Lecture 6
Thur. 9.12.2013

Many-body 1D collisions

Elastic examples: Western buckboard, Bouncing column, Newton's cradle
Inelastic examples: "Zig-zag geometry" of freeway crashes
*Super-elastic examples: This really **is** "Rocket-Science"*

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**"*

Topics for Lecture 7

Many-body 1D collisions

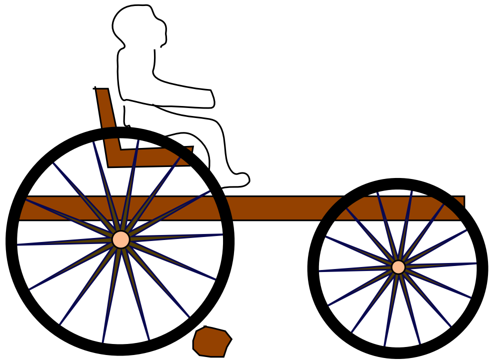
→ *Elastic examples: Western buckboard, Bouncing column, Newton's cradle*

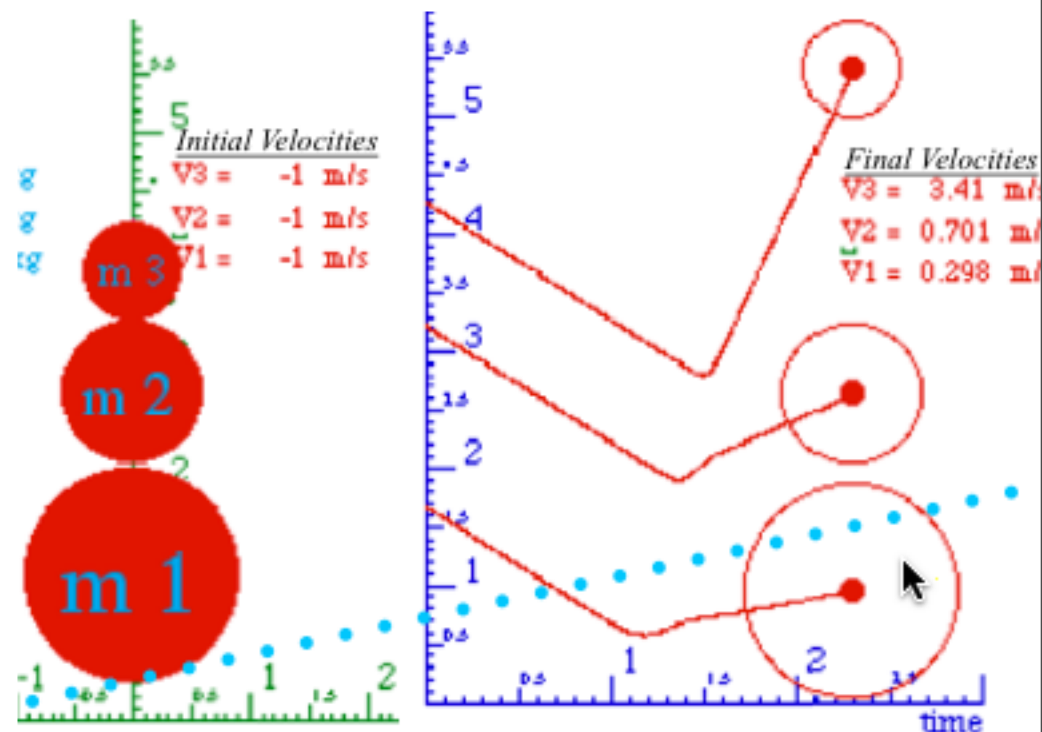
Inelastic examples: "Zig-zag geometry" of freeway crashes

Super-elastic examples: This really __**is**__ *"Rocket-Science"*

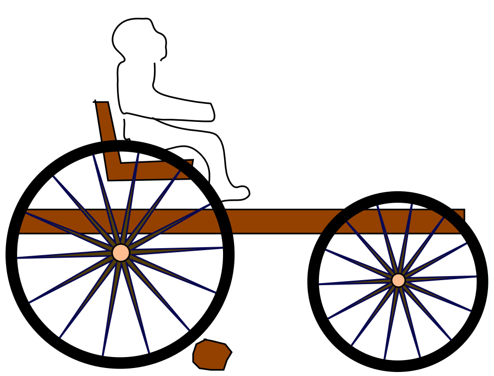
Western buckboard = ?????

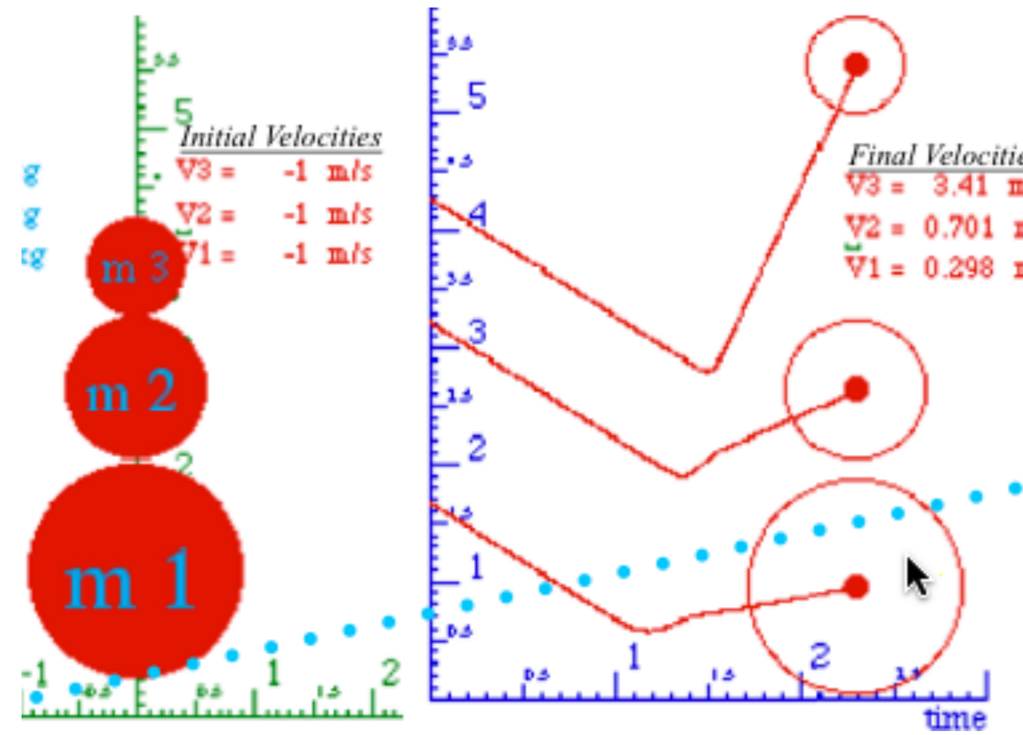
Western buckboard = ?????



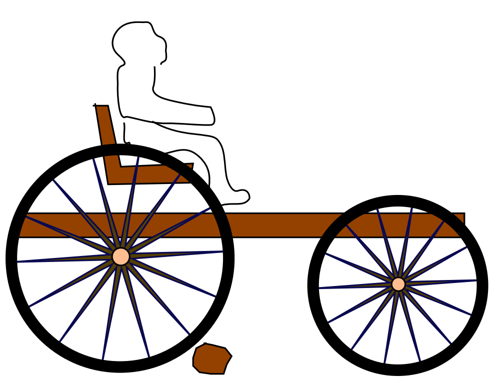


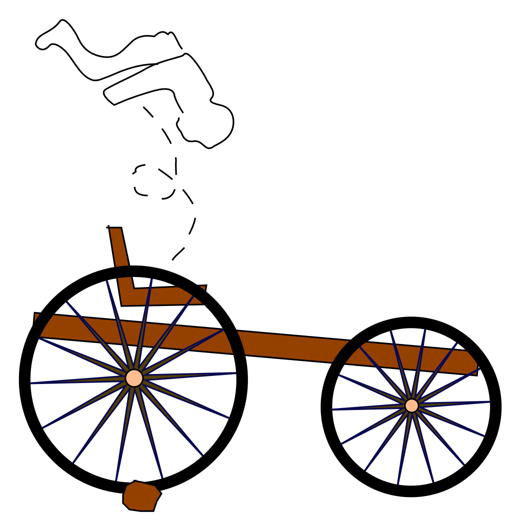
Western buckboard = *3-ball analogy*

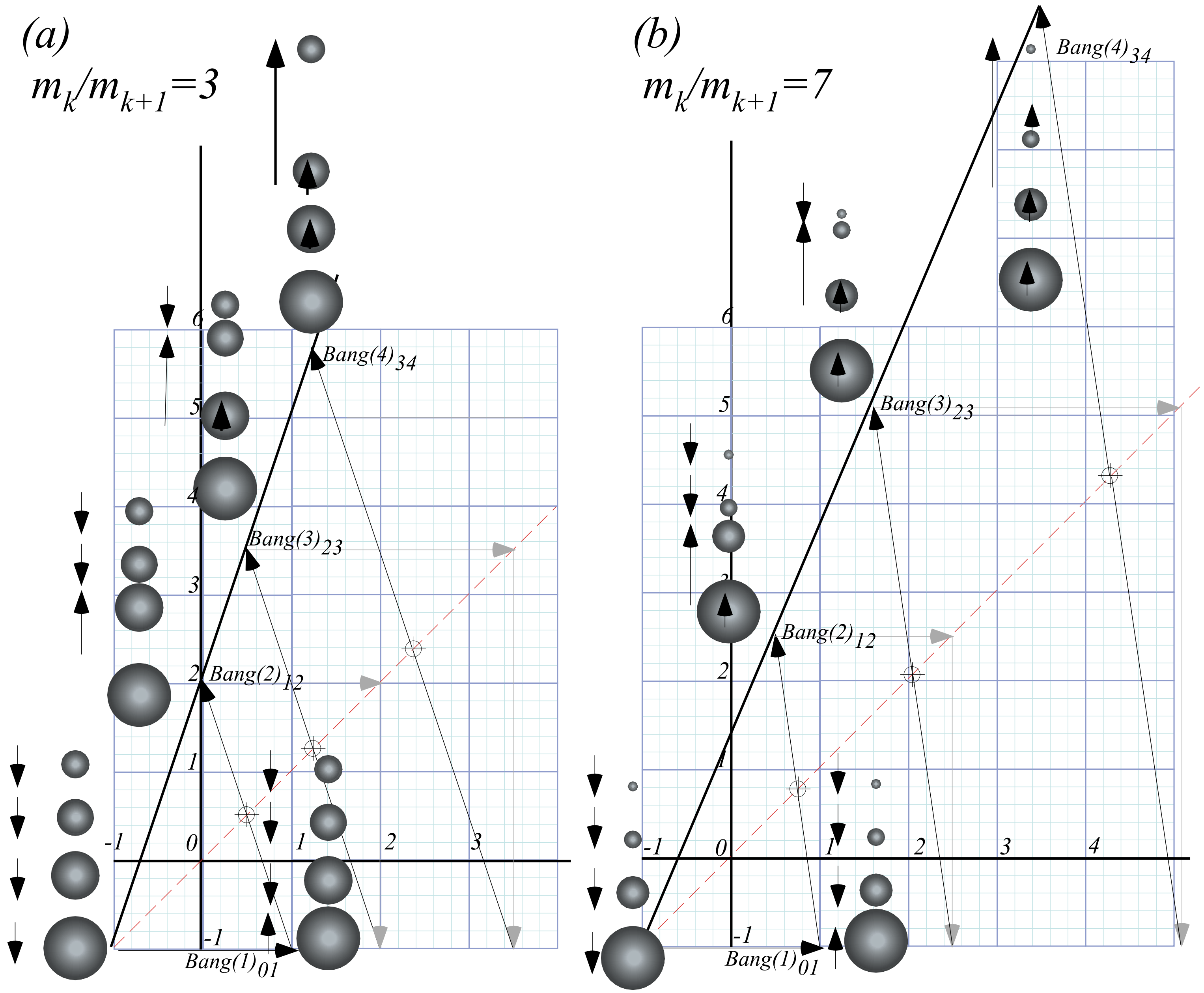




Western buckboard = *3-ball analogy* *Disaster!*

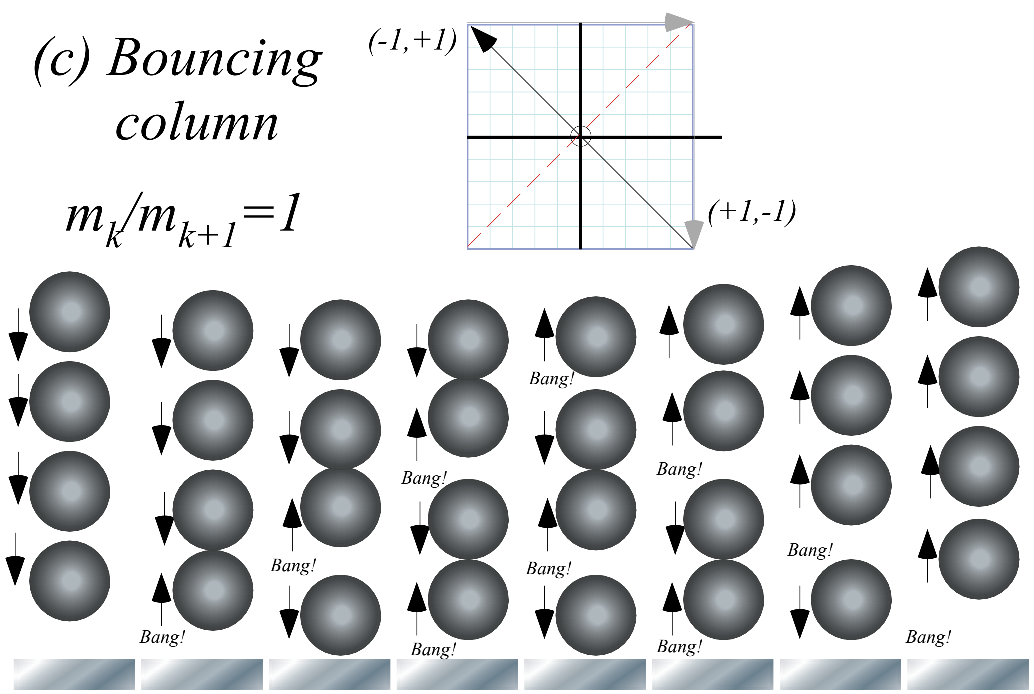


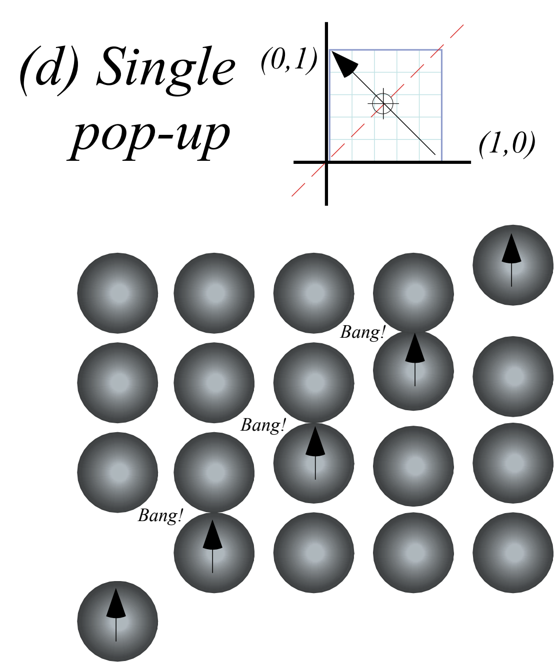




Unit 1
Fig. 8.2a-b
4-Body IBM Geometry
Fig. 8.2c-d
4-Equal-Body Geometry

http://www.uark.edu/ua/modphys/testing/markup/BounceItWeb.html





4-Equal-Body "Shockwave" or pulse wave Dynamics

Opposite of continuous wave dynamics introduced in Unit 2

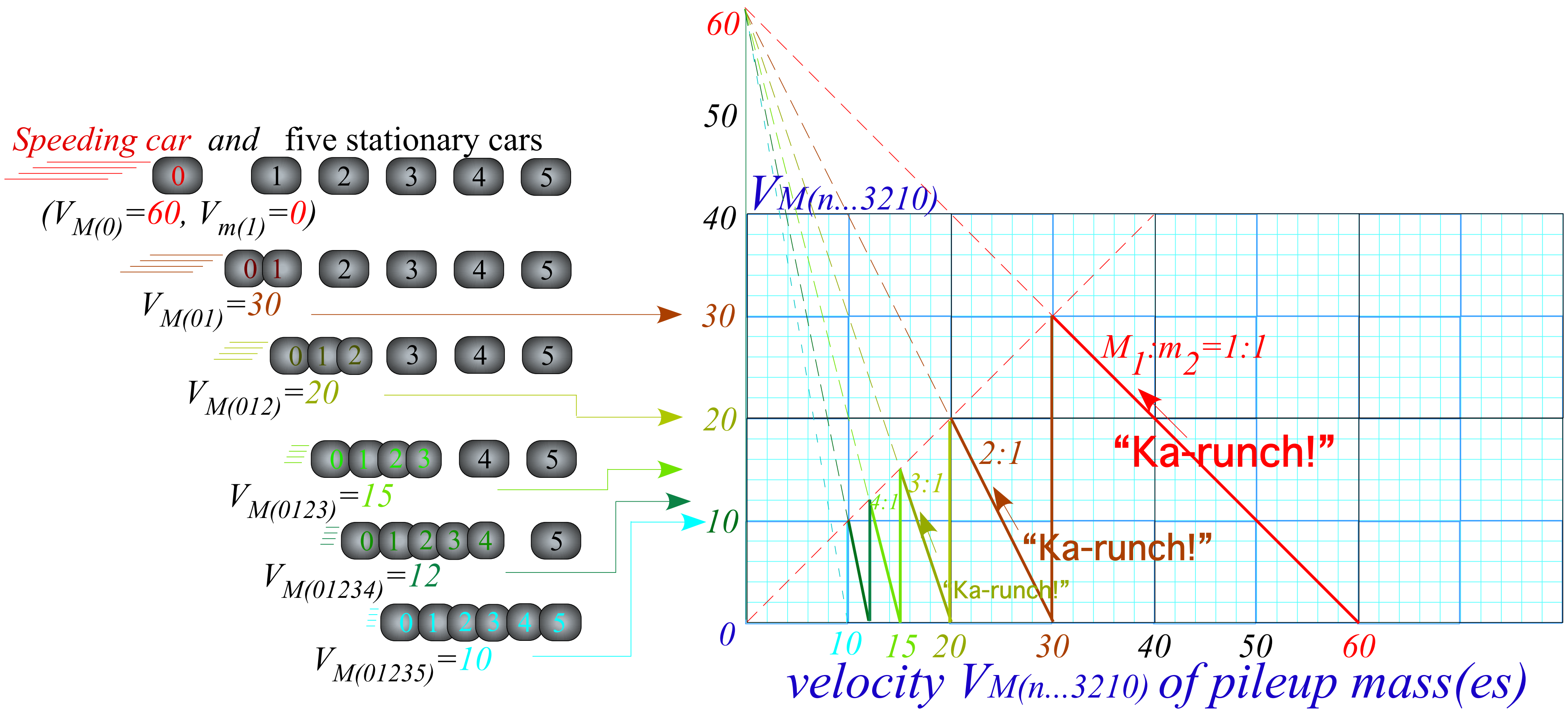
Many-body 1D collisions

Elastic examples: Western buckboard, Bouncing column, Newton's cradle

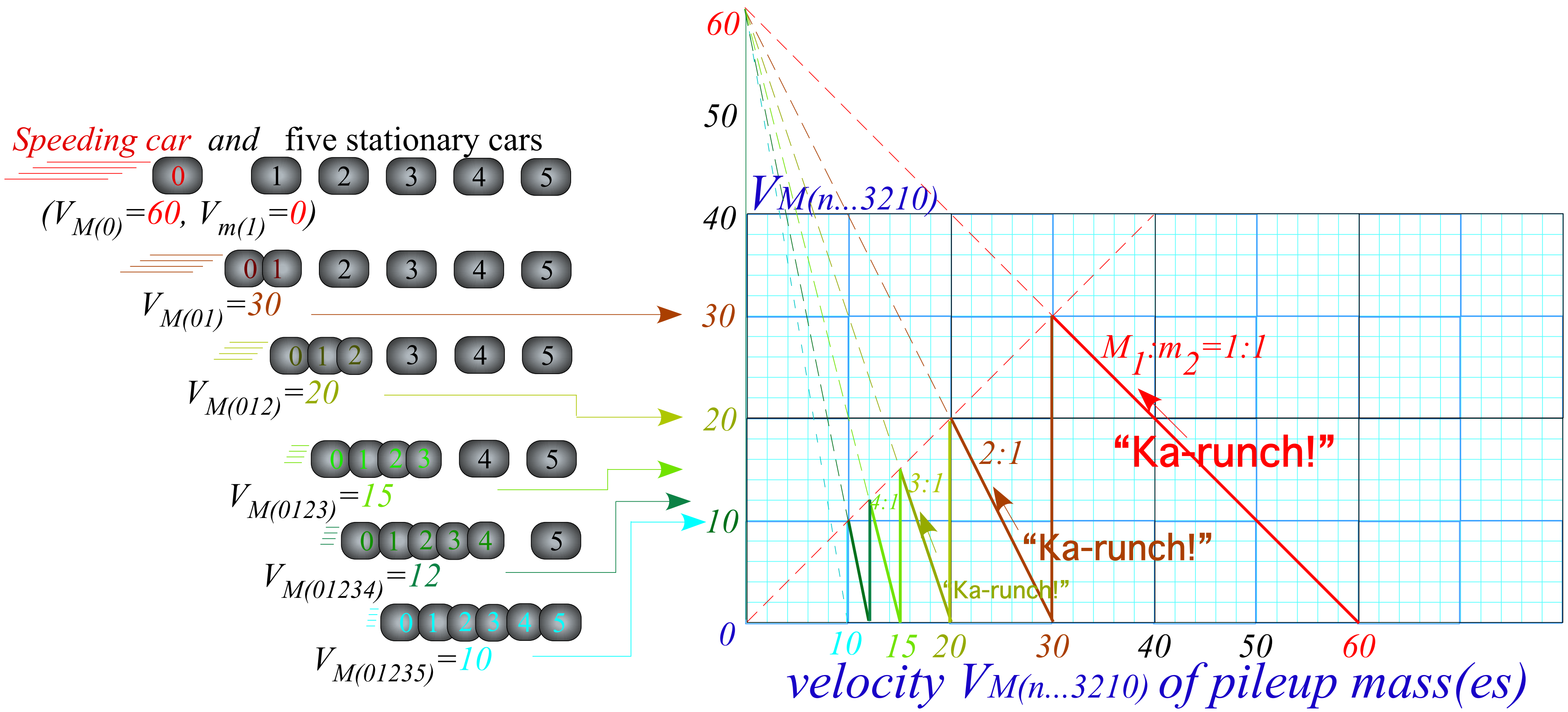
→ *Inelastic examples: "Zig-zag geometry" of freeway crashes*

Super-elastic examples: This really **is** *"Rocket-Science"*

Unit 1
Fig. 8.5
Pile-up:
One *60mph* car
hits
five standing cars



Unit 1



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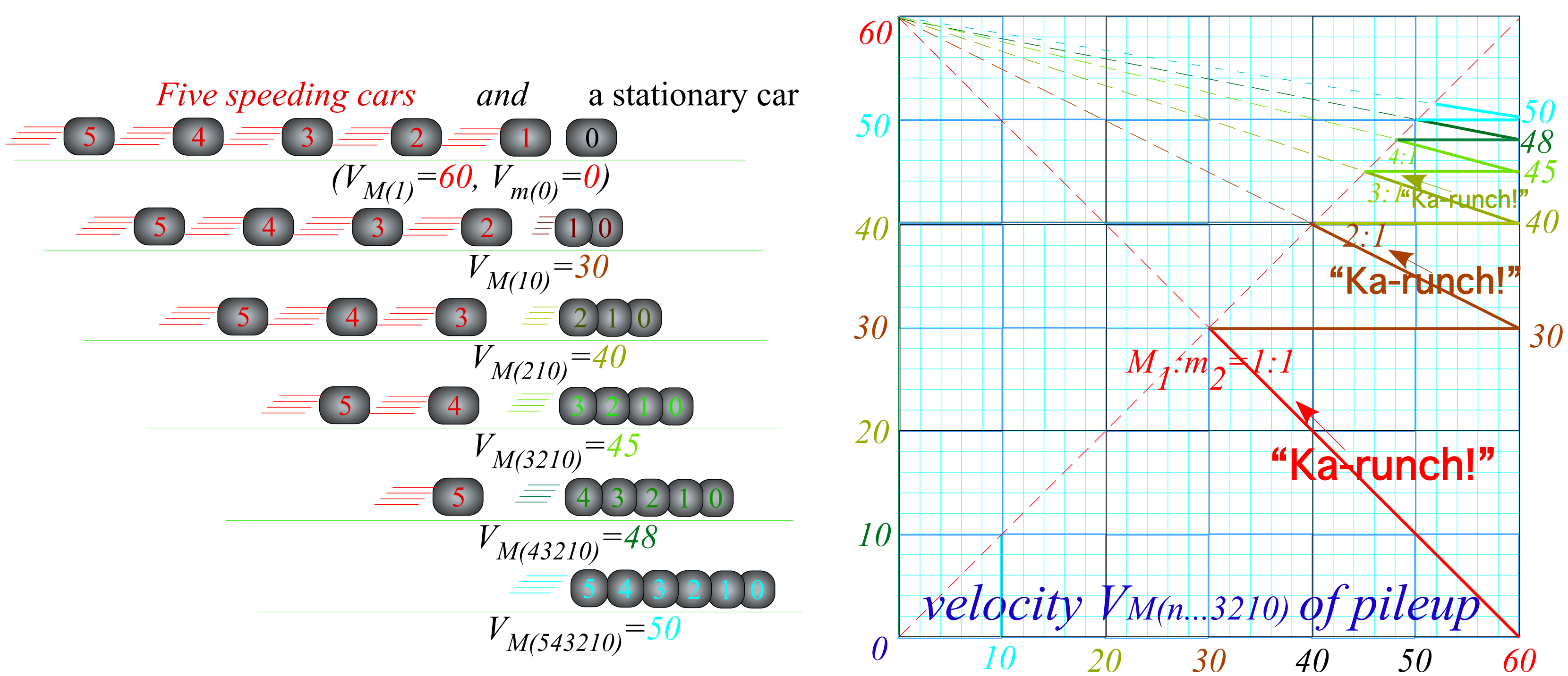
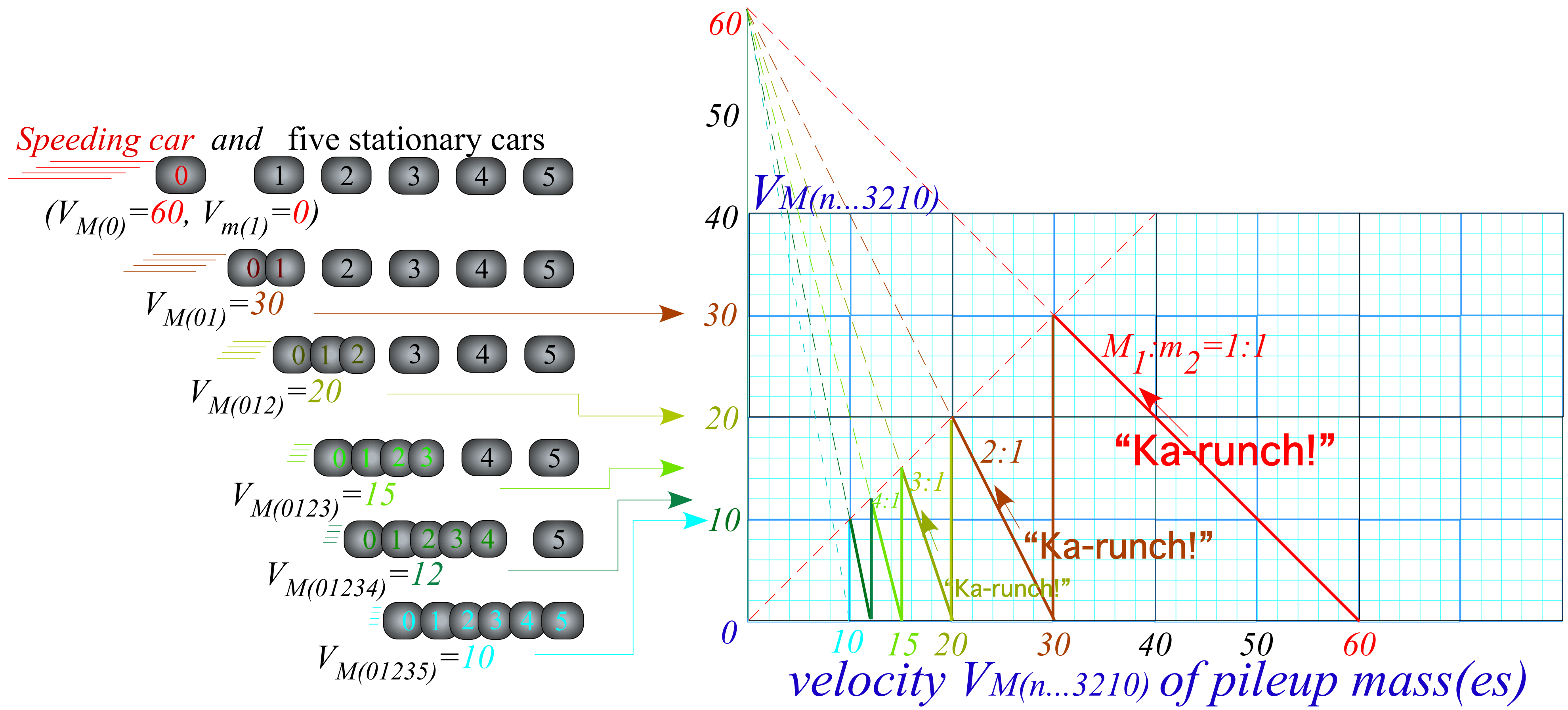


Fig. 8.6
Pile-up:
Five *60mph* cars
hit
one standing cars

Unit 1



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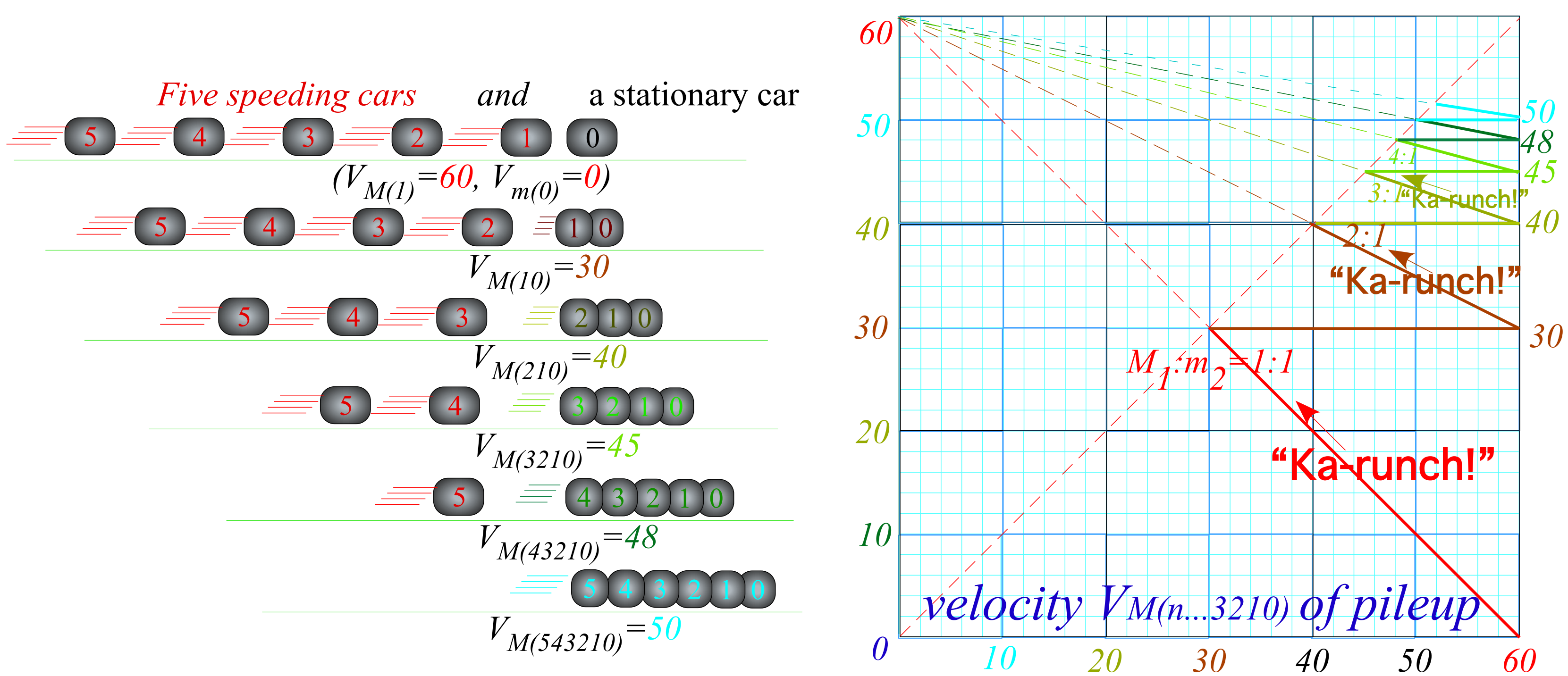

Fig. 8.6
Pile-up:
Five *60mph* cars
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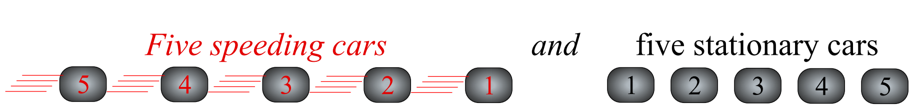


(Fug-gedda-aboud-dit!!)

Fig. 8.7
Pile-up:
Five *60mph* cars
hit
five standing cars

Many-body 1D collisions

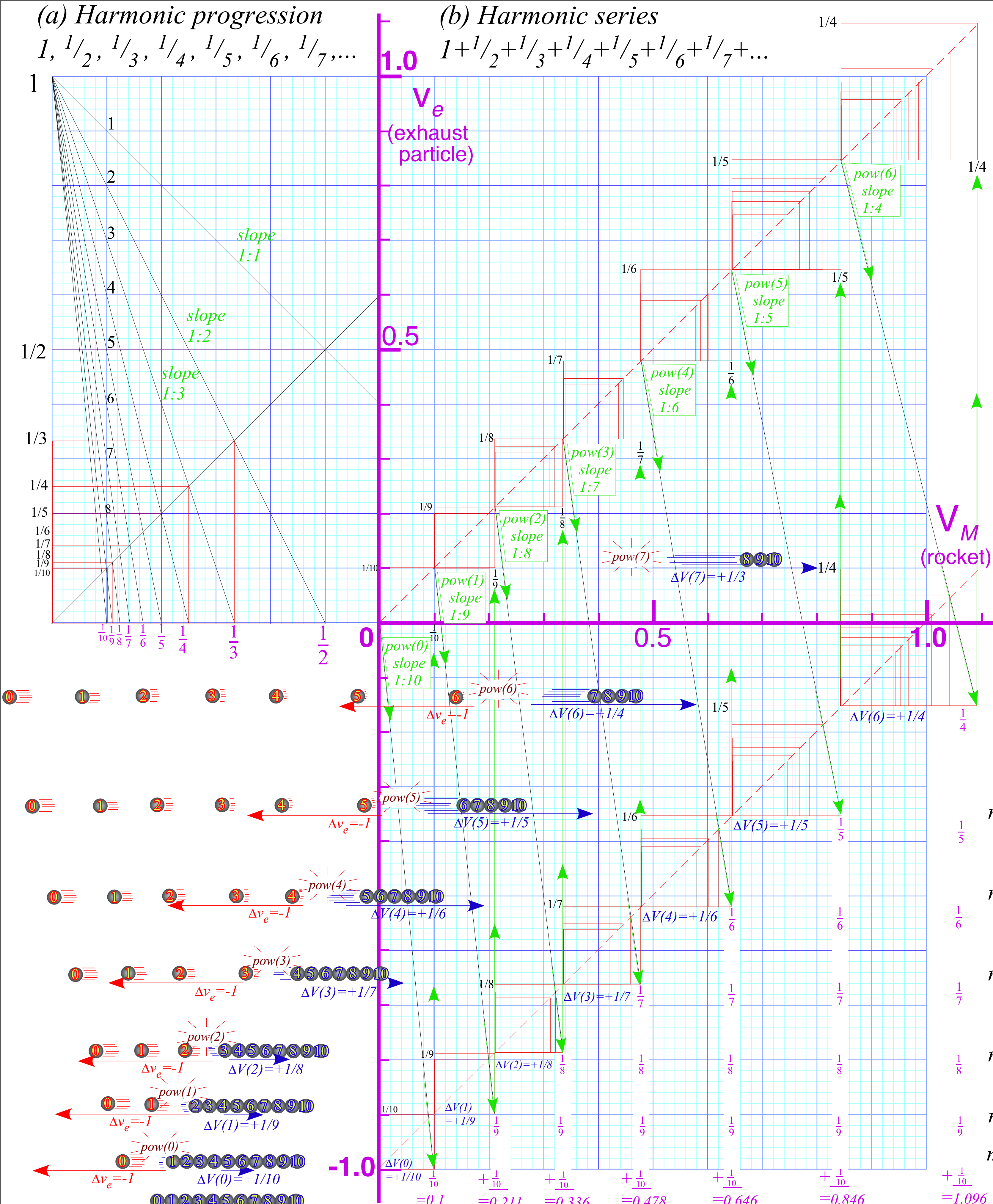
Elastic examples: Western buckboard, Bouncing column, Newton's cradle

Inelastic examples: "Zig-zag geometry" of freeway crashes

→ *Super-elastic examples: This really* **is** *"Rocket-Science"*

Unit 1
Fig. 8.8a-b

Rocket Science!



$m \cdot \Delta v_7 + 3m \cdot \Delta V_M(7) = 0$

$m \cdot \Delta v_6 + 4m \cdot \Delta V_M(6) = 0$

$m \cdot \Delta v_5 + 5m \cdot \Delta V_M(5) = 0$

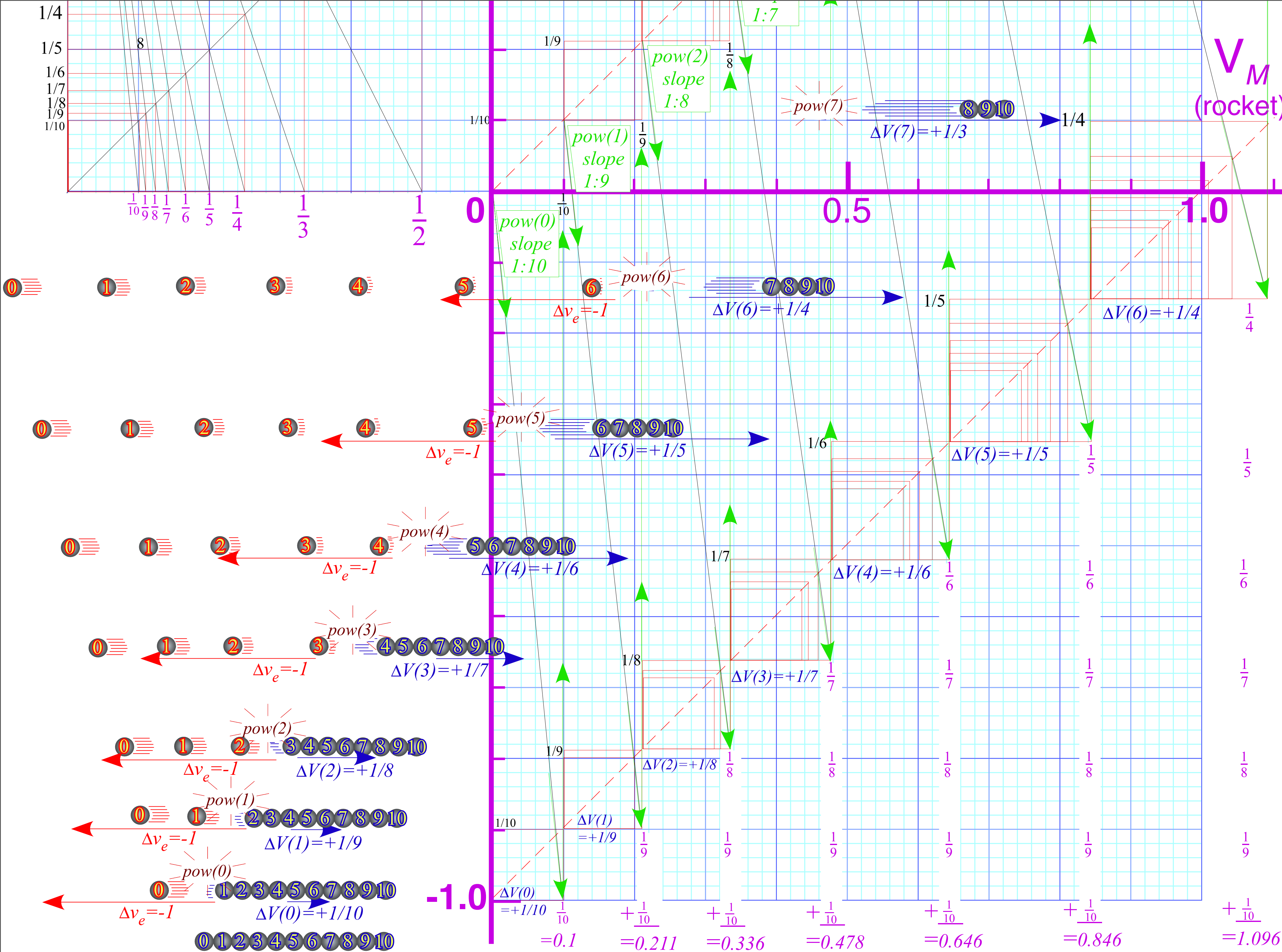
$m \cdot \Delta v_4 + 6m \cdot \Delta V_M(4) = 0$

$m \cdot \Delta v_3 + 7m \cdot \Delta V_M(3) = 0$

$m \cdot \Delta v_2 + 8m \cdot \Delta V_M(2) = 0$

$m \cdot \Delta v_1 + 9m \cdot \Delta V_M(1) = 0$

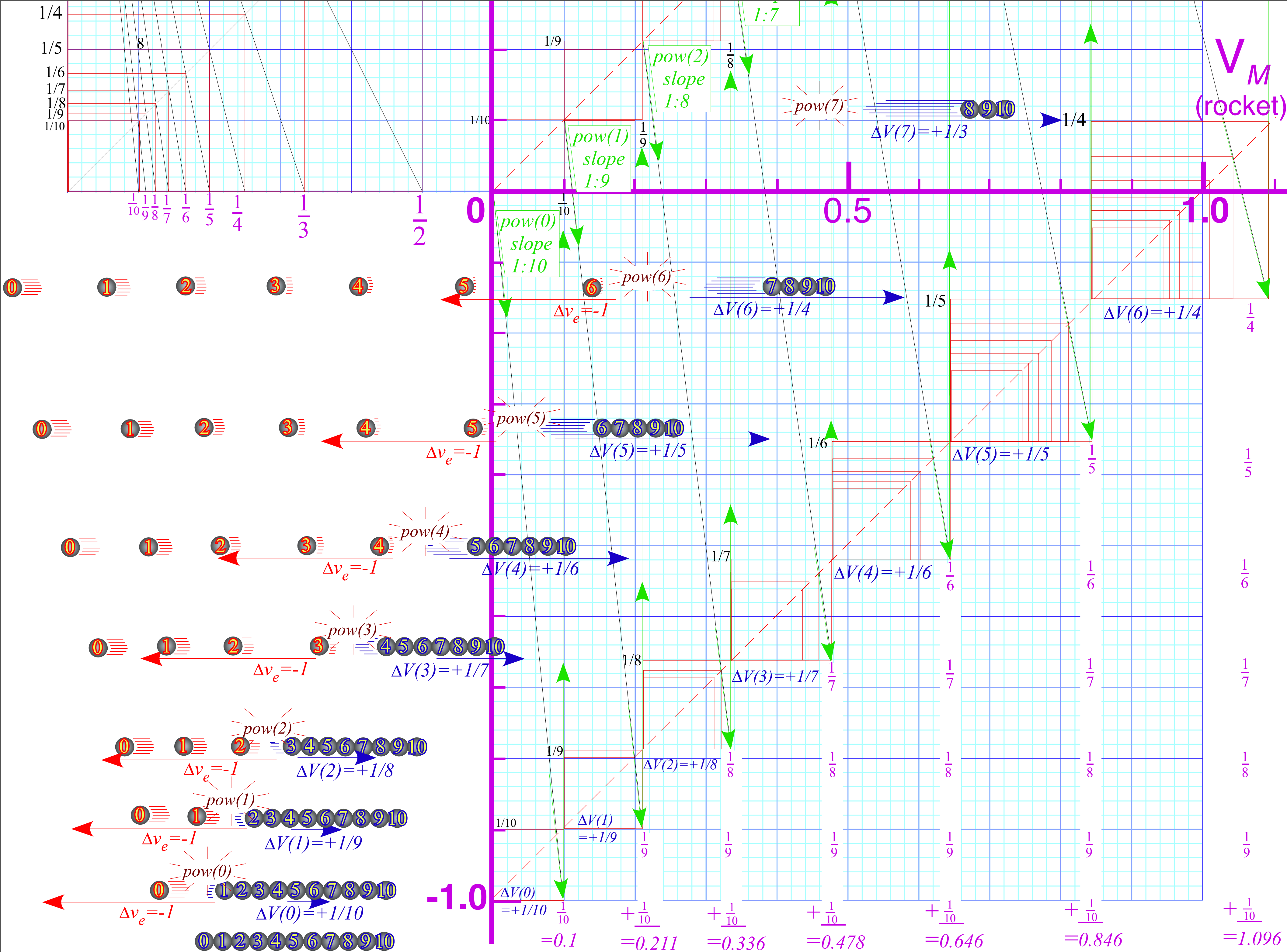
$m \cdot \Delta v_0 + 10m \cdot \Delta V_M(0) = 0$



0^{th}: $V(0)=1/10=0.1$ 1^{st}: $V(1)=1/10+1/9=0.211$ 2^{nd}: $V(2)=1/10+1/9+1/8=0.336$

3^{rd}: $V(3)=V(2)+1/7=0.478$ 4^{th}: $V(4)=V(3)+1/6=0.646$ 5^{th}: $V(5)=V(4)+1/5=0.846$

6^{th}: $V(6)=V(5)+1/4=1.096$ 7^{th}: $V(7)= V(6)+1/3=1.429$ 8^{th}: $V(8)=V(7)+1/2=1.929$



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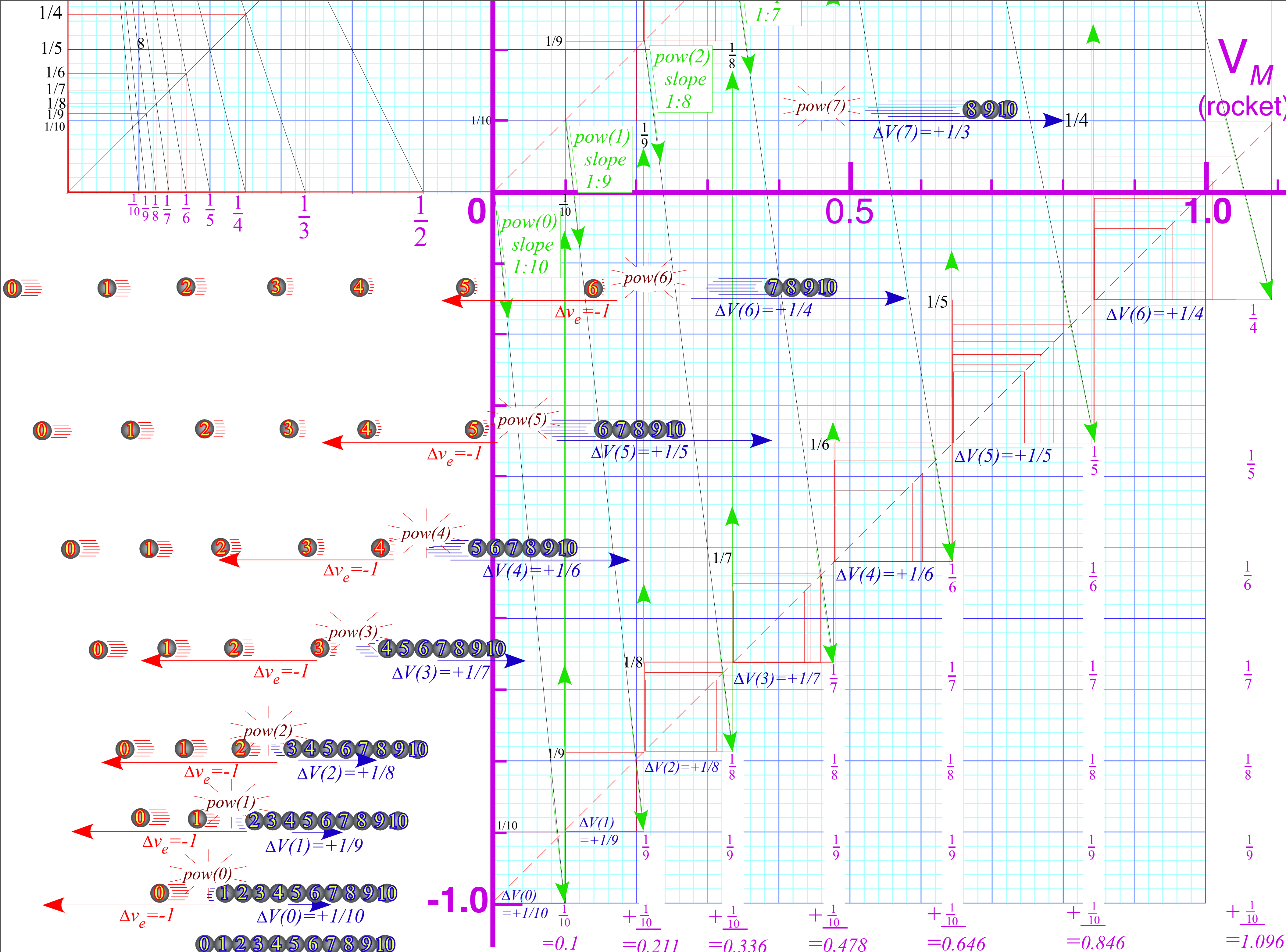
v_e *known as* *"Specific Impulse"*

By calculus: $M\cdot\Delta V=-v_e\cdot\Delta M$ or: $dV=-v_e\dfrac{dM}{M}$ Integrate: $\int_{V_{IN}}^{V_{FIN}} dV = -v_e\int_{M_{IN}}^{M_{FIN}}\dfrac{dM}{M}$



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v_e *known as* **"Specific Impulse"**

By calculus: $M\cdot\Delta V=-v_e\cdot\Delta M$ $\quad$ or: $dV=-v_e\dfrac{dM}{M}$ $\quad$ Integrate: $\int_{V_{IN}}^{V_{FIN}} dV=-v_e\int_{M_{IN}}^{M_{FIN}}\dfrac{dM}{M}$

The Rocket Equation: $\quad V_{FIN}-V_{IN}=-v_e\left[\ln M_{FIN}-\ln M_{IN}\right]=v_e\left[\ln\dfrac{M_{IN}}{M_{FIN}}\right]$

Geometry of common power-law potentials

Geometric (Power) series

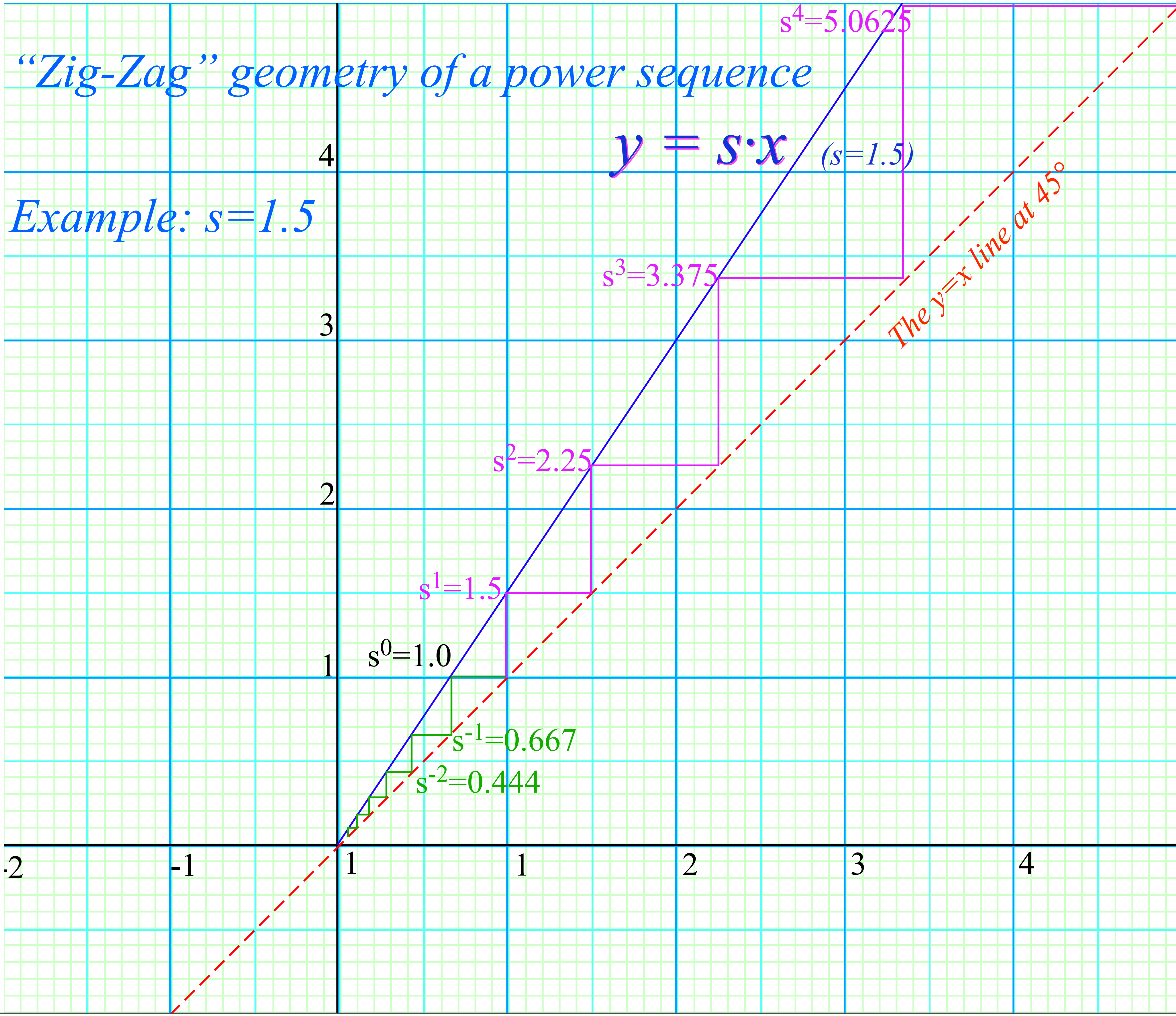
→ *"Zig-Zag" exponential geometry*

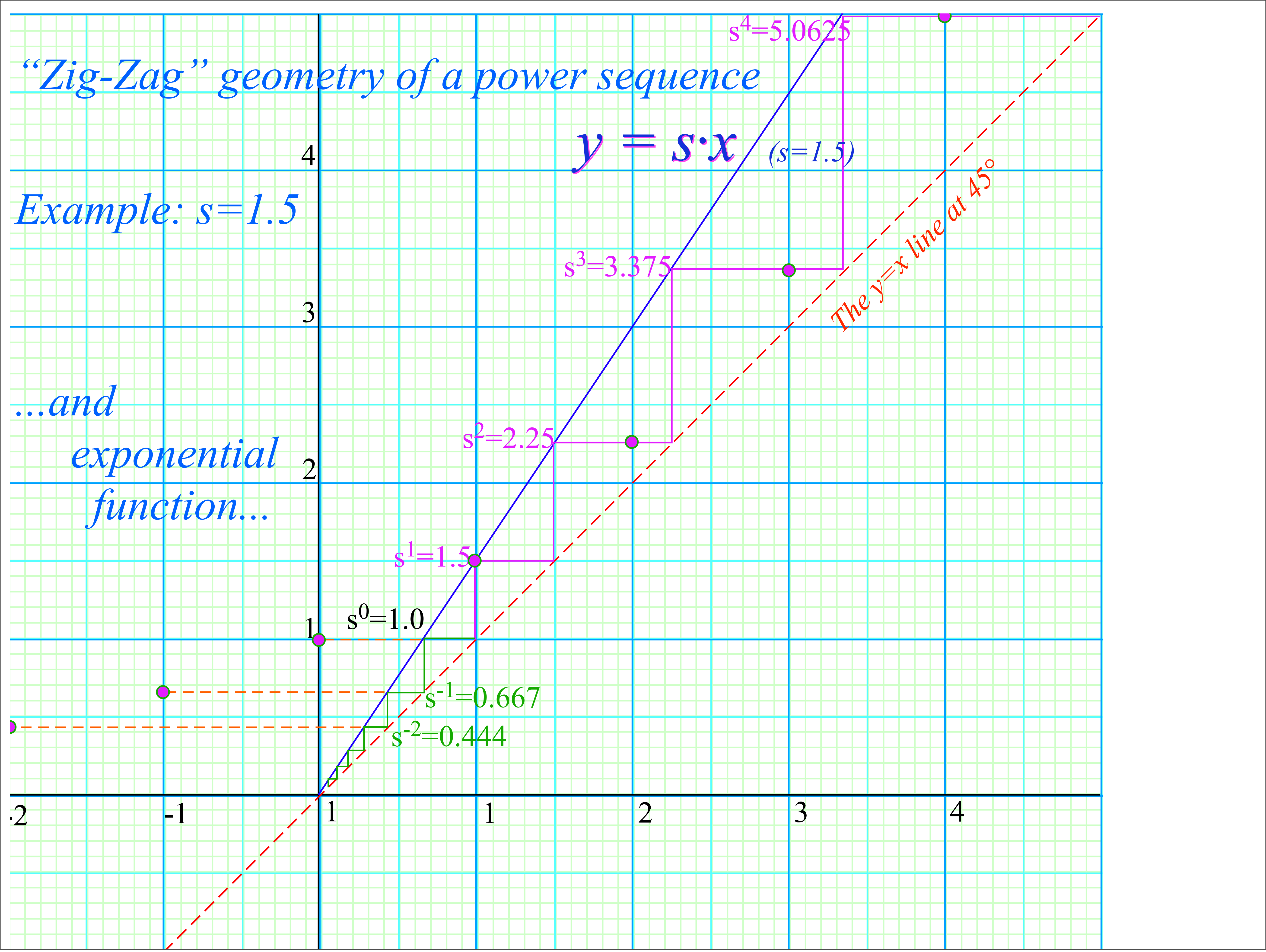
Projective or perspective geometry

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-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
s0=1.0
s-1=0.667
s-2=0.444
4
3
2
1
-2
-1
1
1
2
3
4



"Zig-Zag" geometry of a power sequence
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Example: s=1.5
...and
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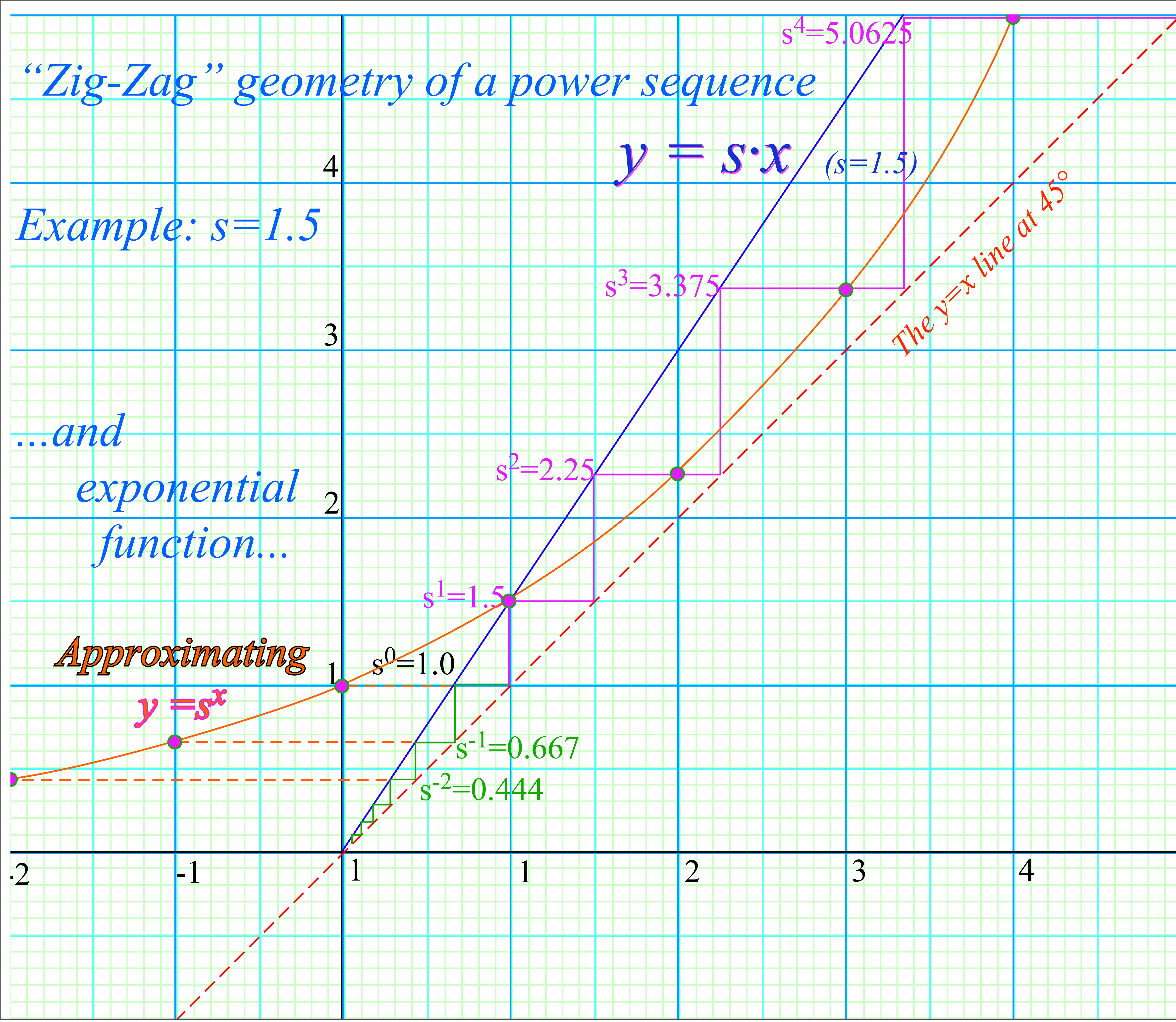
1
2
3
4


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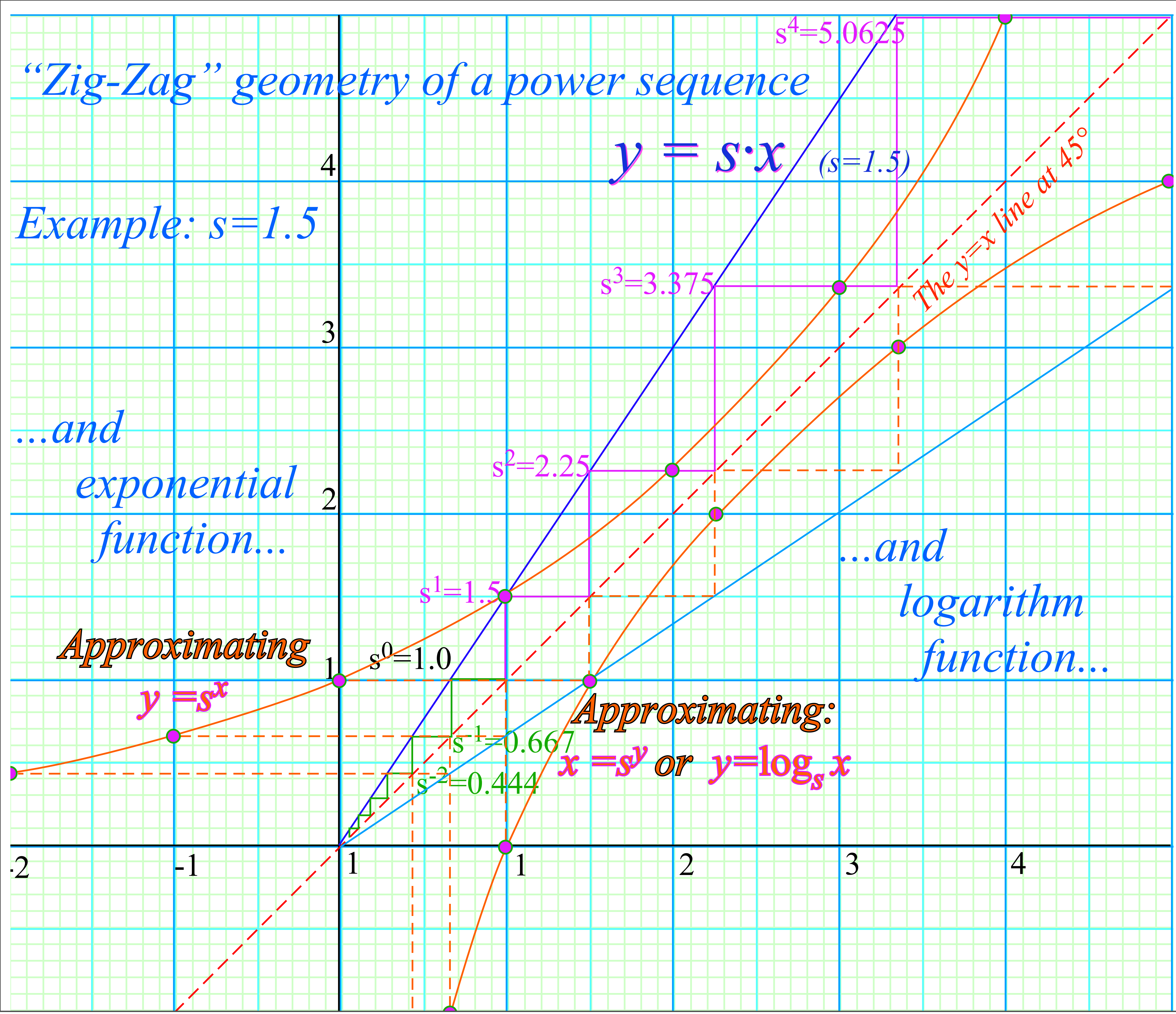
s^-1=0.667
s^-2=0.444
4
3
2
1
-2
-1
1
1
2
3
4


"Zig-Zag" geometry of a power sequence
y = s·x (s=1.5)
Example: s=1.5
...and
exponential
function...
Approximating
y =s^x
...and
logarithm
function...
Approximating:
x =s^y or y=log_s x
The y=x line at 45°
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
4
3
2
1
-2
-1
1
1
2
3
4

Geometry of common power-law potentials

Geometric (Power) series

"Zig-Zag" exponential geometry

→ *Projective or perspective geometry*

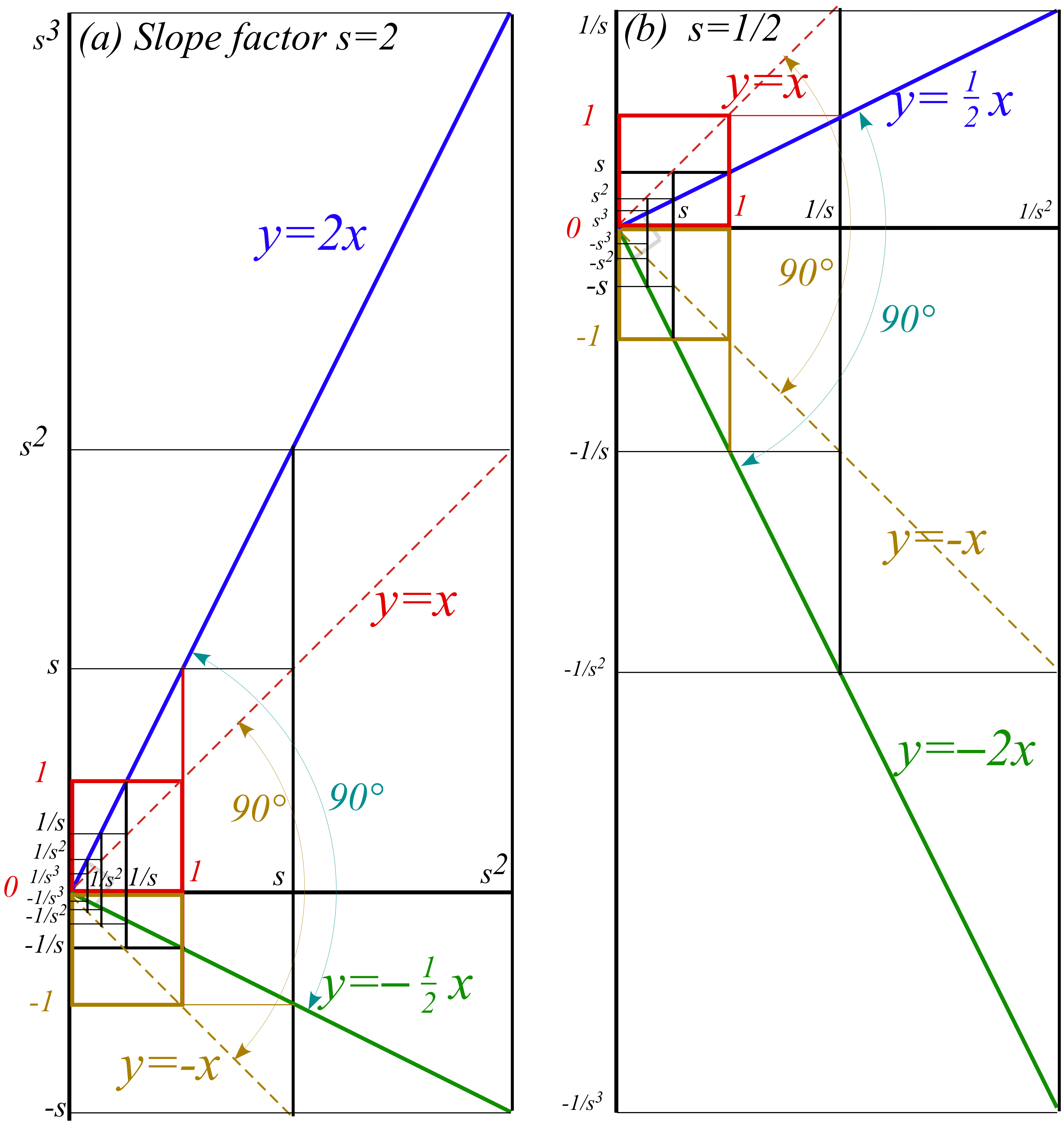
Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

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

Compare mks units of Coulomb Electrostatic vs. Gravity

"Zig-Zags" give perspective geometry

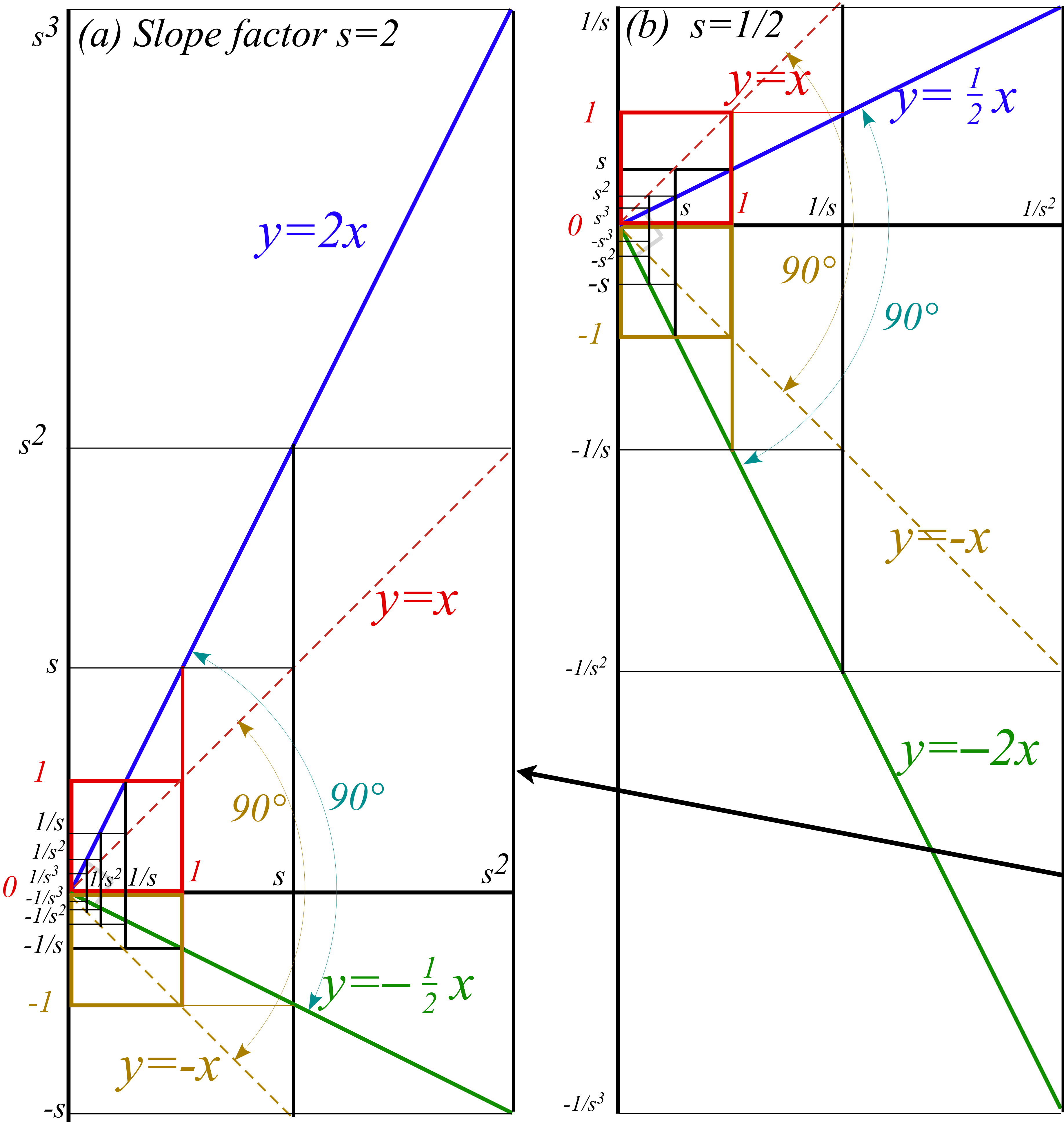
(1D-vanishing point)



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

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

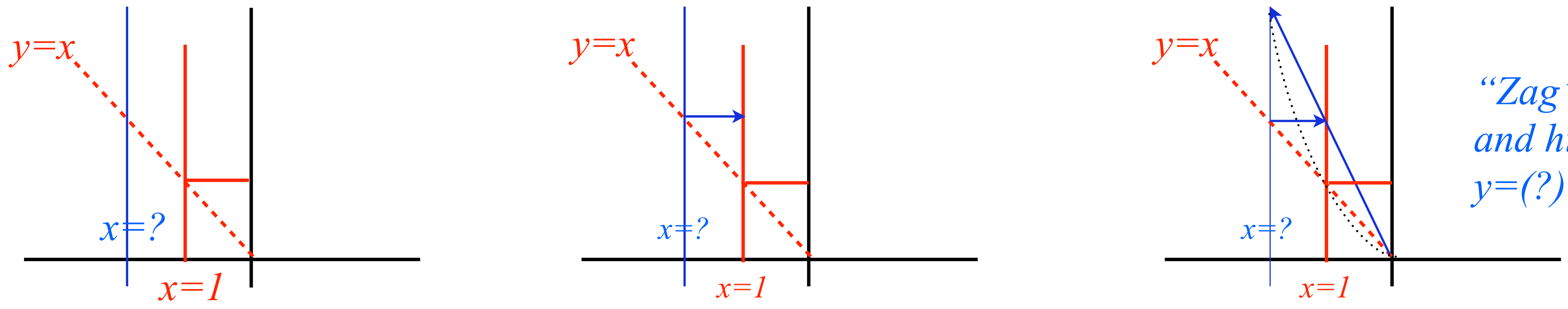
Compare mks units of Coulomb Electrostatic vs. Gravity

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 $y=(?)\cdot(?)=(?)^2$

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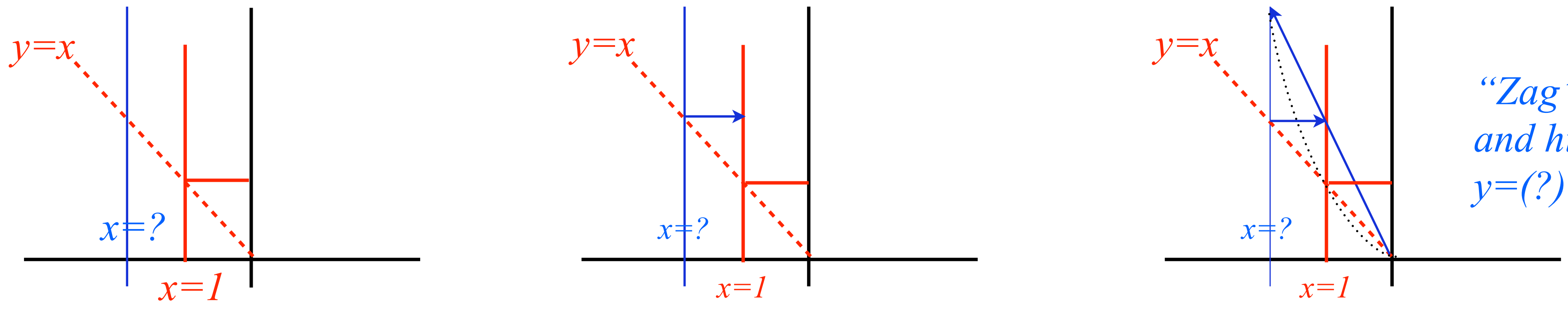

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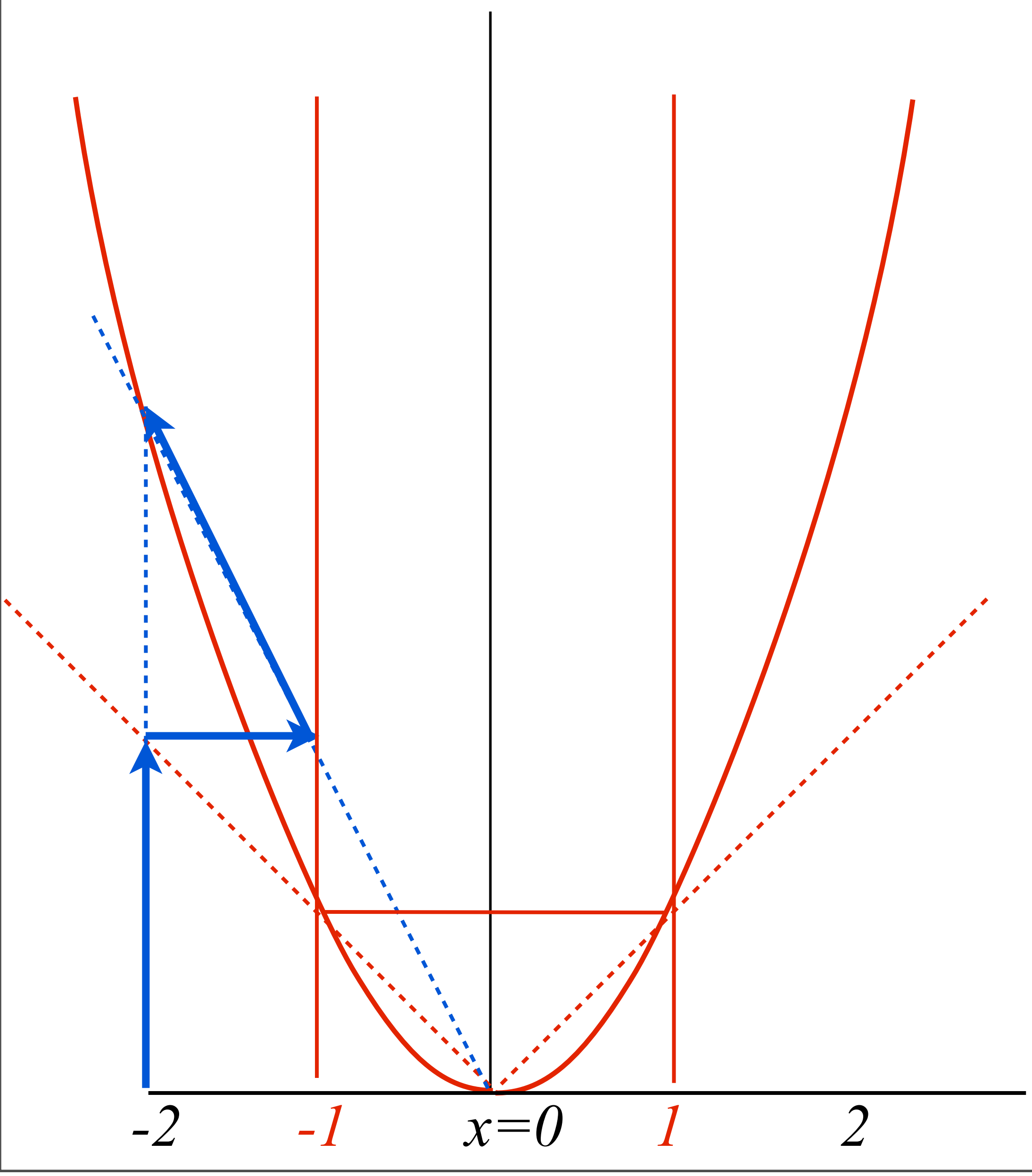

Unit 1
Fig. 9.1

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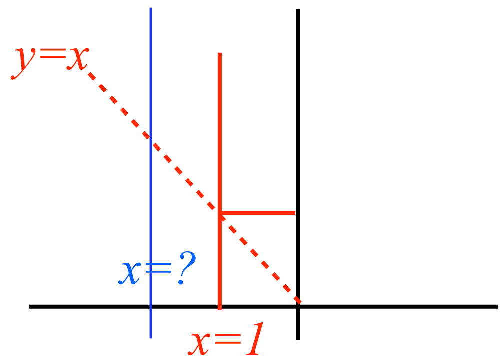
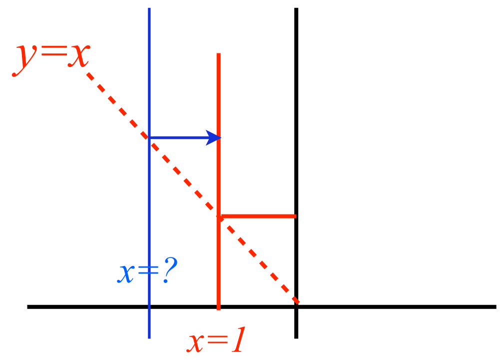
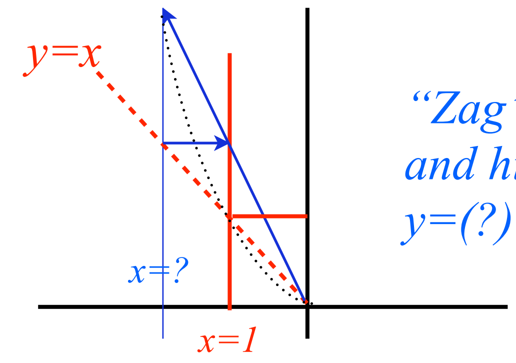
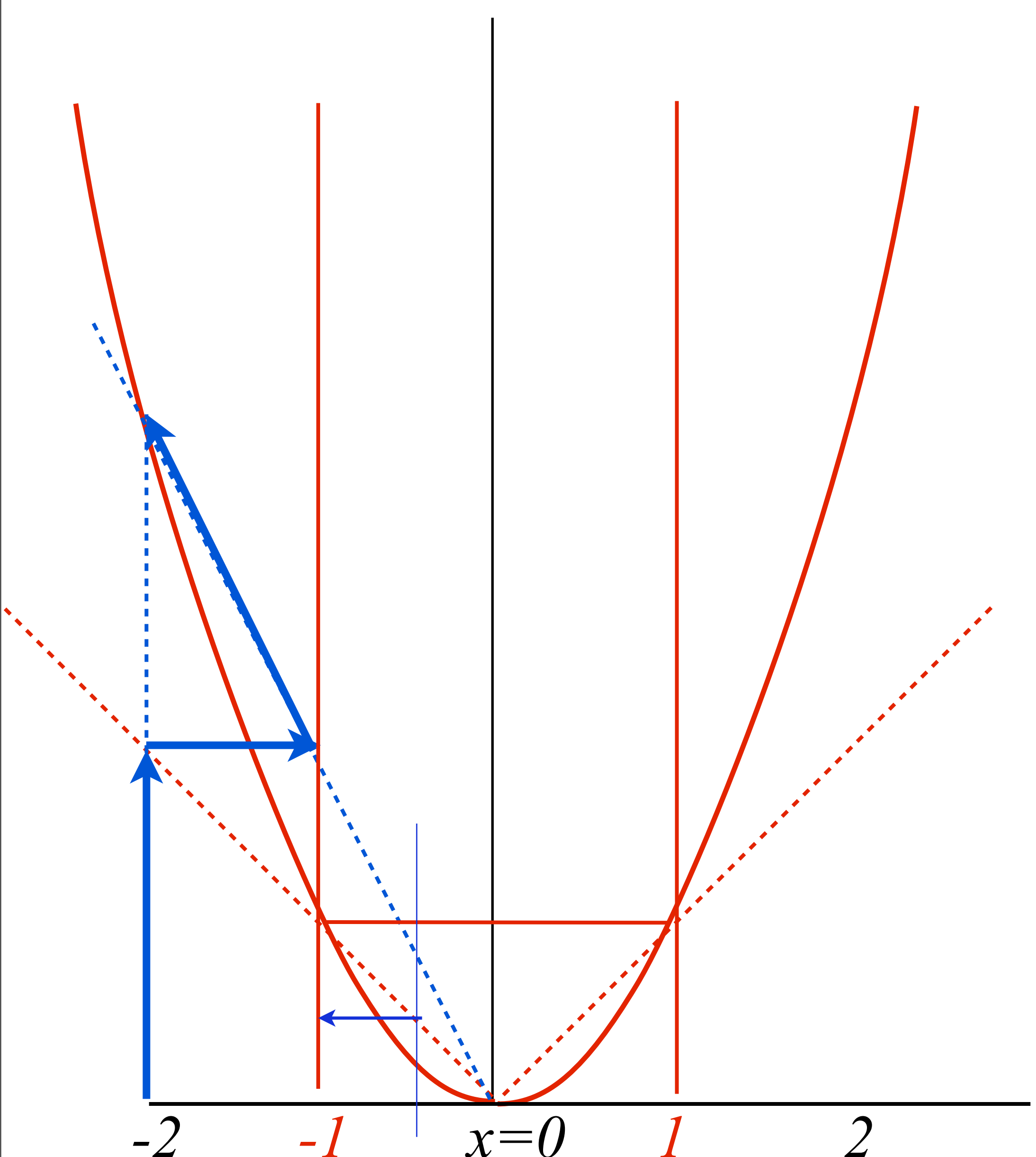






"Zag" line is y=(?)·x and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$



Unit 1
Fig. 9.1

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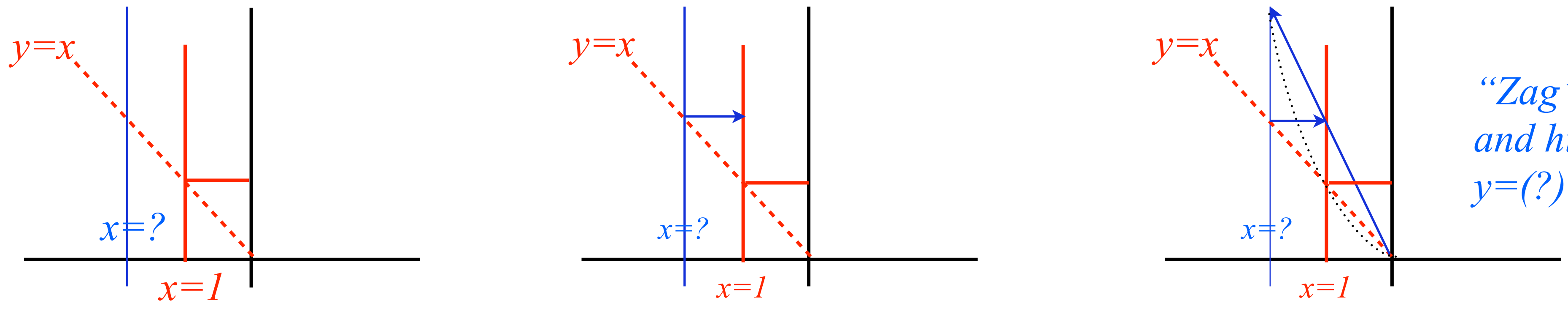

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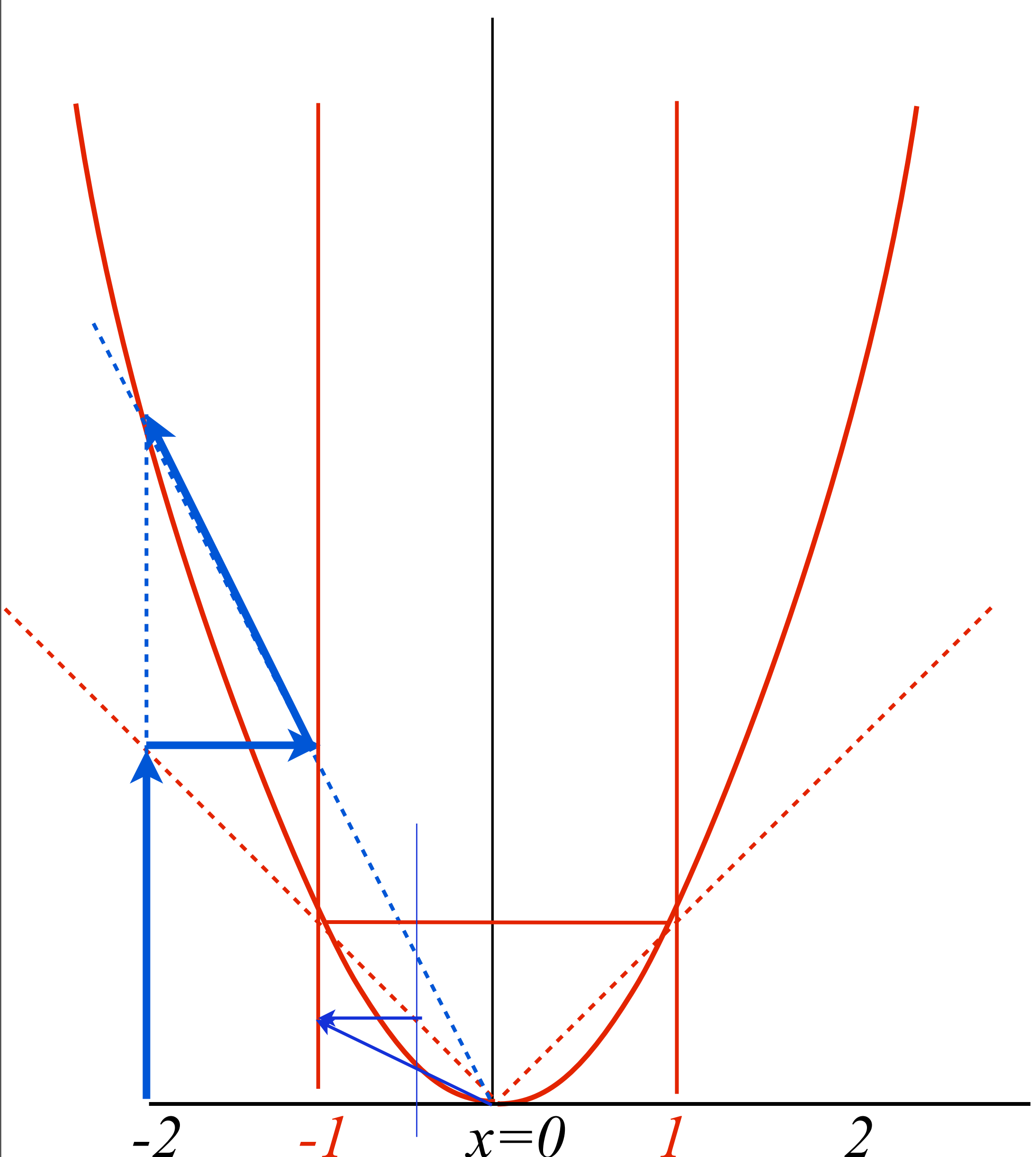

Unit 1
Fig. 9.1

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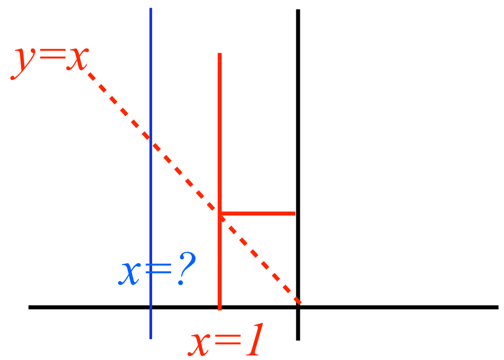
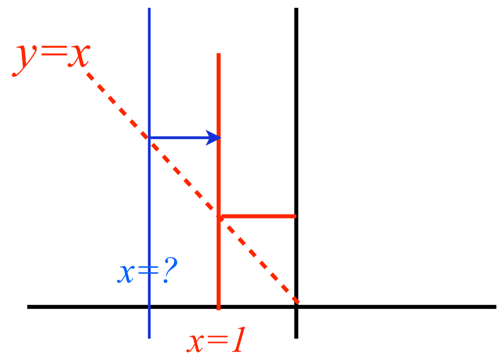
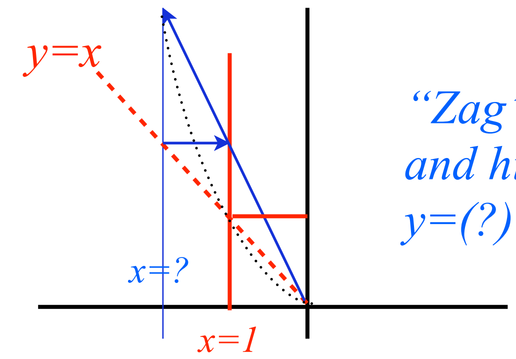
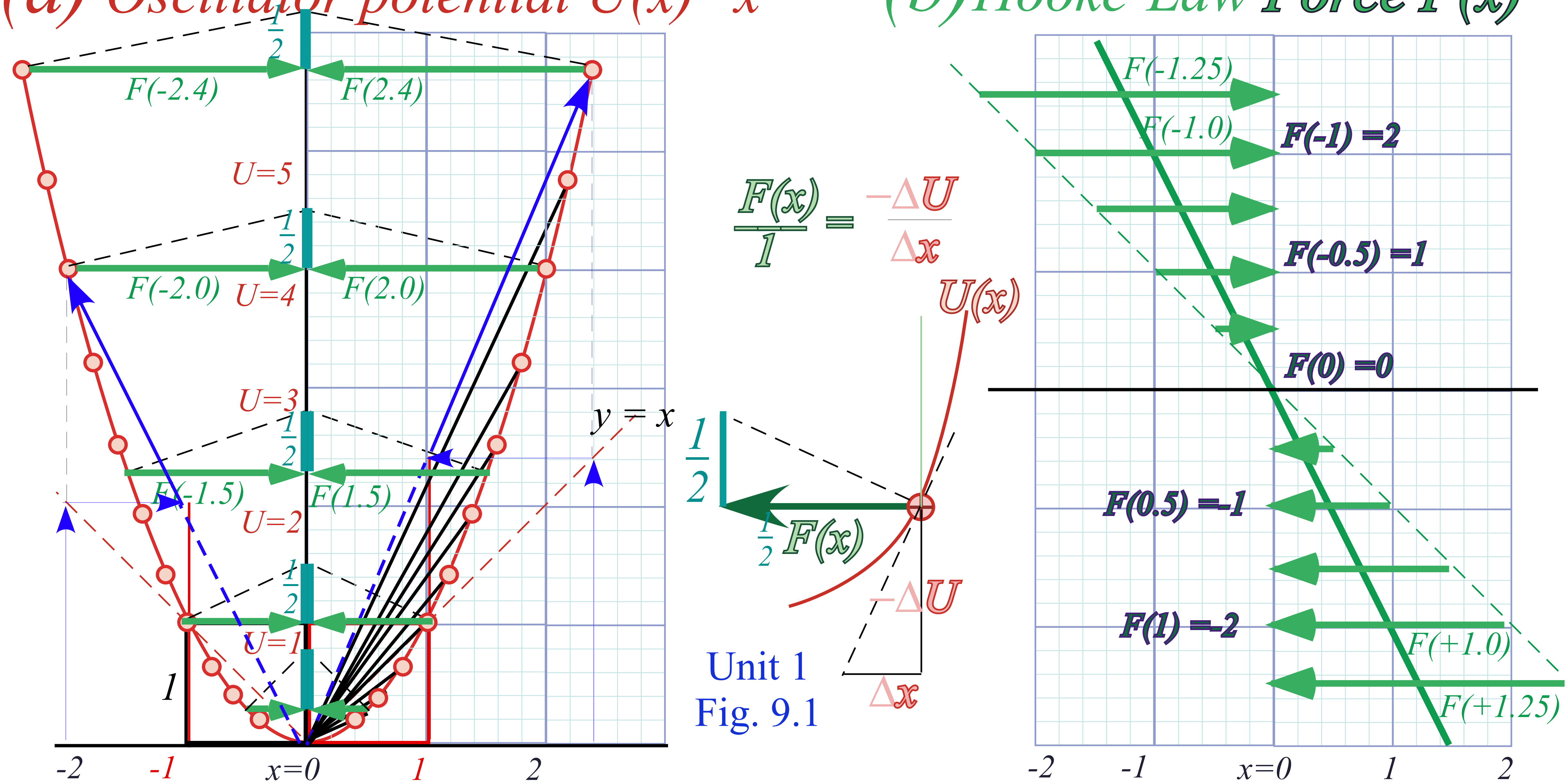




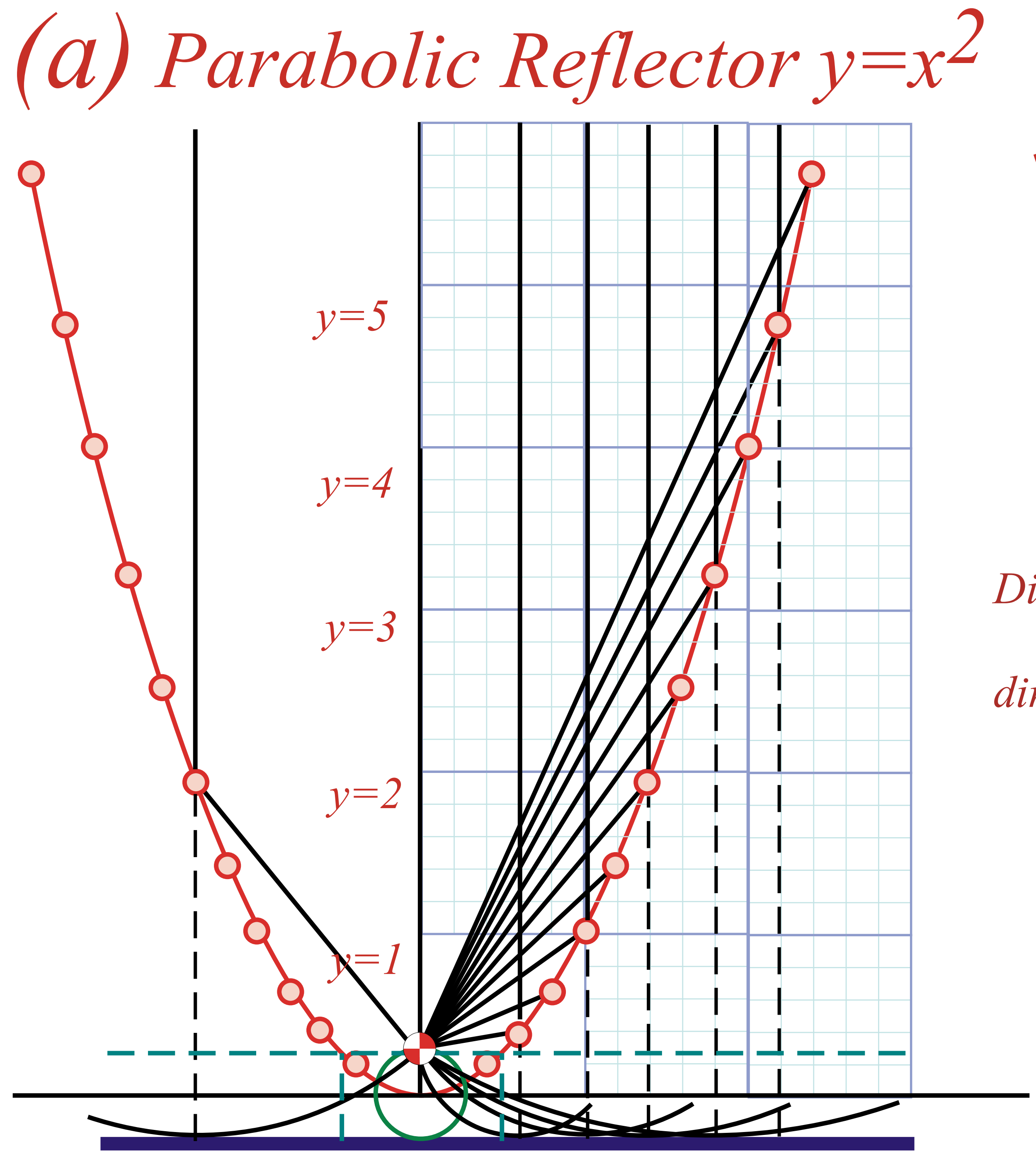


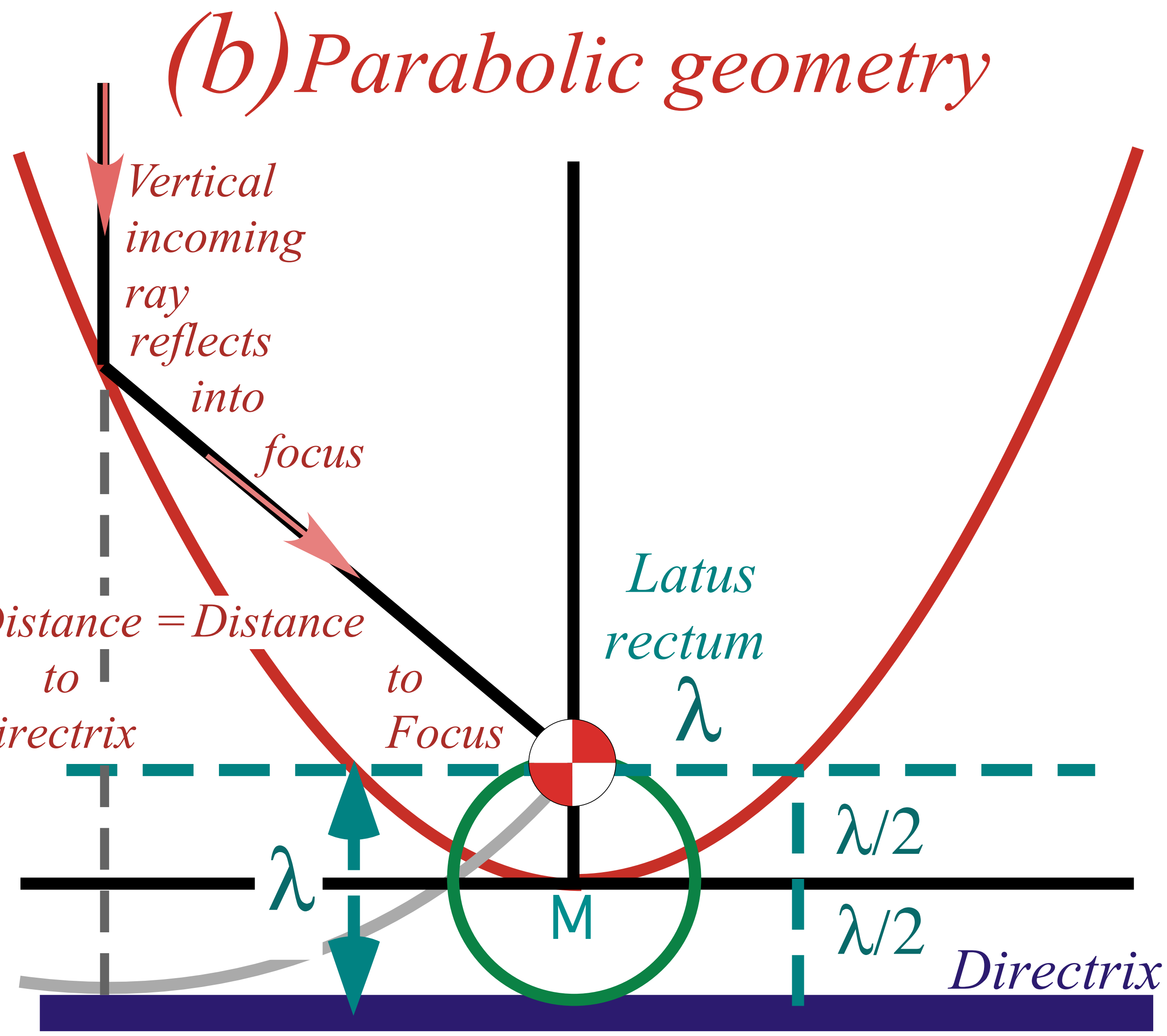
"Zag" line is y=(?)·x and hits (x=?)-line at $y=(?)\cdot(?)=(?)^2$

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



A more conventional parabolic geometry…(uses focal point)

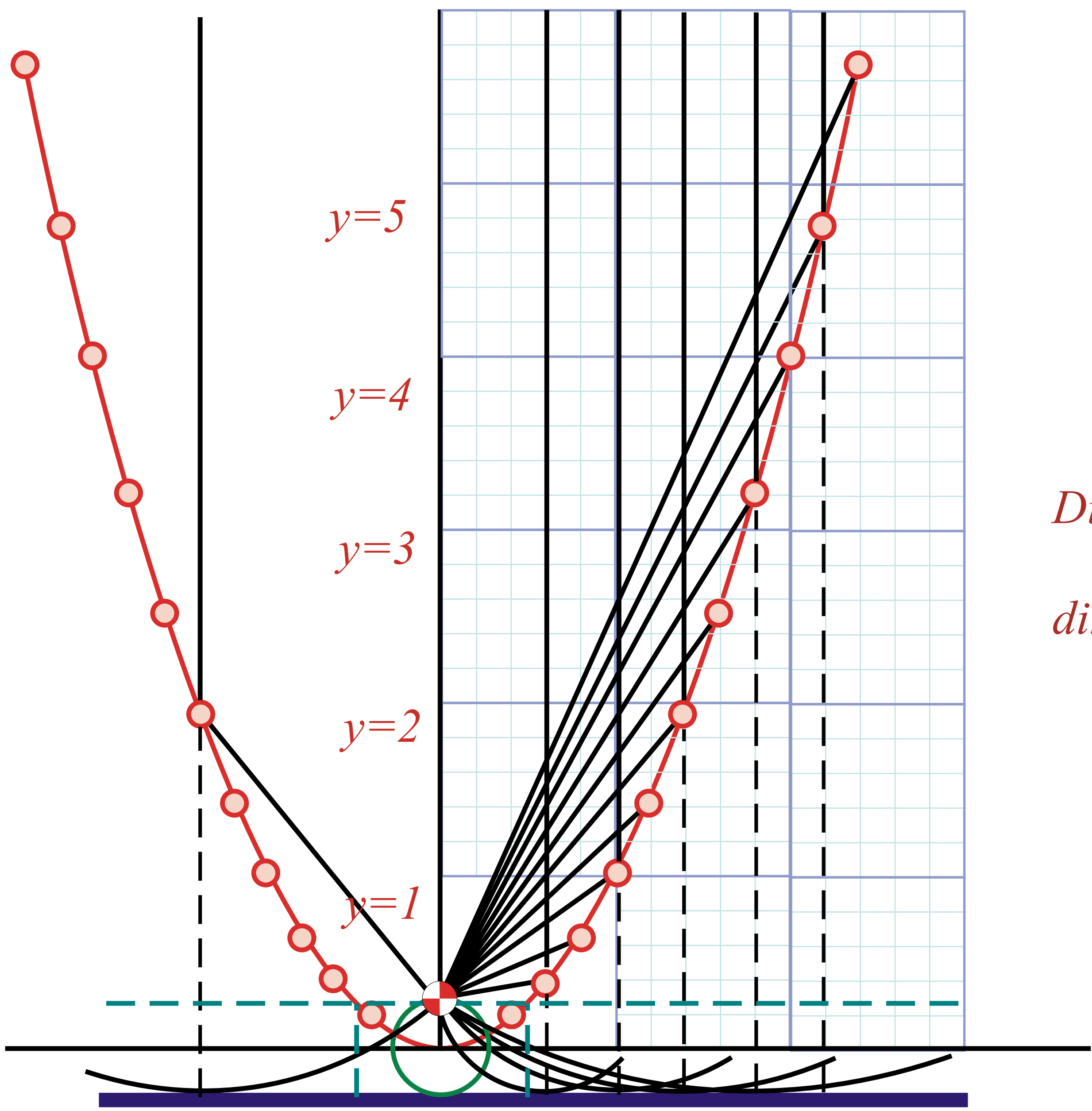




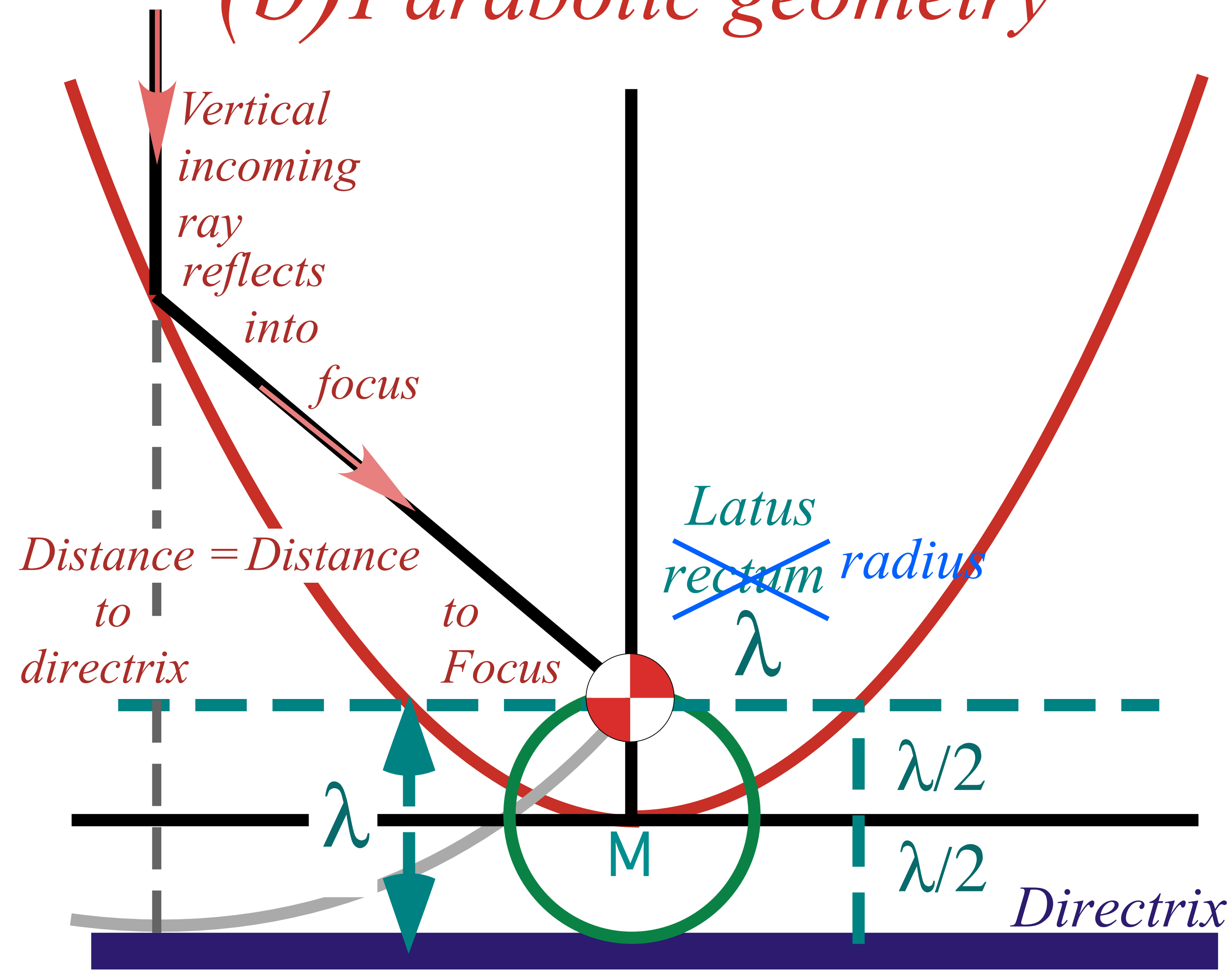
Unit 1
Fig. 9.3

A more conventional parabolic geometry...

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



(b) Parabolic geometry

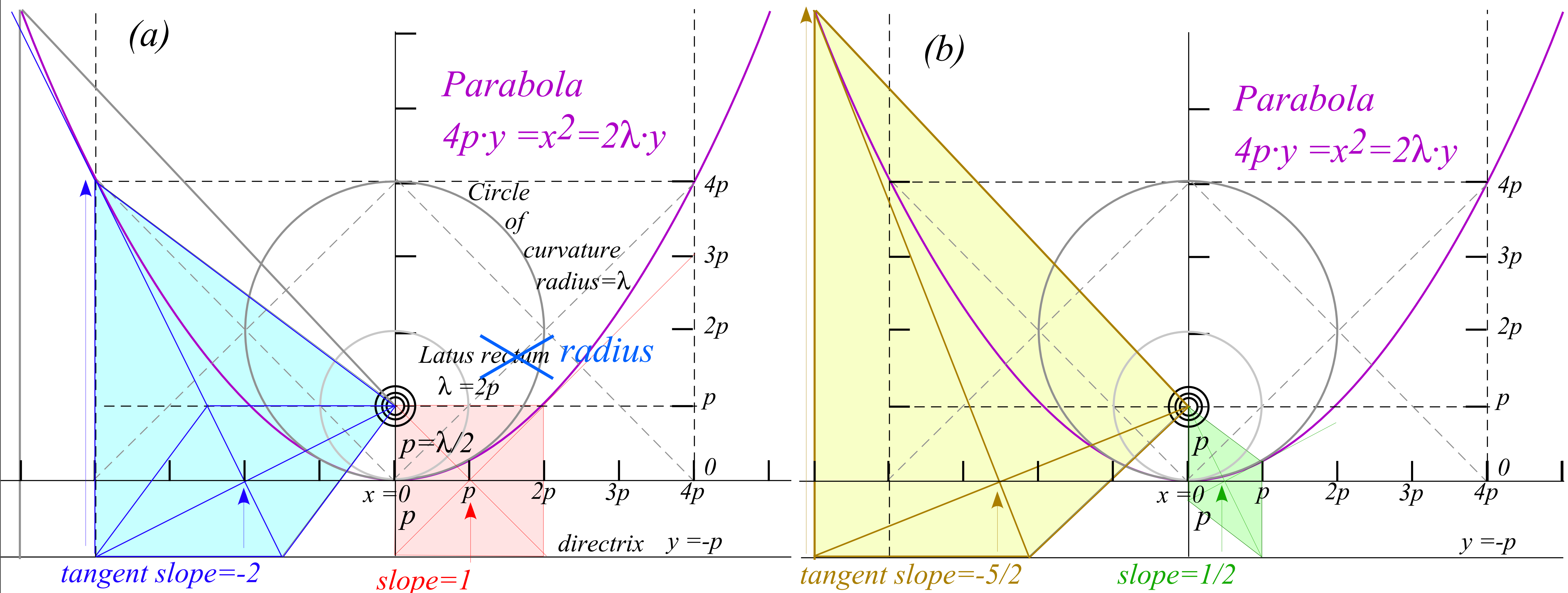


Better name† for λ : *latus radius*

†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

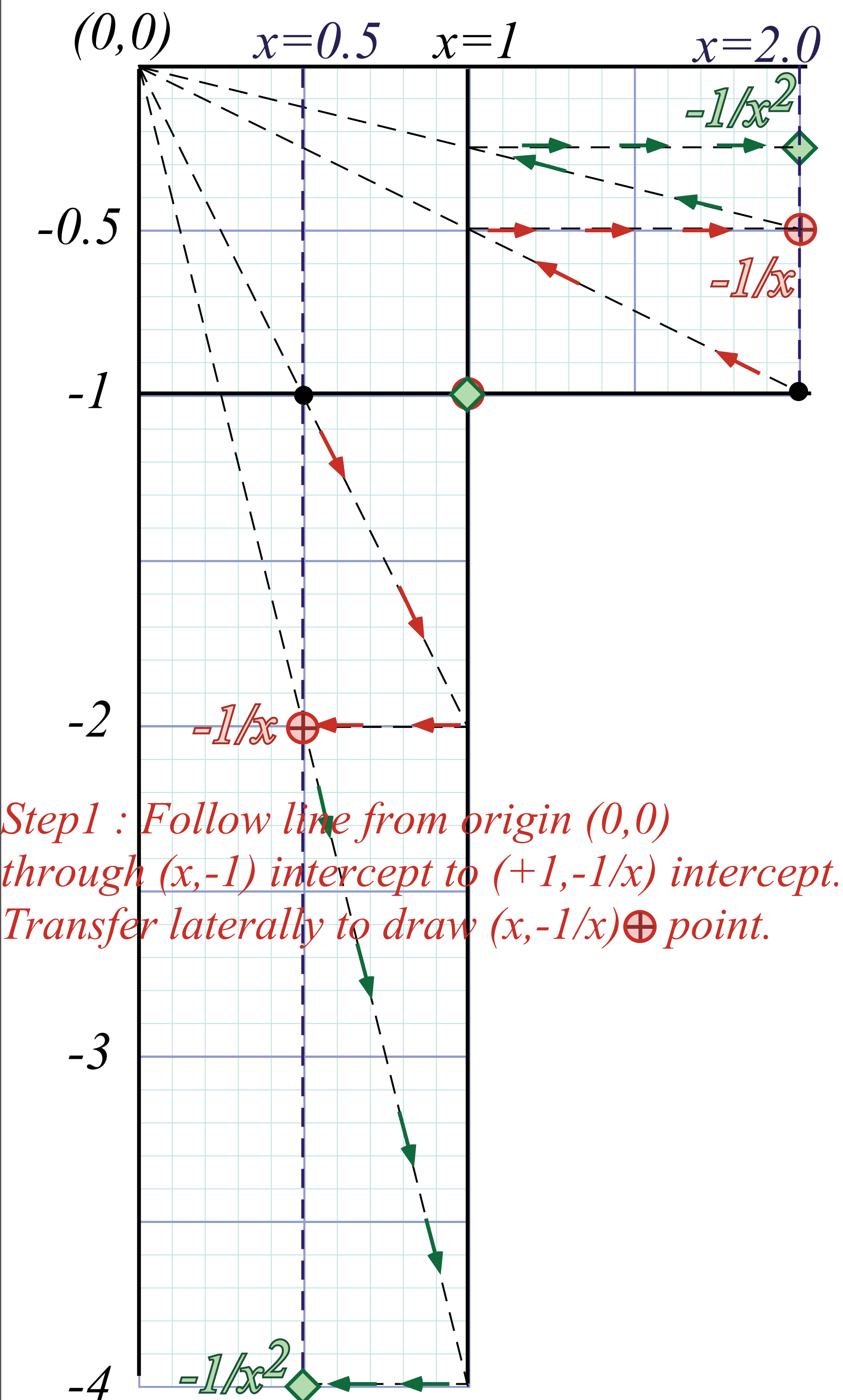
Parabolic geometry of harmonic oscillator $kr^2/2$ potential and $-kr^1$ force fields

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

Compare mks units of Coulomb Electrostatic vs. Gravity

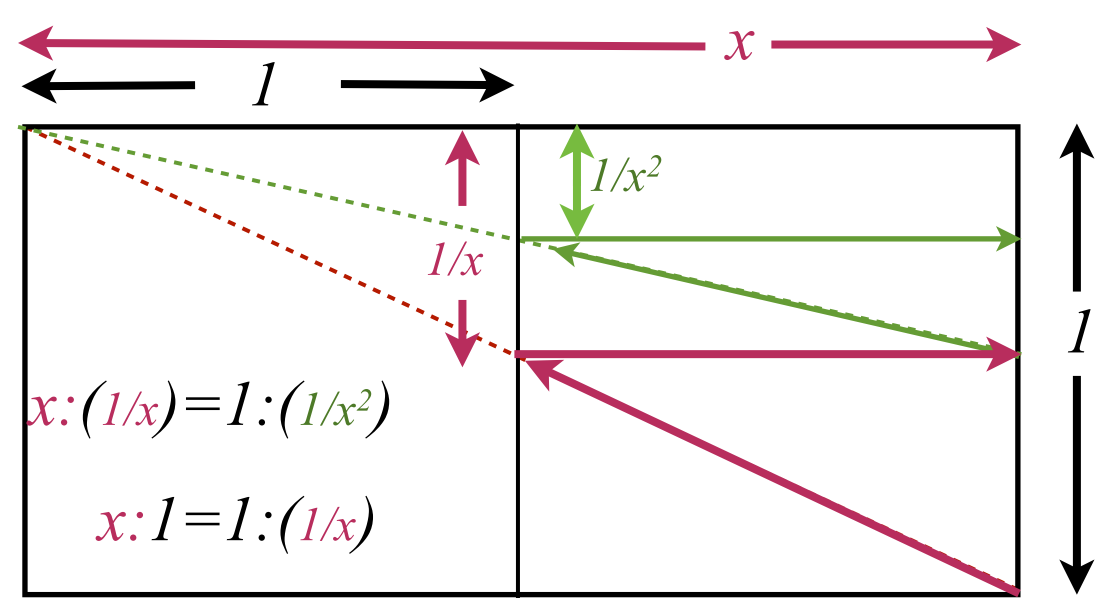
Unit 1
Fig. 9.4

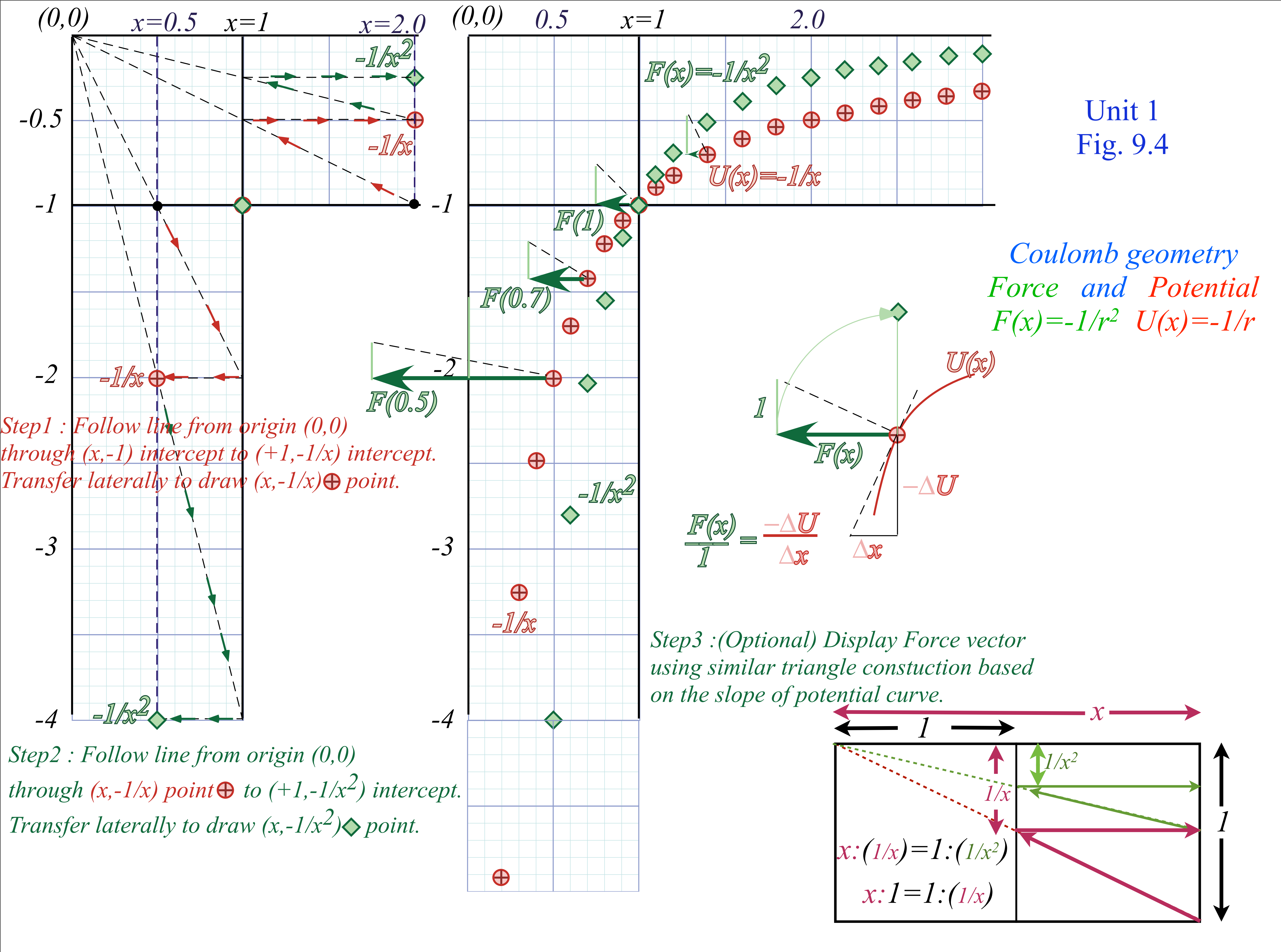
Coulomb geometry
Force and Potential
$F(x)=-1/r^2$ $U(x)=-1/r$



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/x²) intercept. Transfer laterally to draw (x,-1/x²)◇ 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
F(x)=-1/x²
U(x)=-1/x
F(1)
F(0.7)
F(0.5)
U(x)
F(x)
1
−ΔU
Δx
F(x)/1 = −ΔU/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
x:(1/x)=1:(1/x²)
x:1=1:(1/x)

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.)

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

Compare mks units for Coulomb fields

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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.

Compare mks units for Coulomb fields

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

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

"Fingertip Physics" of Ch. 9 notes that 1 $(cm)^3$ of water (1/38 Mole) has (1/38) $6 \cdot 10^{23}$ molecules (about $6 \cdot 10^{23}$ electrons)

That's about $6 \cdot 10^{23}\, 1.6022 \cdot 10^{-19}$ Coulomb
or about 10^{+5} C or 100,000 Coulomb

Compare mks units for Coulomb fields

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

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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.)

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

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

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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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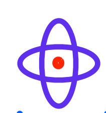
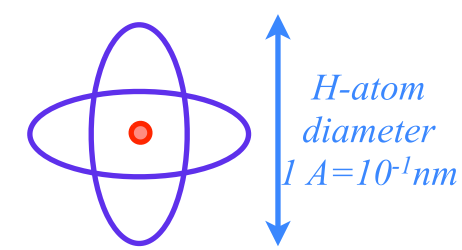


Nuclear size ~ 10^{-15} m = 1 femtometer =1fm

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

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



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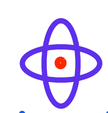

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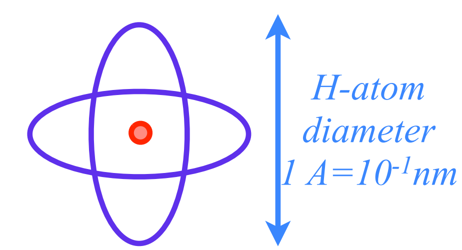

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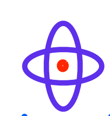

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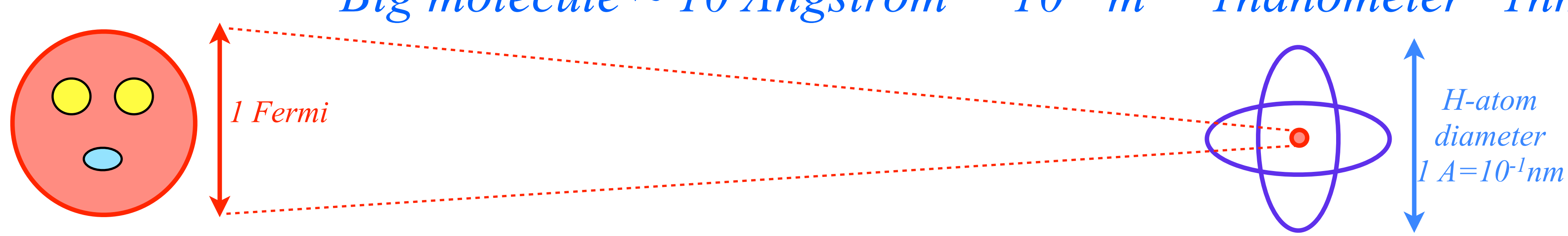
also:1fm = 10^{-13} cm =1Fermi
=1Fm



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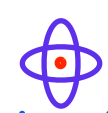

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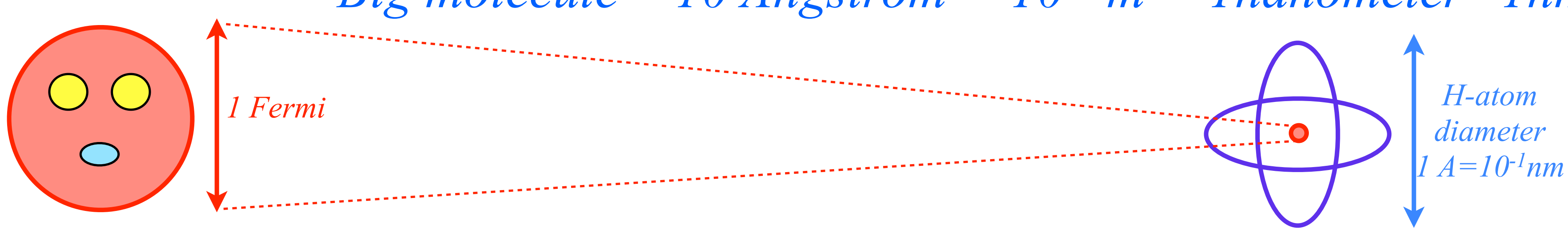


nuclear radii are 100,000 to 1,000,000 times smaller than atomic/chemical radii

*...so nuclear qQ/r energy 100,000 to 1,000,000 times **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)

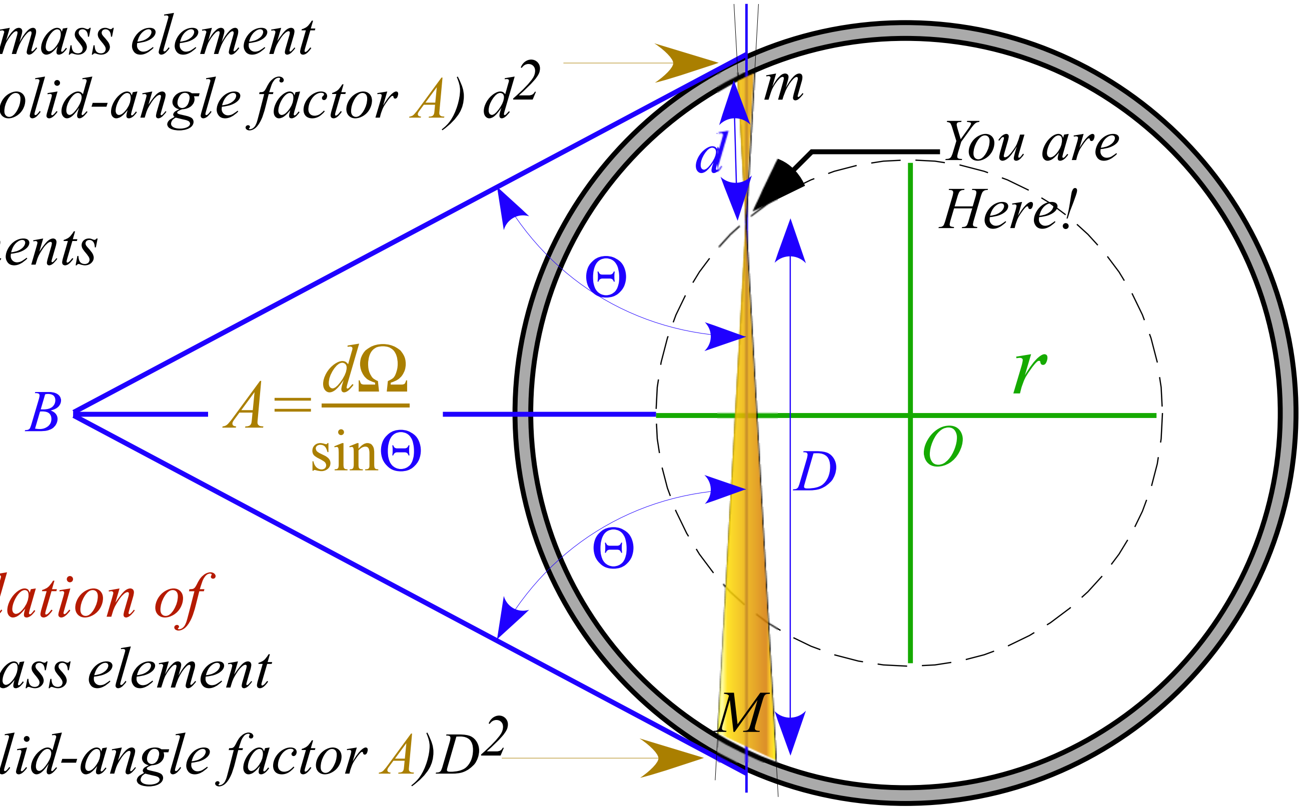
Shell mass element
m =(solid-angle factor A) d^2

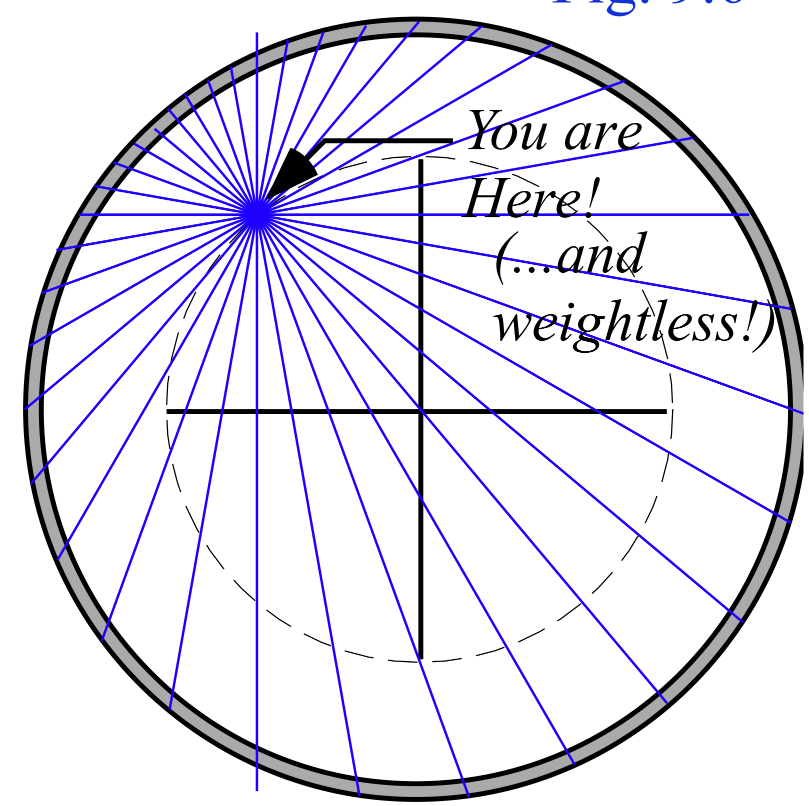
Gravity at r
due to shell mass elements

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

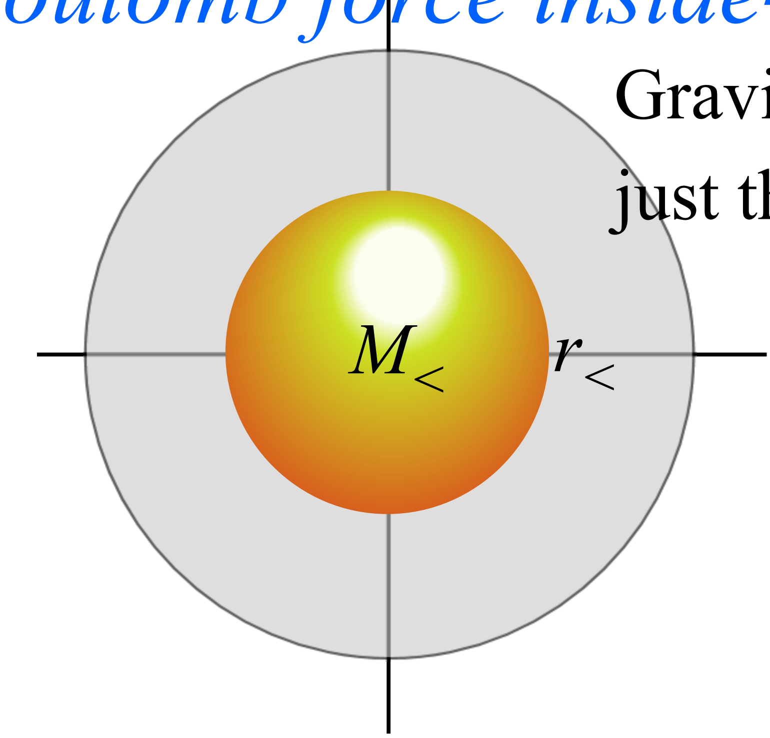
$$\left(\frac{D^2}{D^2} - \frac{d^2}{d^2}\right)A = 0$$

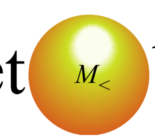
Cancellation of
Shell mass element
M =(solid-angle factor A)D^2





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



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

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

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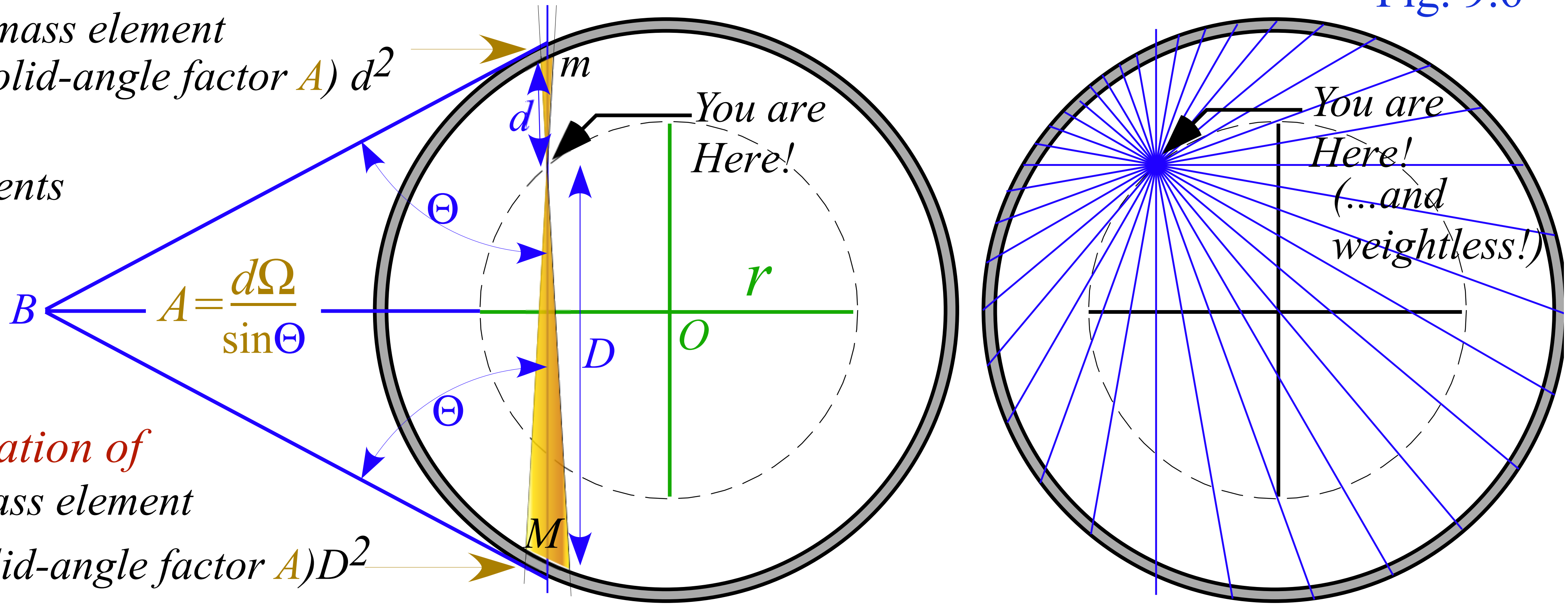

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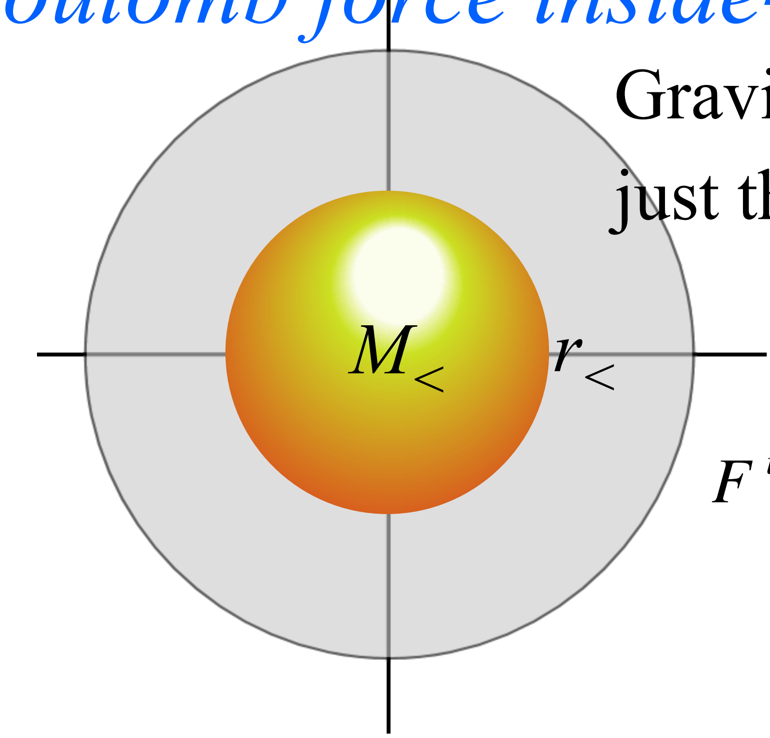

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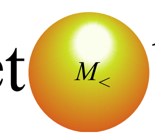
just that of planet  below $r_<$

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)

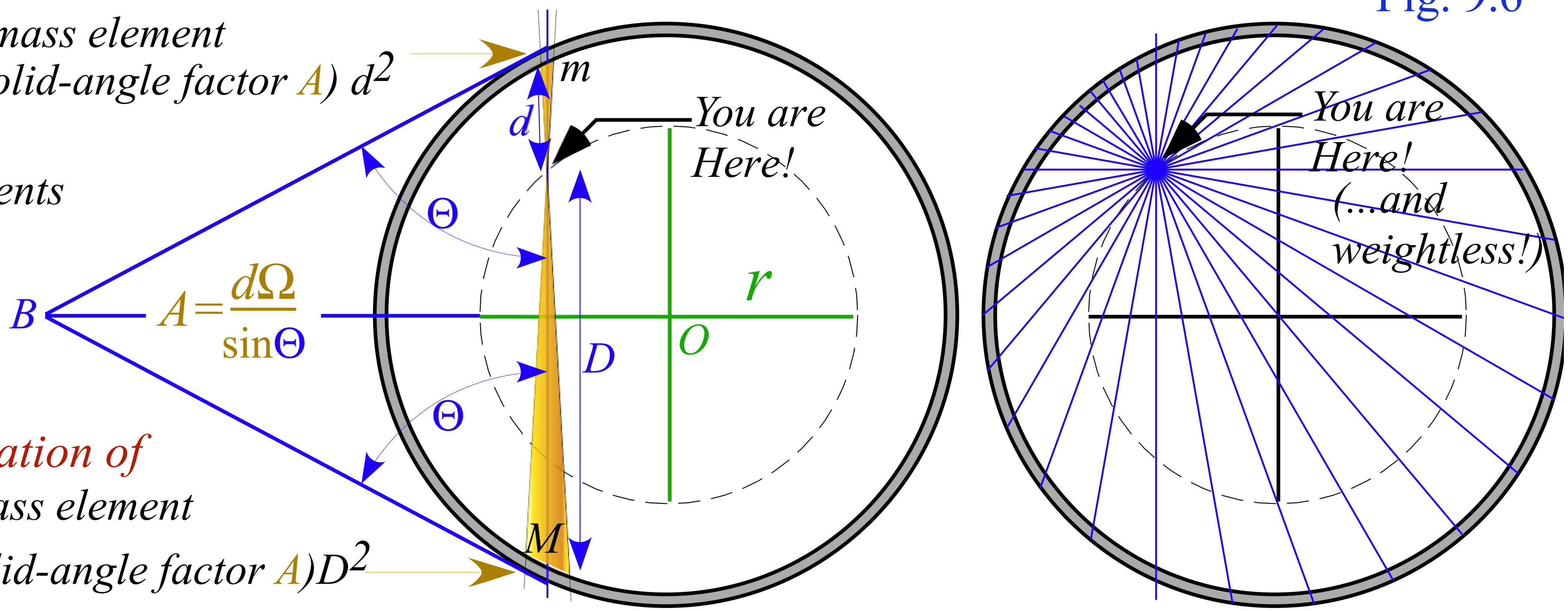
Unit 1
Fig. 9.6

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
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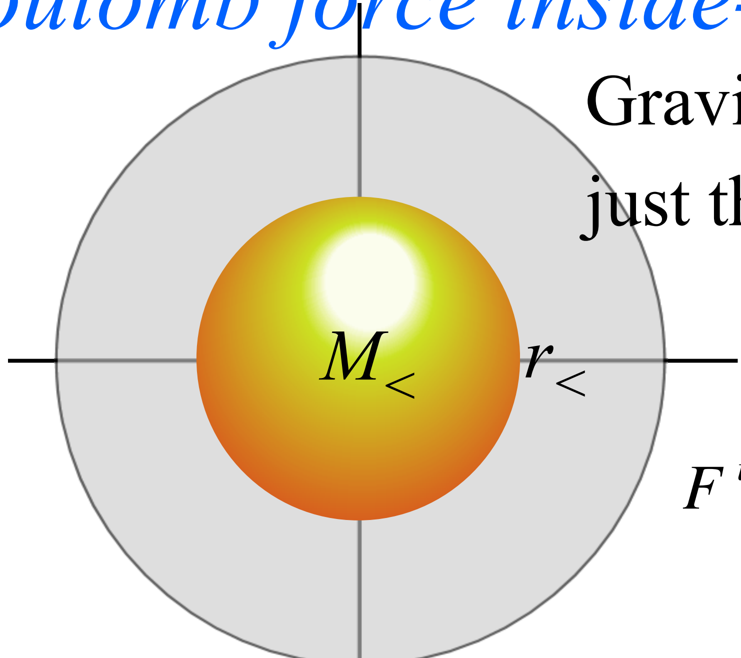

Gravitational force at $r_<$ is
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Earth surface gravity acceleration: $g = G\frac{M_\oplus}{R_\oplus^2} = G\frac{M_\oplus}{R_\oplus^3}R_\oplus = G\frac{4\pi}{3}\frac{M_\oplus}{\frac{4\pi}{3}R_\oplus^3}R_\oplus = G\frac{4\pi}{3}\rho_\oplus R_\oplus =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

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

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

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

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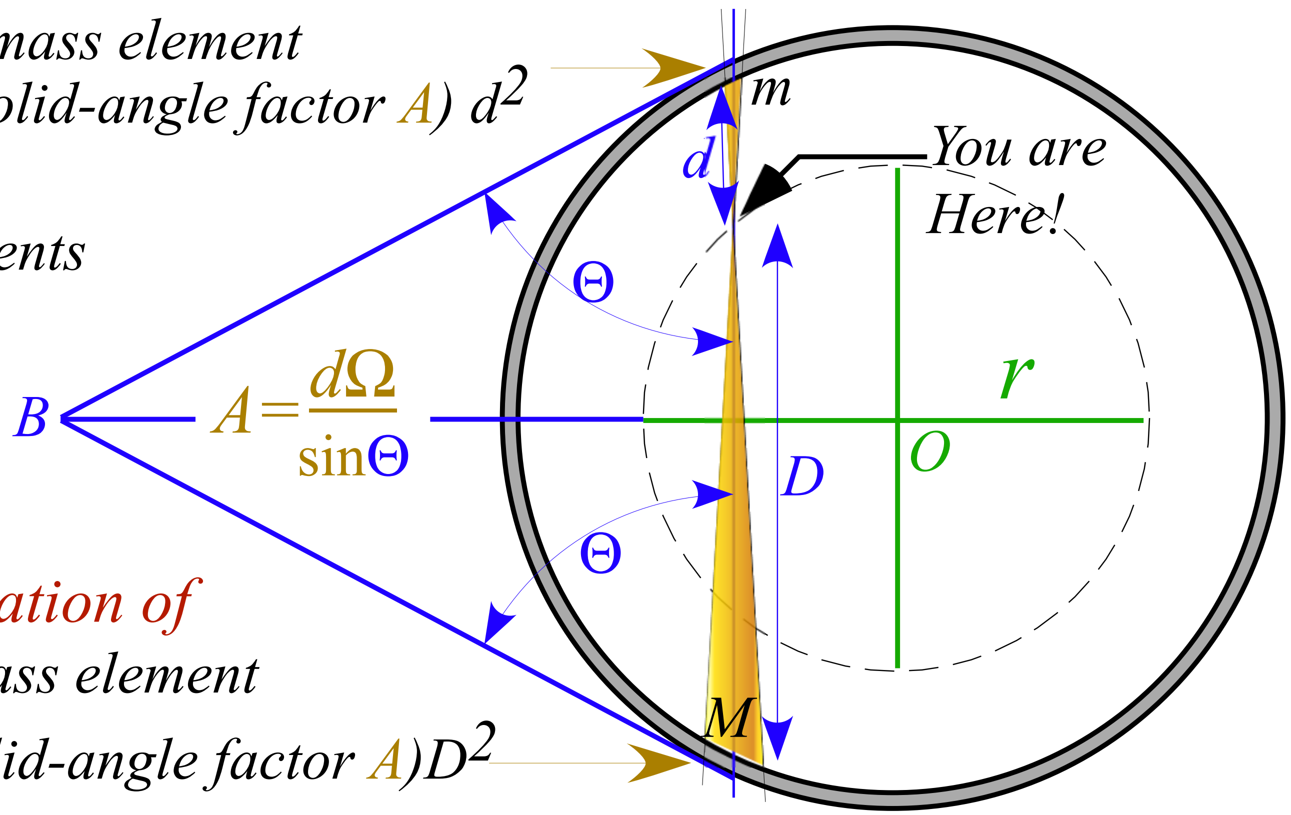

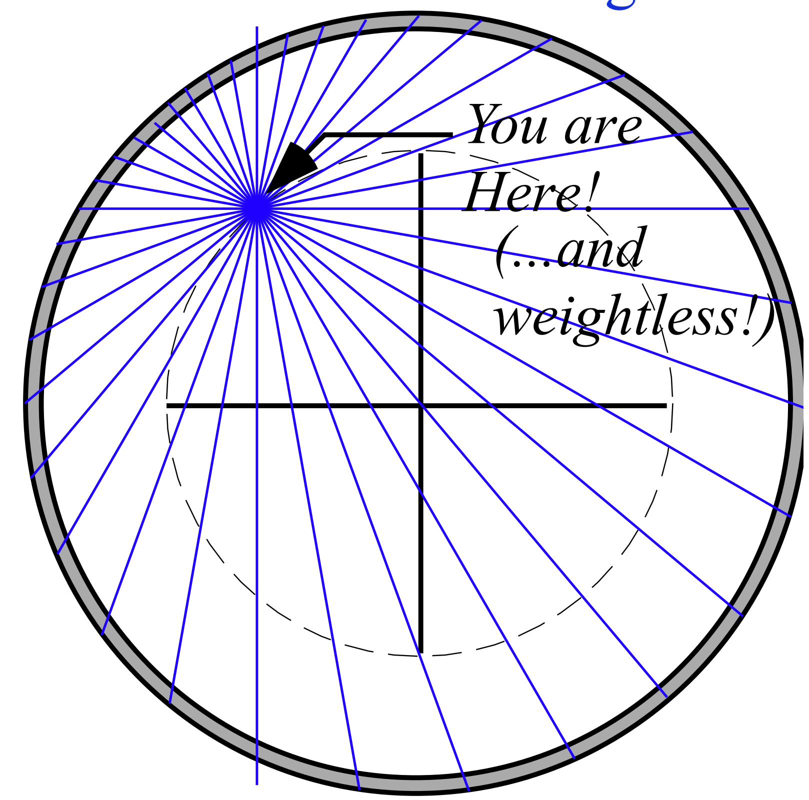

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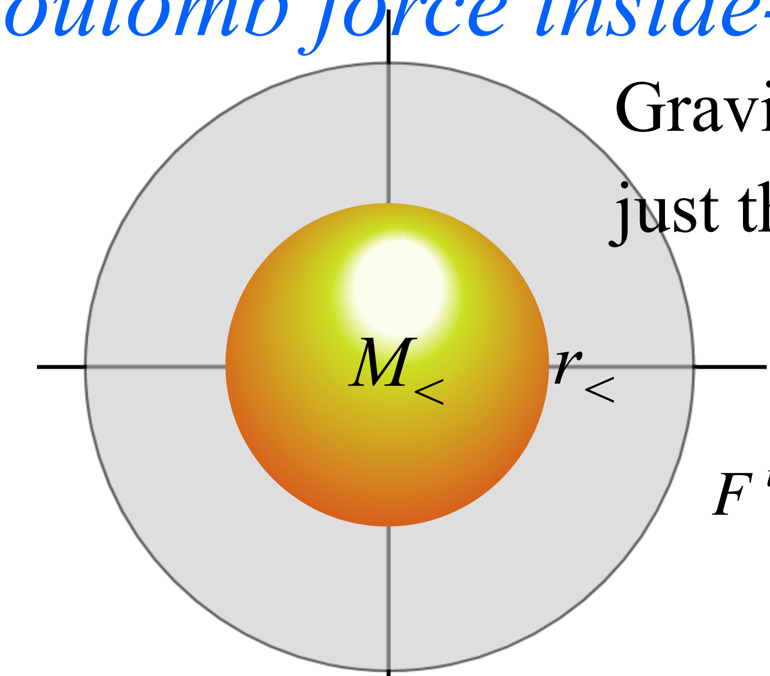

Gravitational force at $r_<$ is
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$G=6.67384(80)\cdot10^{-11}Nm^2/C^2 \sim (2/3)10^{-10}$

Earth radius : $R_\oplus = 6.371\cdot10^6\,m \simeq 6.4\cdot10^6\,m$

Earth mass : $M_\oplus = 5.9722 \times 10^{24}\,kg. \simeq 6.0\cdot10^{24}\,kg.$

Solar radius : $R_\odot = 6.955 \times 10^8\,m. \simeq 7.0\cdot10^8\,m.$

Solar mass : $M_\odot = 1.9889 \times 10^{30}\,kg. \simeq 2.0\cdot10^{30}\,kg.$

Geometry of idealized "Sophomore-physics Earth"

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

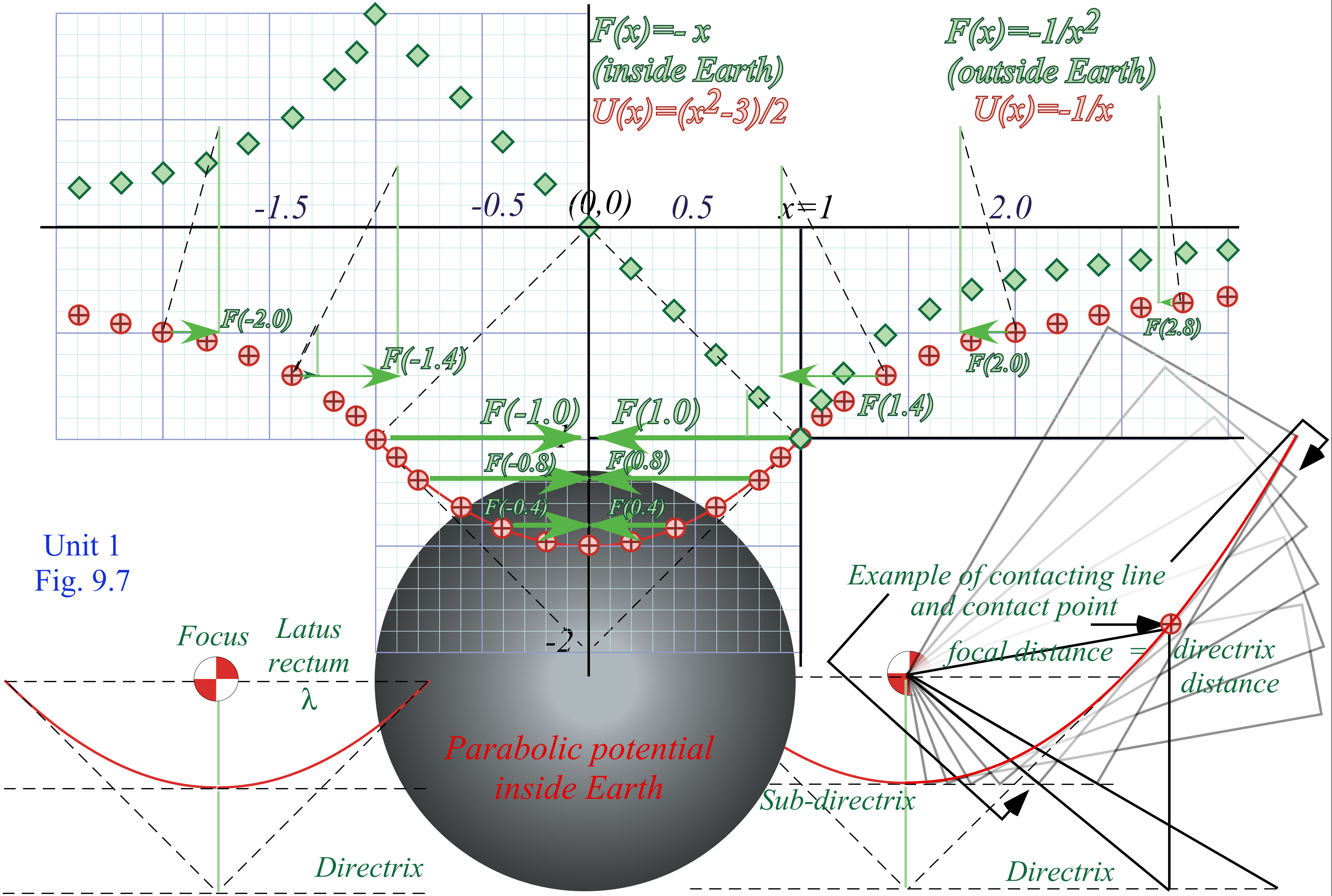
→ *Contact-geometry of potential curve(s)*

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

Earth matter vs nuclear matter:

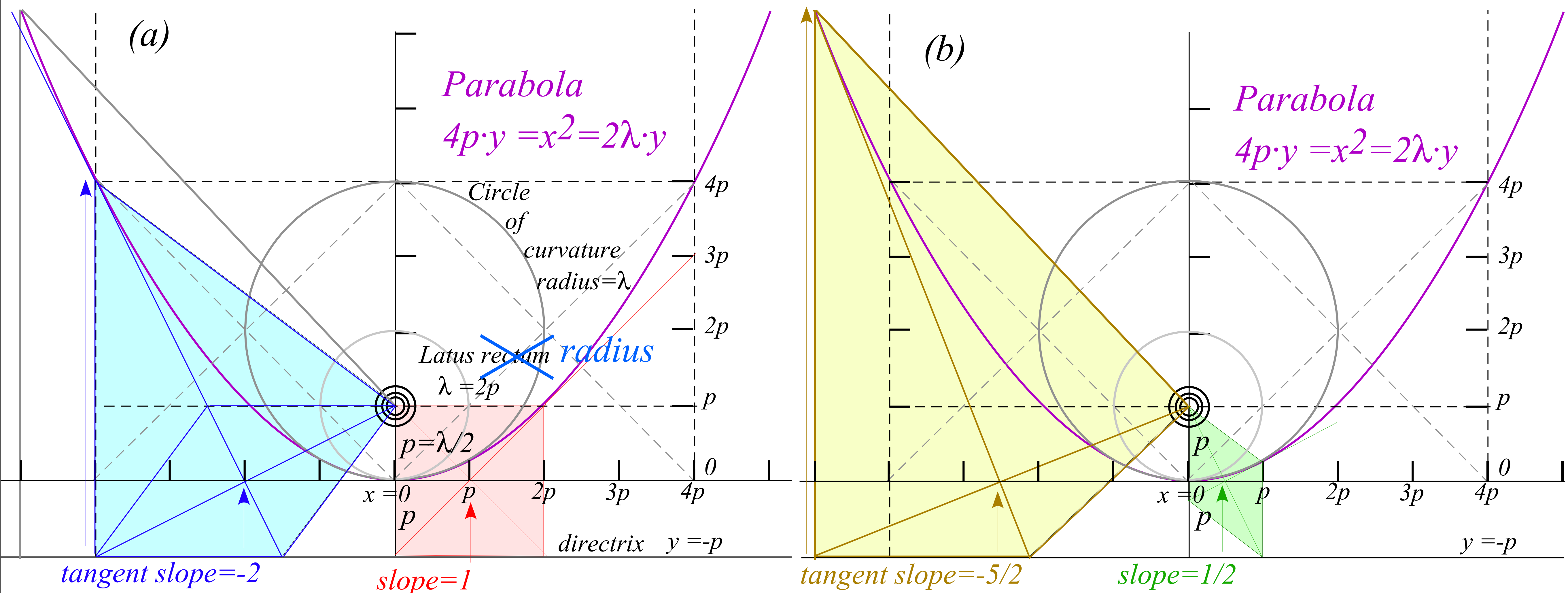
*Introducing the "neutron starlet" and "***Black-Hole-Earth***"*

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



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

(Review of Lect. 6 p.29)



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)

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The "Three (equal) steps from Hell"