Kinematics Unit Outline

I. Six Definitions:
Distance, Position, Displacement, Speed, Velocity, Acceleration

II. Graphical Interpretations

III. Constant acceleration model

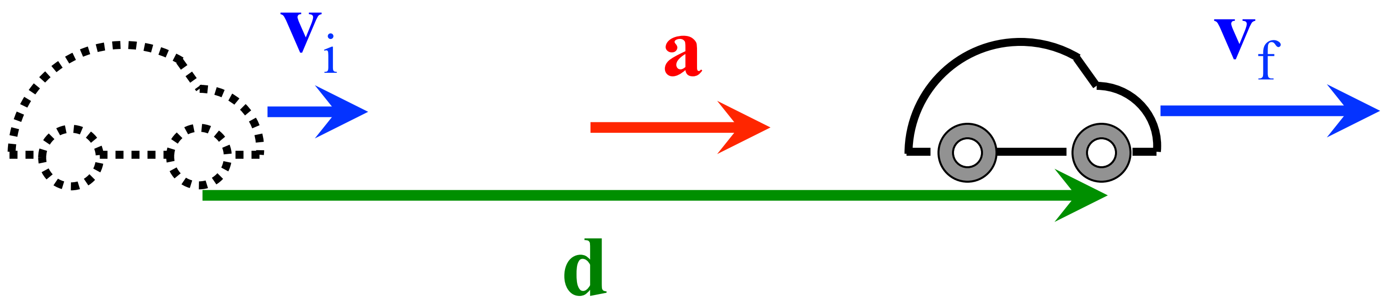
IV. Freefall

	The student will be able to:	HW:
1	Define, distinguish, and apply the concepts: distance, displacement, position.	✓ 1, 2
2	Define, distinguish, and apply the concepts: average speed, instantaneous speed, constant speed, average velocity, instantaneous velocity, constant velocity.	✓ 3 – 9
3	Define, distinguish, and apply the concepts: average acceleration and instantaneous acceleration, and constant acceleration.	✓ 10, 11
4	Analyze a graph of distance, position, or displacement as a function of time in order to determine speed and/or velocity.	✓ 12 – 14
5	Analyze a graph of speed or velocity as a function of time in order to determine distance, position, displacement, and/or acceleration.	✓ 15 – 19
6	State the displacement and velocity relations for cases of constant acceleration and use these to solve problems given appropriate initial conditions and values.	20 – 34
7	State and use the conditions of freefall, including the value of g, to solve associated problems.	35 – 42
8	Measure and analyze data for a moving object and produce appropriate graphs including line or curve of best fit.	lab
9	Evaluate error, deviation, accuracy, and precision in experimental results.	lab

A Kinematics Model

- The six kinematics concepts (position, displacement, distance, speed, velocity, and acceleration) are interrelated.
- Two fairly simple formulas that relate some of these variables can be used to solve a huge variety of problems.
- The two formulas can be thought of as a simple and yet comprehensive *model* of moving objects.

Consider an object with initial velocity, **v_i**, and acceleration, **a**.



After a given amount of time, *t*, the object will have a final velocity, **v_f**, and undergo displacement, **d**. It can be shown that:

$$\vec{v}_f = \vec{v}_i + \vec{a}t \qquad \vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

A "Standard" Model of Motion

velocity: $\vec{v}_f = \vec{v}_i + \vec{a}t$

displacement: $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

Important!

- Acceleration must be **constant** for these equations to be true.
- Vector directions must be accounted for using +/- signs.

Constant Acceleration Formulae

velocity: $$\vec{v} = \vec{v}_0 + \vec{a}t$$

displacement: $$\Delta \vec{x} = \vec{v}_0 t + \tfrac{1}{2}\vec{a}t^2$$

position: $$\vec{x} = \vec{x}_0 + \vec{v}_0 t + \tfrac{1}{2}\vec{a}t^2$$

Constant Acceleration Formulae

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

$$v^2 = v_0^2 + 2ad$$

$$\Delta\vec{x} = \vec{v}_0 t + \tfrac{1}{2}\vec{a}t^2$$

$$\Delta\vec{x} = \tfrac{1}{2}\left(\vec{v}_0 + \vec{v}\right)t$$

It is possible to derive many other equations from the two most fundamental formulas. These additional equations are not essential but can be useful for certain types of problems – subject to the same condition of constant acceleration!

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7	State and use the conditions of freefall, including the value of *g*, to solve associated problems.	35 – 42
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Fascinating Freefall Facts

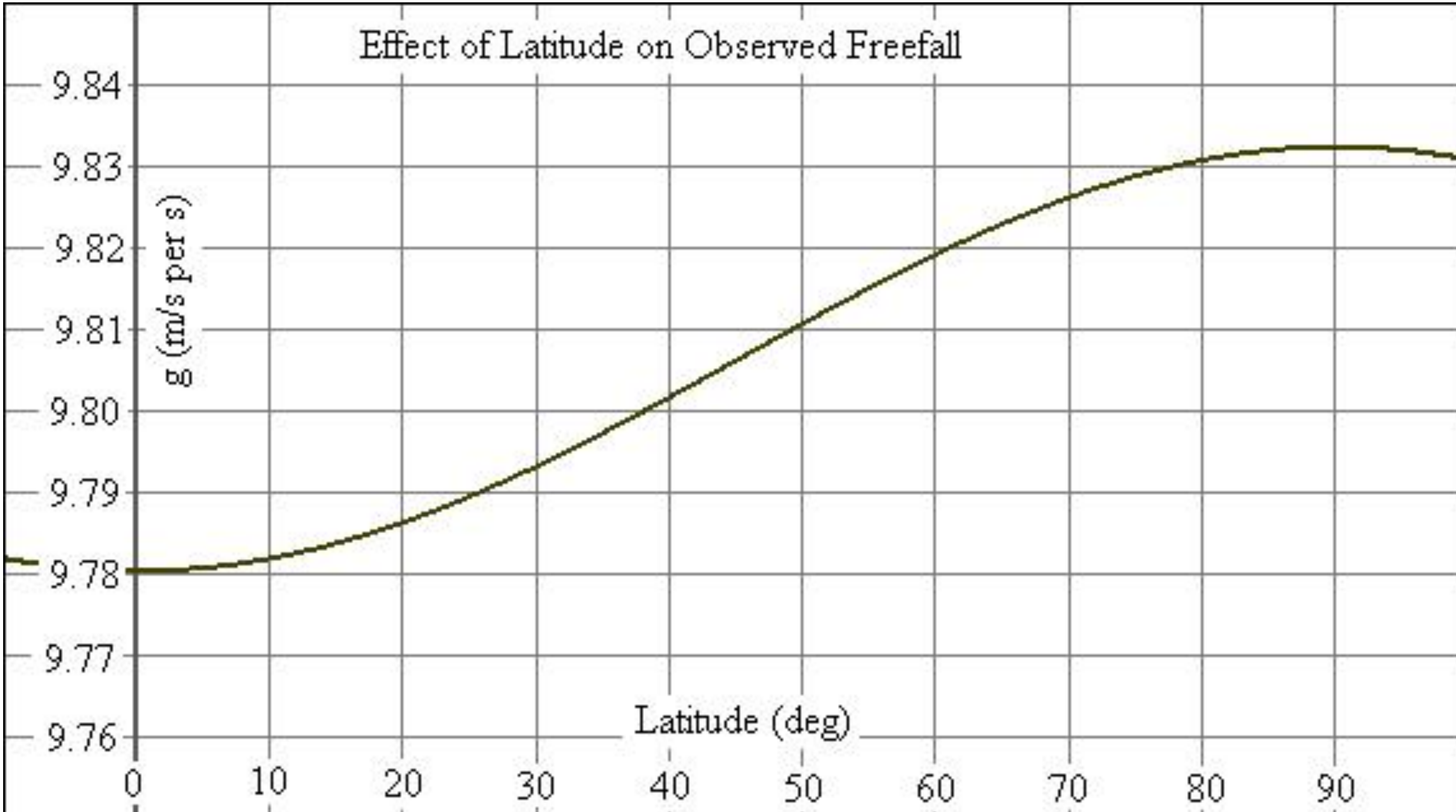
- Any and all objects under the sole influence of gravity have the same acceleration regardless of size or mass.
- The acceleration of gravity is denoted *g*.
Its mean value near the earth's surface:

$$\mathbf{g} = 9.80 \text{ m/s}^2 \text{ downward}$$

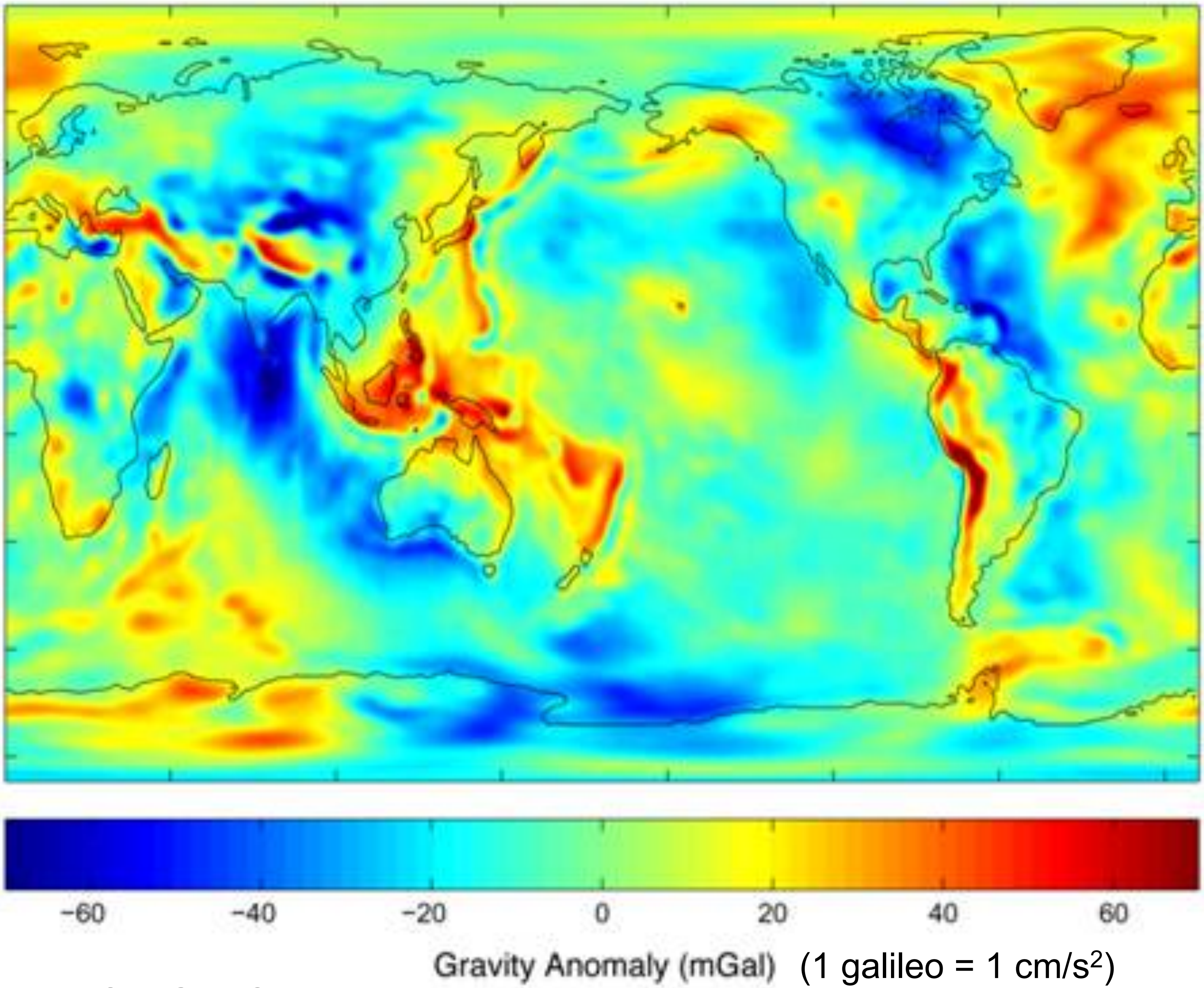
- This value is quite accurate for any object in freefall when forces other than gravity are relatively small.

Values of g (in m/s^2)

Mexico City	9.779	Madrid	9.800
Jakarta	9.781	San Francisco	9.800
Manila	9.784	Washington DC	9.801
Rio de Janeiro	9.788	New York	9.802
Miami	9.7902096	Chicago	9.803
Los Angeles	9.796	Rome	9.803
Denver	9.7961848	Seattle	9.8072544
Knoxville, TYS	9.7968816	Paris	9.809
Knoxville, UT	9.7969745	Vancouver BC	9.809
Buenos Aires	9.797	London	9.812
Sydney	9.797	Amsterdam	9.813
Tokyo	9.798	Oslo	9.819



$$g = 9.780327\left(1 + 0.0053024\sin^2\theta - 0.0000058\sin^2 2\theta\right)$$



(1 galileo = 1 cm/s^2)

Source: NASA, GRACE 2003

The Effect of Air Resistance

Air can have a significant effect on a freefalling object depending on:

- **Size** – the greater the "cross section", the greater the air resistance
- **Shape** – the less streamlined, the greater the air resistance
- **Speed** – the greater the speed through the air, the greater the air resistance