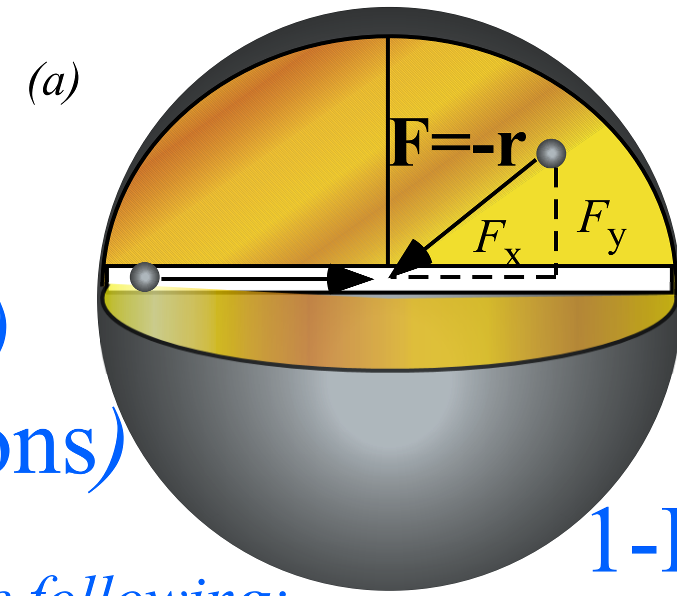
by **(1)** — *by def.* **(3)** — *by* **(2)**

by def. **(3)**

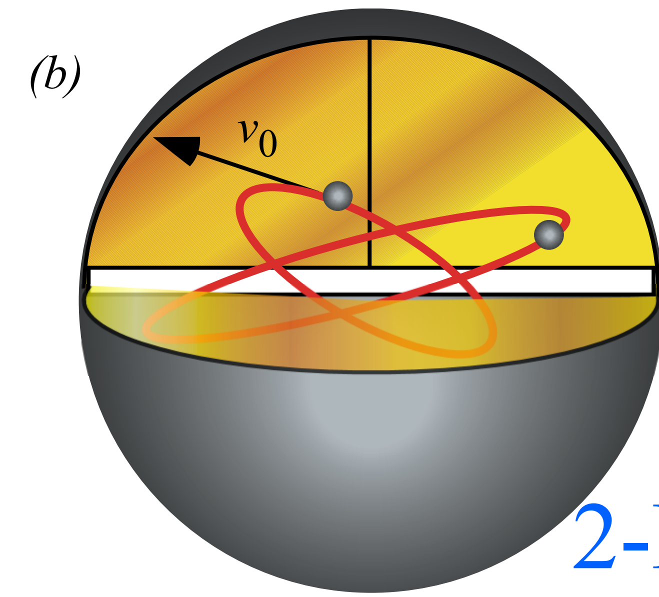
$$\omega = \frac{d\theta}{dt} = \frac{\sqrt{\frac{2E}{m}}\cos\theta}{\sqrt{\frac{2E}{k}}\cos\theta} = \sqrt{\frac{k}{m}}$$

divide **(1)** *by* **(2)** *derivative*

Isotropic Harmonic Oscillator phase dynamics in uniform-body



1-D



Unit 1
Fig. 9.10

2-D or 3-D
(Paths are *always* 2-D ellipses if viewed right!)

I.H.O. Force law

F =-*x* (1-Dimension)

F =-**r** (2 or 3-Dimensions)

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by (1) — by def. (3) — by (2)

by def. (3)

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

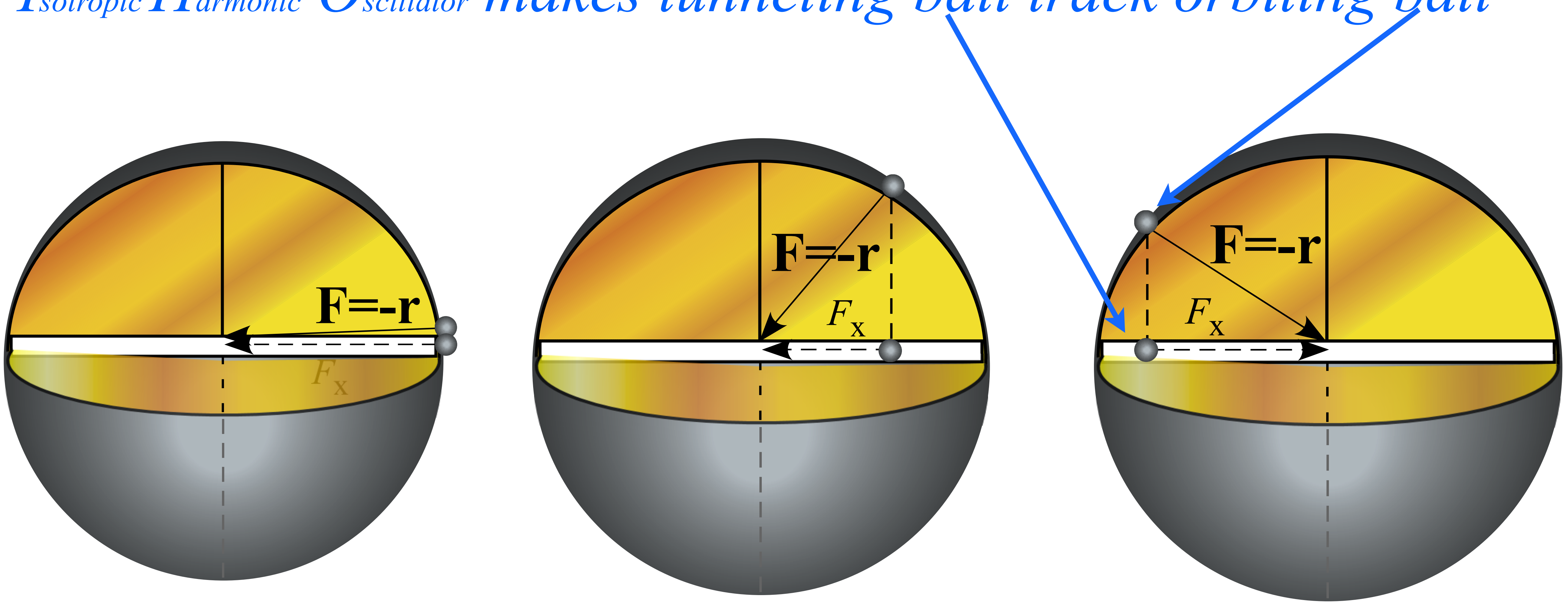
by integration given constant ω:

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

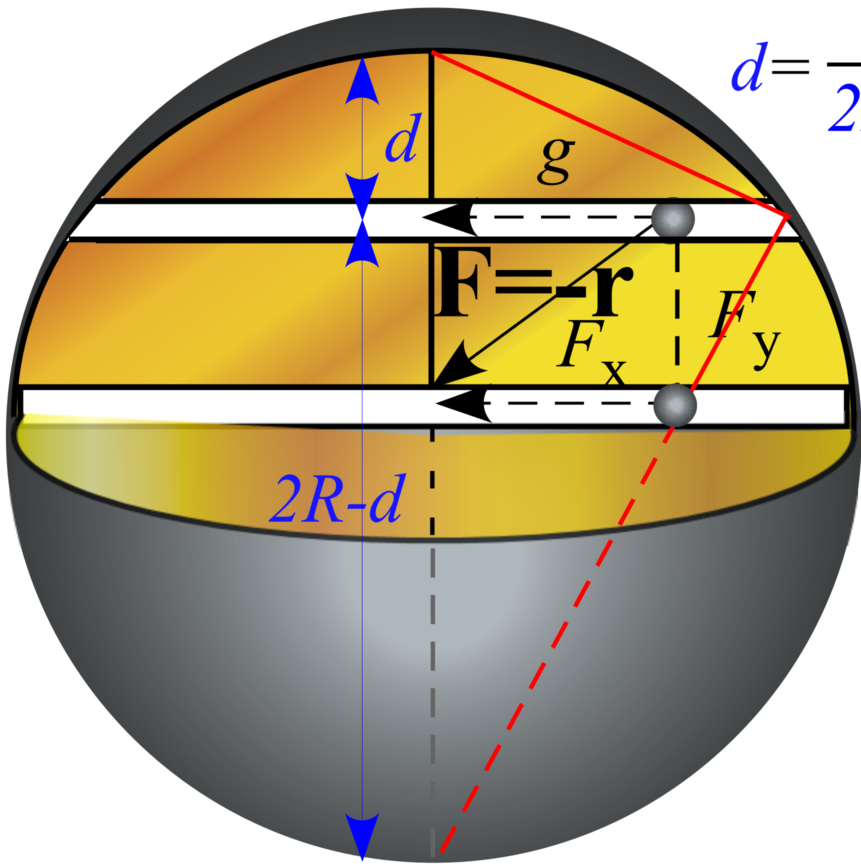
→ *Introducing 2D IHO orbits and phasor geometry*

Phasor "clock" geometry

Isotropic Harmonic Oscillator makes tunneling ball track orbiting ball

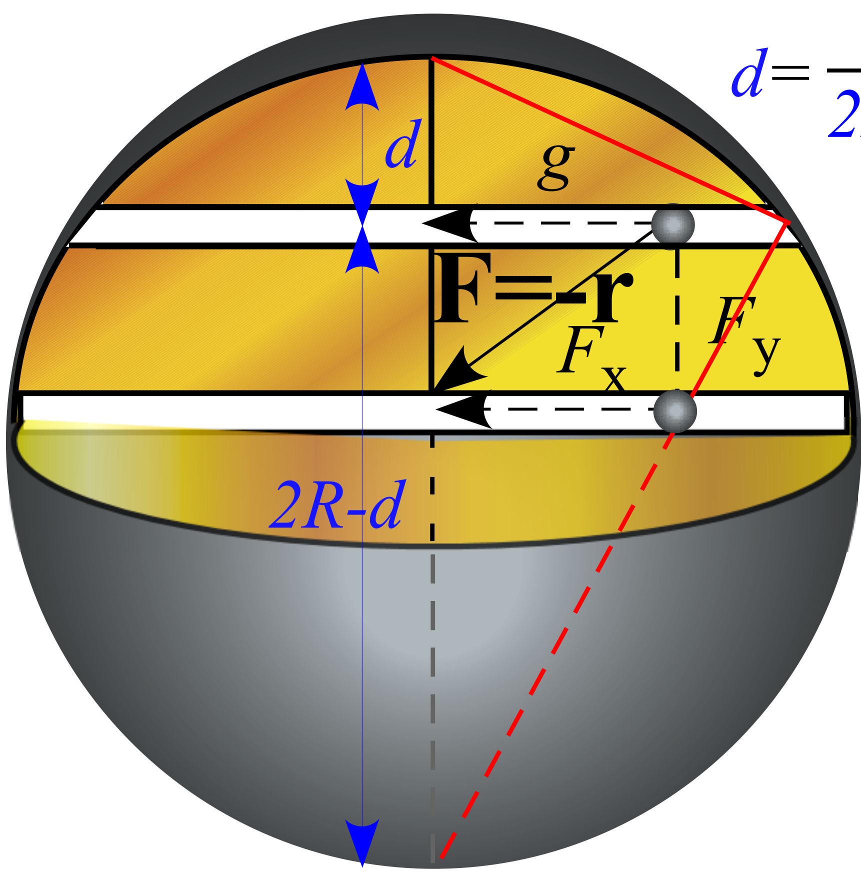


Isotropic Harmonic Oscillator makes balls in parallel tunnel track each other



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

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



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

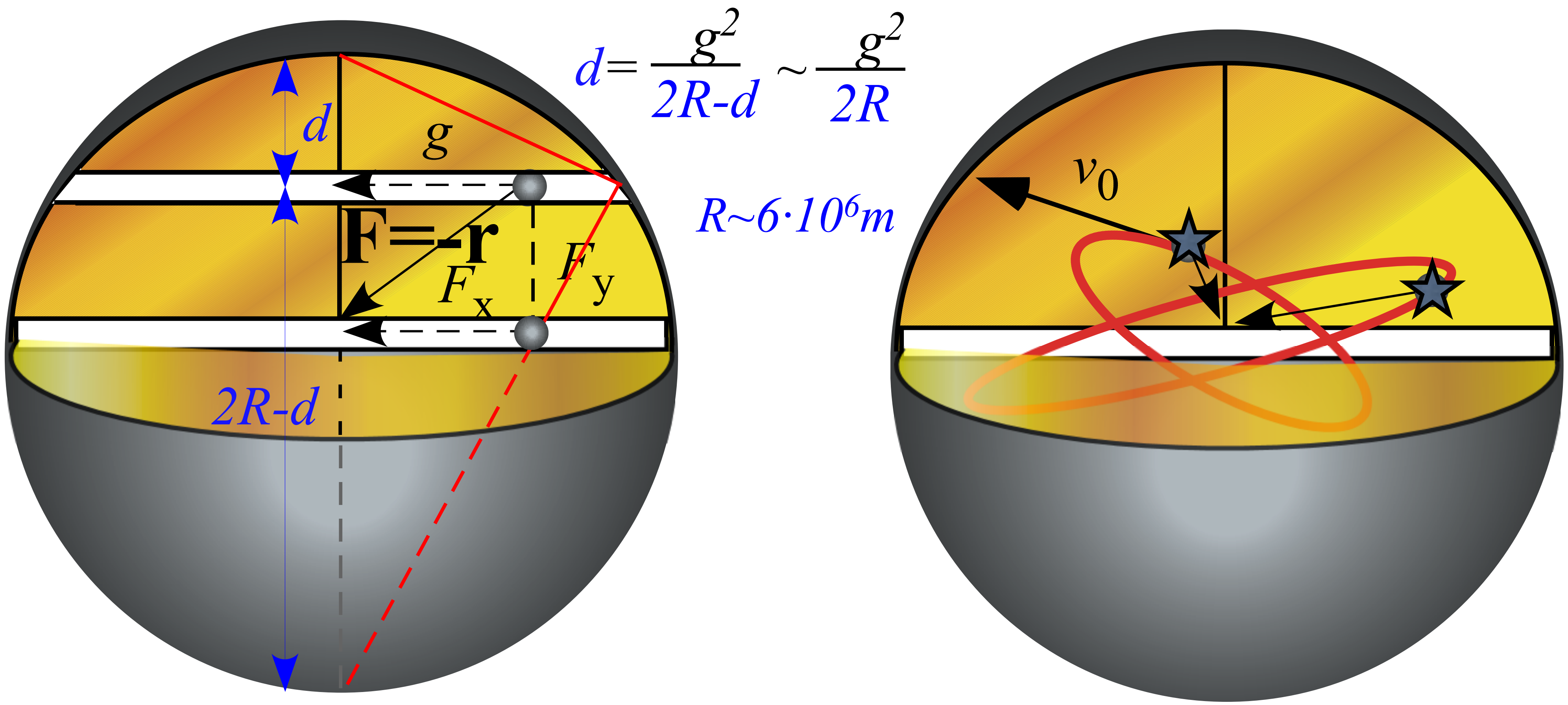
$R \sim 6 \cdot 10^6 m$

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

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

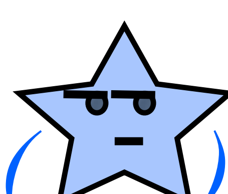
They all take about 84 minutes to go from right to left and back, again.

*I*sotropic *H*armonic *O*scillator *makes balls in parallel tunnels track each other...*



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

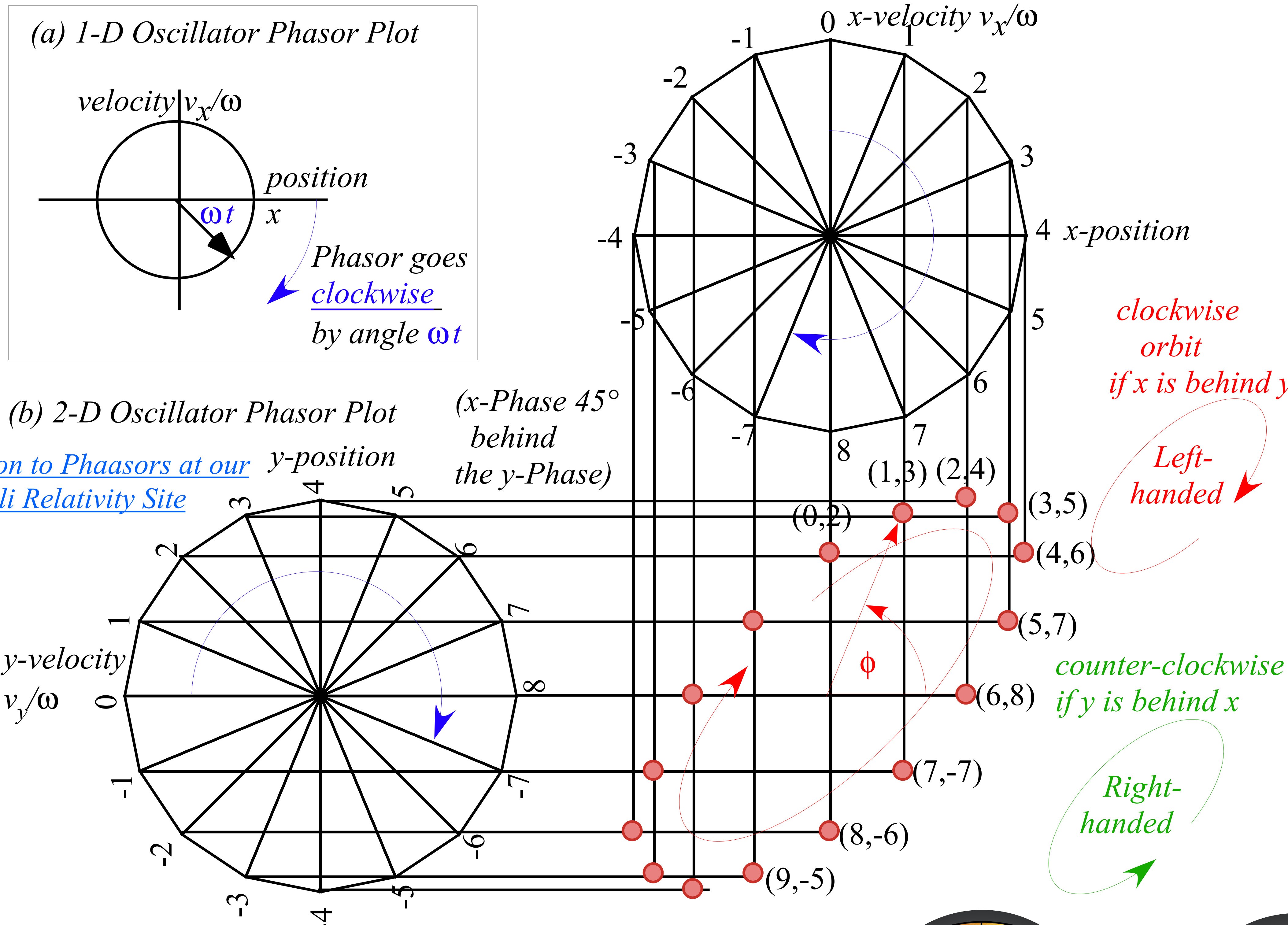
The all take about 84 minutes to go from right to left and back, again.

Most neutron starlet ( *)orbits are centered ellipses*

Isotropic Harmonic Oscillator phase dynamics in uniform-body

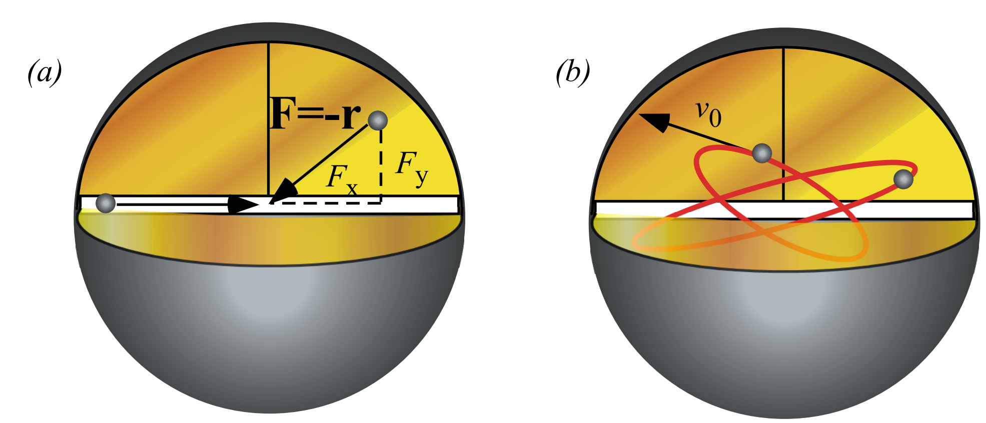
Unit 1
Fig. 9.10

[*Introduction to Phaasors at our Pirelli Relativity Site*]



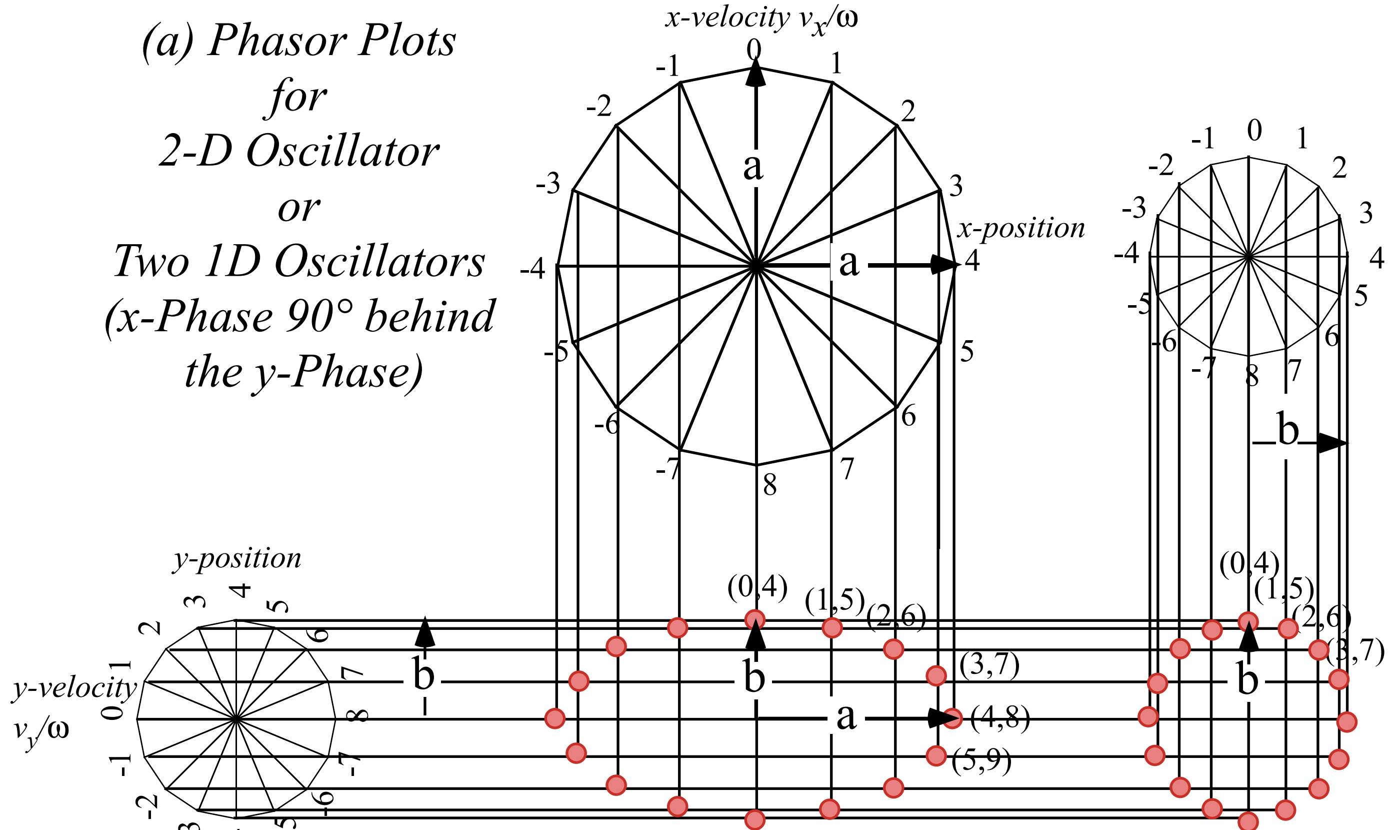
[BoxIt web simulation - *With y-Phasor is on other side of xy plot*]

[RelaWavity web simulation - Contact ellipsometry]



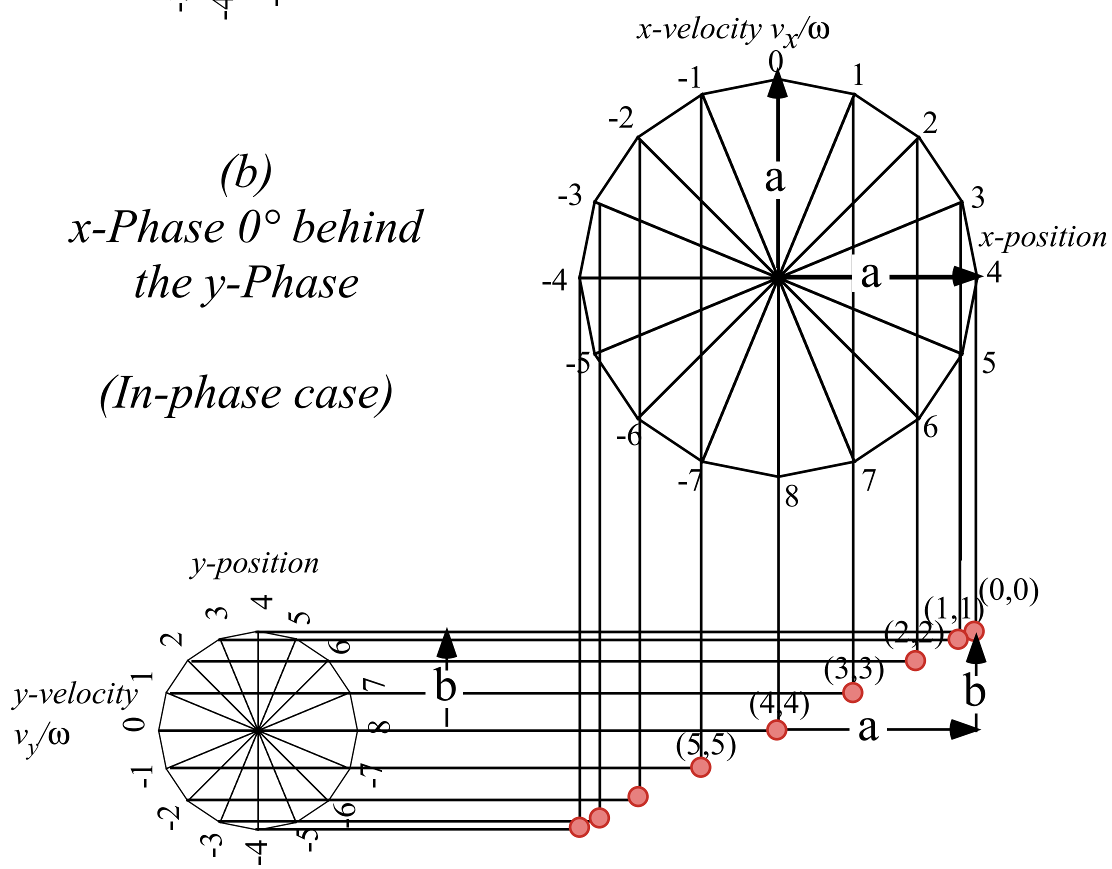
Unit 1
Fig. 9.12

(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)*