Newton's 2nd Law

Lecture 18

ME 231: Dynamics

Question of the Day

Which defensive player generates the largest tackling force?

DB 5’-11” 203 lb (92 kg)
4.35 s 40-yd dash
a = 33.63 m/s^2

LB 5’-10” 224 lb (101 kg)
4.94 s 40-yd dash
a = 29.60 m/s^2

Outline for Today

- Question of the day
- Kinetics: cause of motion
- Possible solutions to kinetics problems
- Force:acceleration ratio experiment
- Newton's 2nd Law for a particle
- Force and mass units
- Newton's 2nd Law for a system of particles
- Answer your questions!

Where are we in the course?

Concept: What is dynamics?

Chapters 1, 2, 6

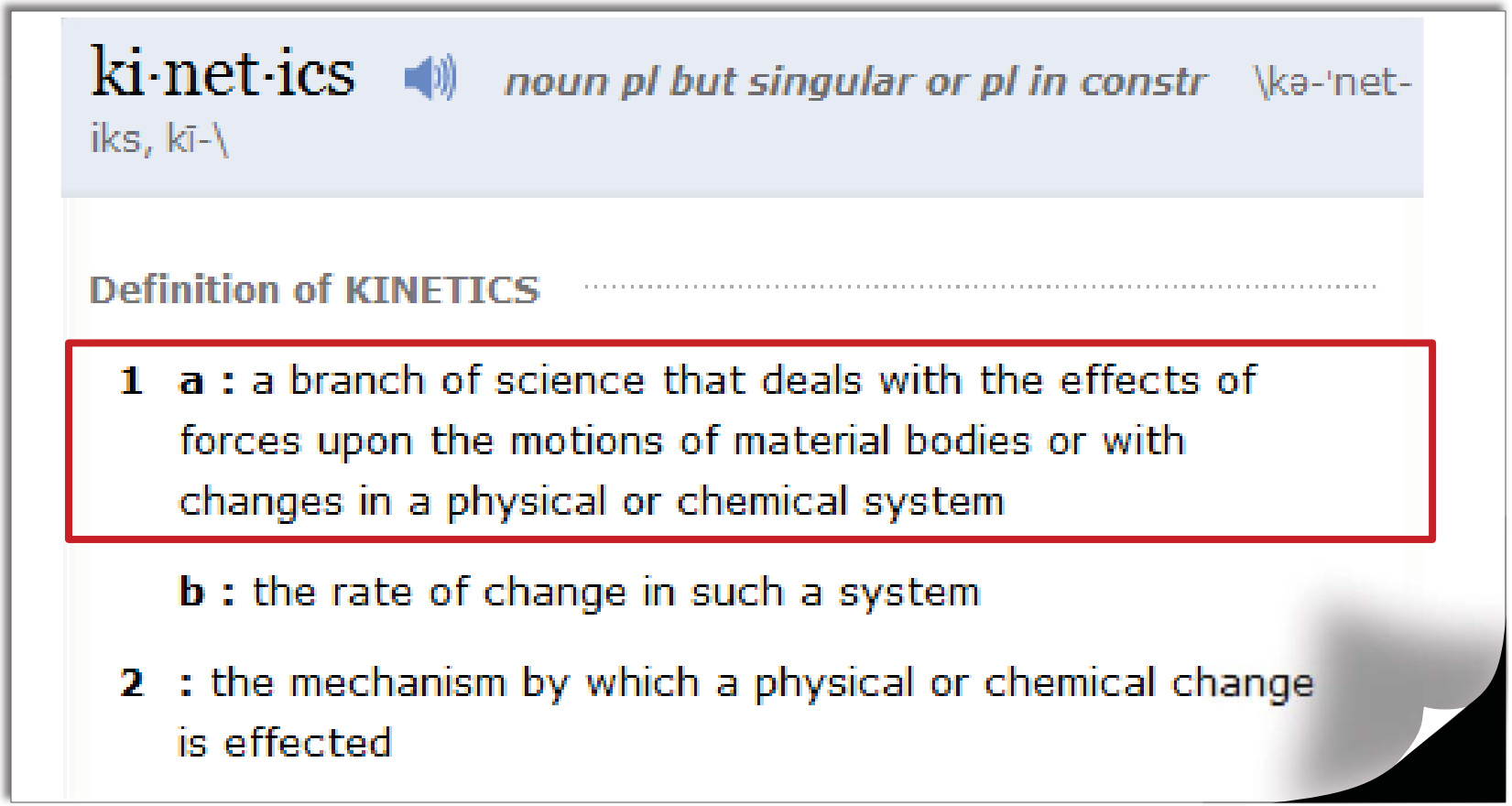
Chapters 3, 5, 7, 8

Relationship among ***position***, ***velocity***, and ***acceleration***

Relationship among ***forces (and moments)***and ***acceleration***

Kinetics: Cause of Motion

Concept: What is kinetics?



ki·net·ics *noun pl but singular or pl in constr* \kə-'net-iks, kī-\

Definition of KINETICS

1 **a :** a branch of science that deals with the effects of forces upon the motions of material bodies or with changes in a physical or chemical system

b : the rate of change in such a system

2 **:** the mechanism by which a physical or chemical change is effected

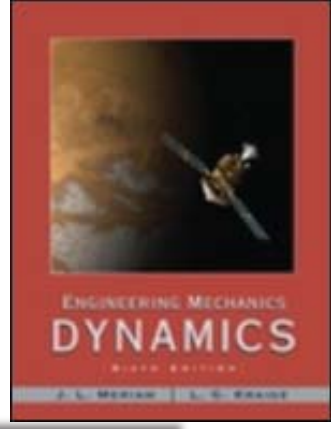
Kinetics: Cause of Motion

Concept: What is kinetics?

In physics and engineering, **kinetics** is a term for the branch of classical mechanics that is concerned with the relationship between the motion of bodies and its causes, namely forces and torques.

Kinetics: Cause of Motion

Concept: What is kinetics?



Kinetics: The study of the relations between ***unbalanced forces (and moments)*** and the resulting ***changes in motion***.

Kinetics: Cause of Motion?

Concept: What is kinetics?

ME 202

Relationship among ***forces (and moments)*** and ***equilibrium***

Chapters 1, 2, 6

Relationship among ***position***, ***velocity***, and ***acceleration***

Chapters 3, 4, 5, 7, 8

Relationship among ***forces (and moments)***and ***acceleration***

Possible Solutions to Kinetics Problems

- Direct application of ***Newton's 2nd Law***
  - force-mass-acceleration method
  - *Chapters 3 and 7*
- Use of ***impulse*** and ***momentum*** methods
  - *Chapters 5 and 8*
- Use of ***work*** and ***energy*** principles
  - *Chapter 4*

Force:Acceleration Ratio Experiment

- ***Force:acceleration*** ratio is ***constant***
- This ***constant*** is a ***measure of inertia*** of the particle (*resistance to rate of change in velocity*)
- ***Acceleration*** in the direction of ***force***

$$C = \frac{\mathbf{F}_1}{\mathbf{a}_1} = \frac{\mathbf{F}_2}{\mathbf{a}_2} = \frac{\mathbf{F}_3}{\mathbf{a}_3} = km$$

Newton's 2nd Law for a Particle

$$\mathbf{F} = m\mathbf{a}$$

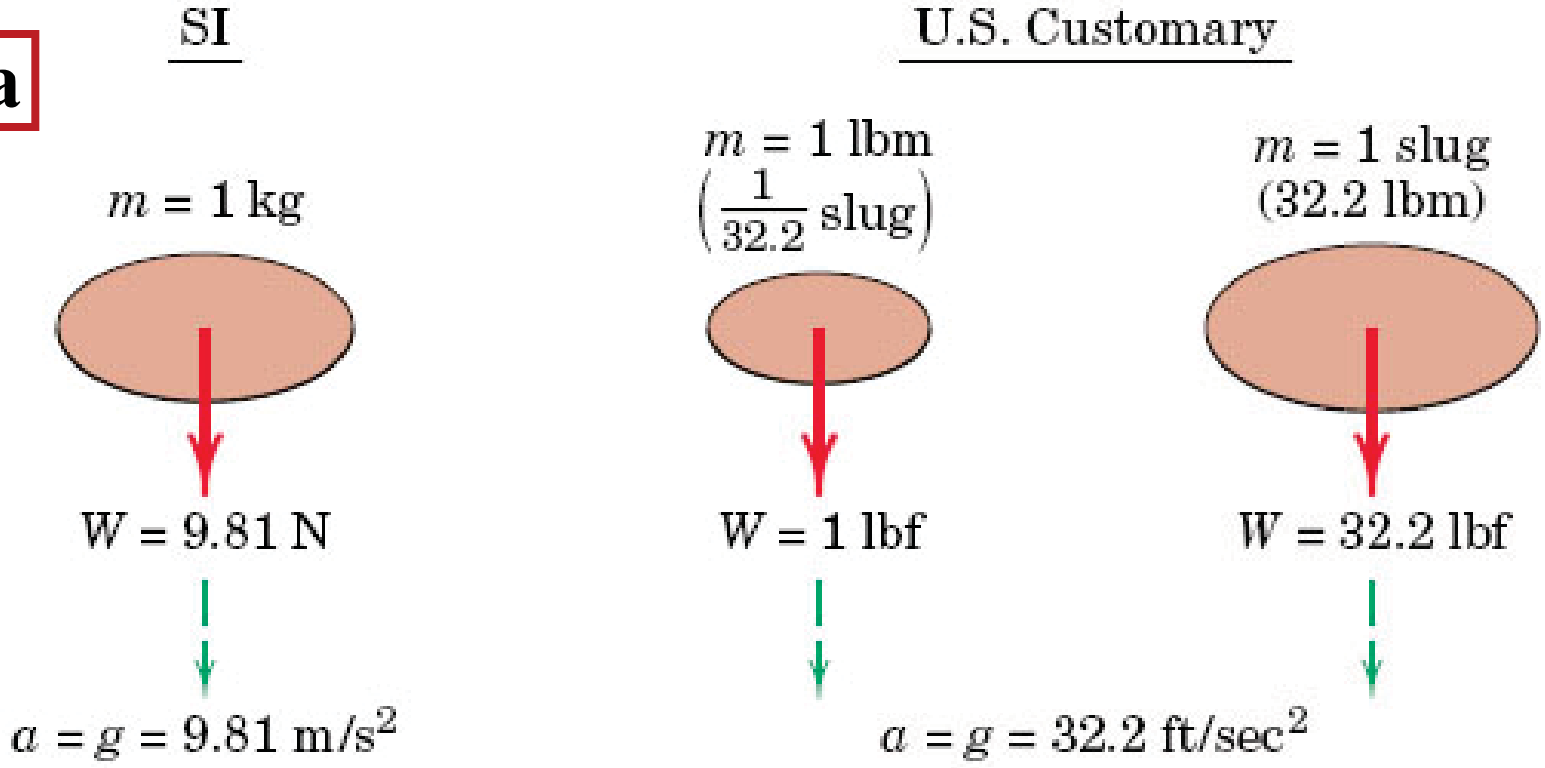
- Customary to take $k = 1$
- Assumes a ***kinetic system*** of units where ***force***, ***mass***, and ***acceleration*** units are ***not independent***

SI	U.S. Customary
N, kg, and m/s^2	lbf, slug, and ft/s^2

- ***Absolute*** kinetic system: ***force*** is dependent on the ***absolute*** value of ***mass*** (N = kg·m/s^2)
- ***Gravitational*** kinetic system: ***mass*** is derived from ***force*** as determined from ***gravitational*** attraction (slug = lbf·s^2/ft)

Force and Mass Units: Free-Fall Experiment

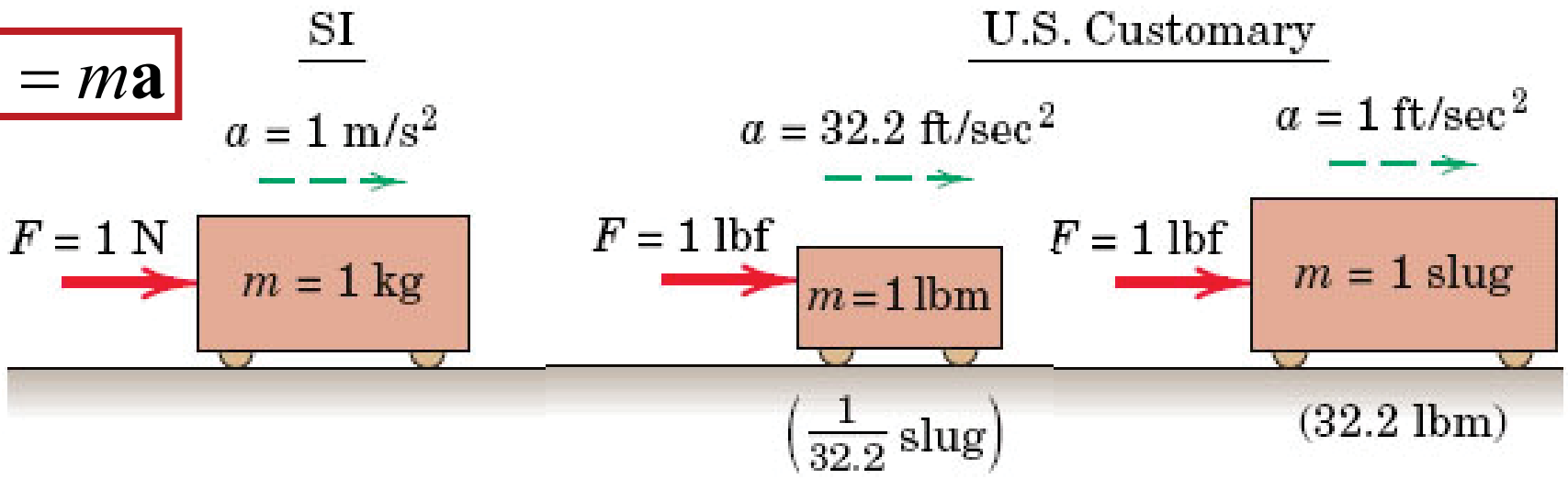
$\mathbf{F} = m\mathbf{a}$



- ***Force*** of gravitational attraction (W) is ***weight***
- ***SI***: Mass m = 1 ***kg***, weight W = 9.81 ***N***, and acceleration a = 9.81 ***m/s²***
- ***U.S. Customary***: Mass m = 1 ***slug*** (or 1 ***lbm***), weight W = 32.2 ***lbf*** (or 1 ***lbf***), and acceleration a = 32.2 ***ft/s²***

Force and Mass Units: Newton's 2nd Law

$$\mathbf{F} = m\mathbf{a}$$



- Simple example: ***accelerate*** an object of ***mass*** m along the horizontal with a ***force*** F

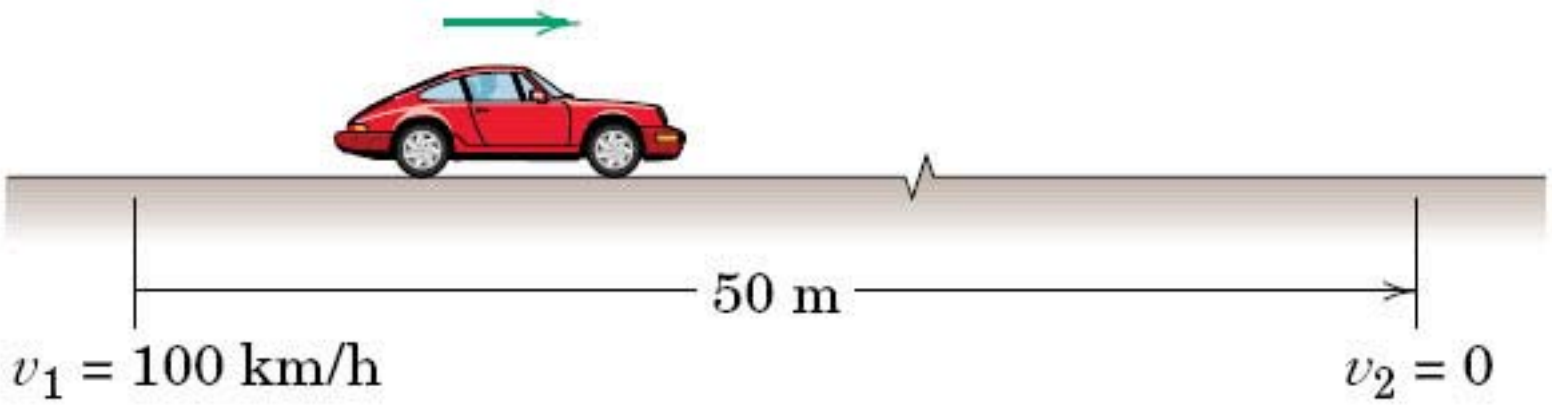
- SI: ***Mass*** in kg, ***force*** in N ($kg \cdot m/s^2$), and ***acceleration*** in m/s^2
- U.S. Customary: ***Mass*** in slug ($lbf \cdot s^2/ft$) or lbm, ***force*** in lbf, and ***acceleration*** in ft/s^2

Newton's 2nd Law: Exercise

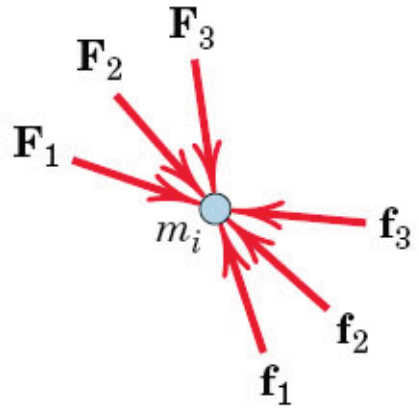
$$\mathbf{F} = m\mathbf{a}$$

During a brake test, a ***1500 kg*** car with a speed of 100 km/h is stopped with a constant ***deceleration*** in a distance of 50 m.

Determine the braking ***force*** F.

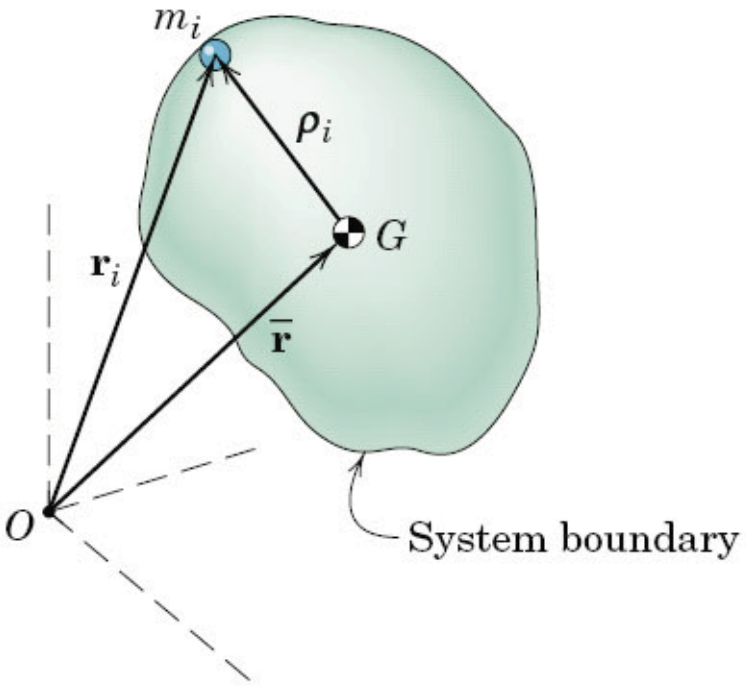


Newton's 2nd Law of a System of Particles



$$\mathbf{F}_1+\mathbf{F}_2+\mathbf{F}_3+\cdots+\mathbf{f}_1+\mathbf{f}_2+\mathbf{f}_3+\cdots=m_i\ddot{\mathbf{r}}_i$$

$$\sum\mathbf{F}+\sum\mathbf{f}=\sum m_i\ddot{\mathbf{r}}_i$$



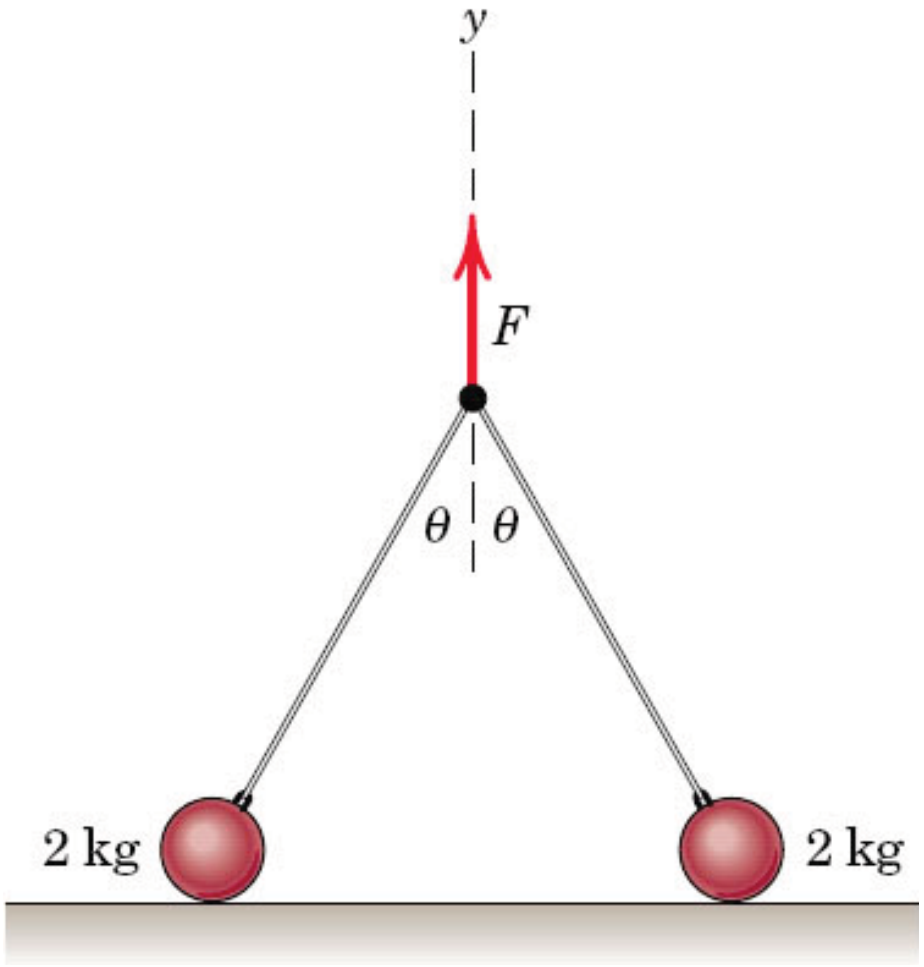
$$\boxed{\sum\mathbf{F}=m\ddot{\bar{\mathbf{r}}}} \quad \text{or} \quad \boxed{\sum\mathbf{F}=m\bar{\mathbf{a}}}$$

$$\sum F_x=m\bar{a}_x$$
$$\sum F_y=m\bar{a}_y$$
$$\sum F_z=m\bar{a}_z$$

Newton's 2nd Law: Exercise

Two ***2-kg*** balls are initially at rest when a vertical ***force*** $F = 60$ N is applied as shown.

Compute the vertical component a_y of the ***acceleration*** by considering the system as a whole.



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For Next Time…

- Begin Homework #7 due 10/17
- Read Chapter 3, Section 3.1