PHYS 1112: General Physics I with Calculus

Lecture session: L1 Tuesday/Thursday 10:30 am - 11:50 am

Mixed mode: RM 2464 / Zoom Meeting (subjected to change)

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Office hours: Tuesday/Thursday 12:00 pm - 12:50 pm
RM 4439 / Zoom

Lecture 1

Physical Quantities, Vectors and 2D Motion

Objectives

1. Understand fundamental physical quantities
   (Units and significant figures)

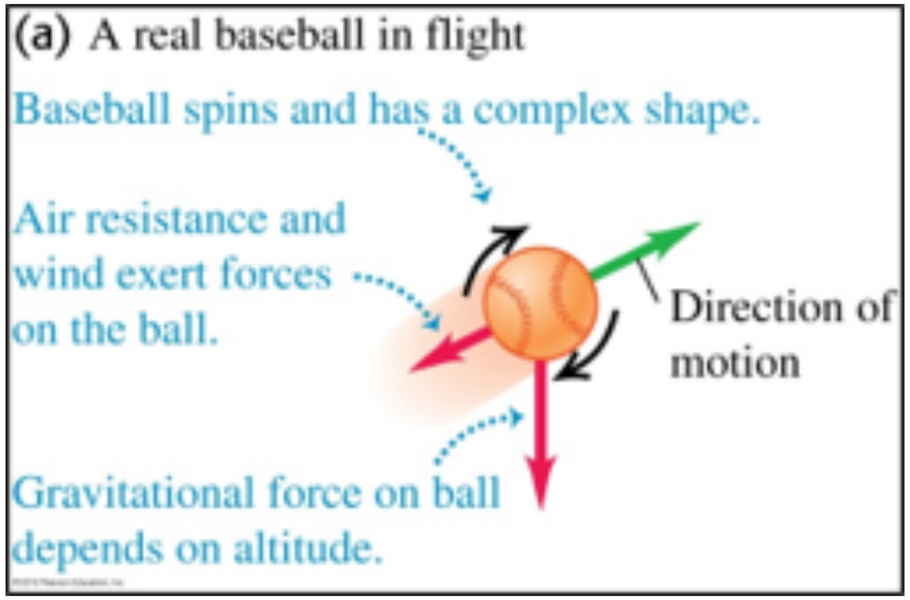
2. Basic vectors and its algebraic operations

3. Displacement, velocity and acceleration

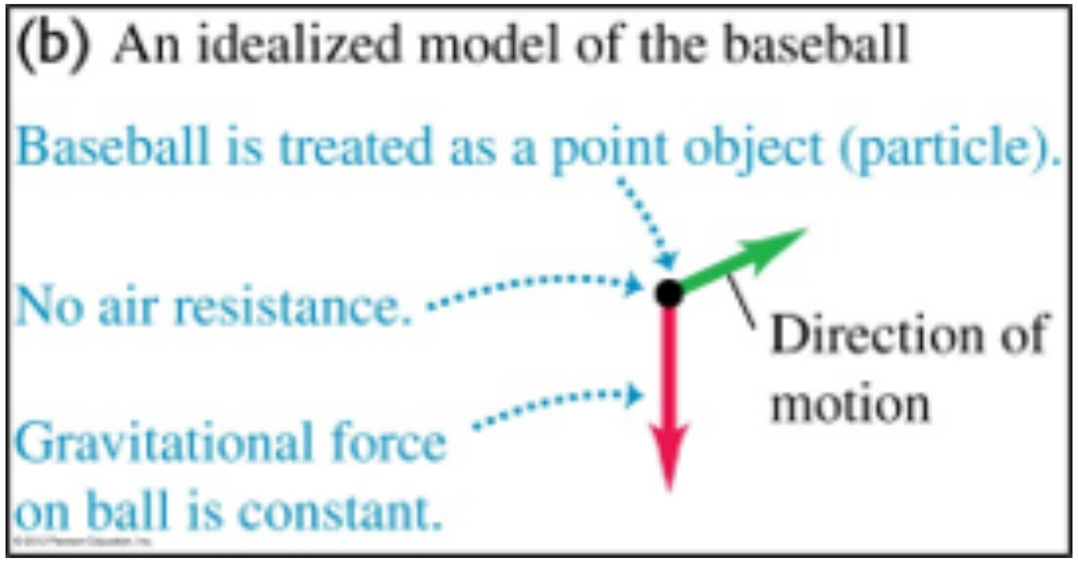
Physics is an experimental natural science

- Theory: an explanation of natural phenomena based on observation and accepted fundamental principles, e.g. theory of evolution in biology.
- Model: a simplified version of a physical system that would be too complicated to analyze in full detail.

Example of a physical model: *flying baseball*



Simplifying model



Standards and Units

In this course:

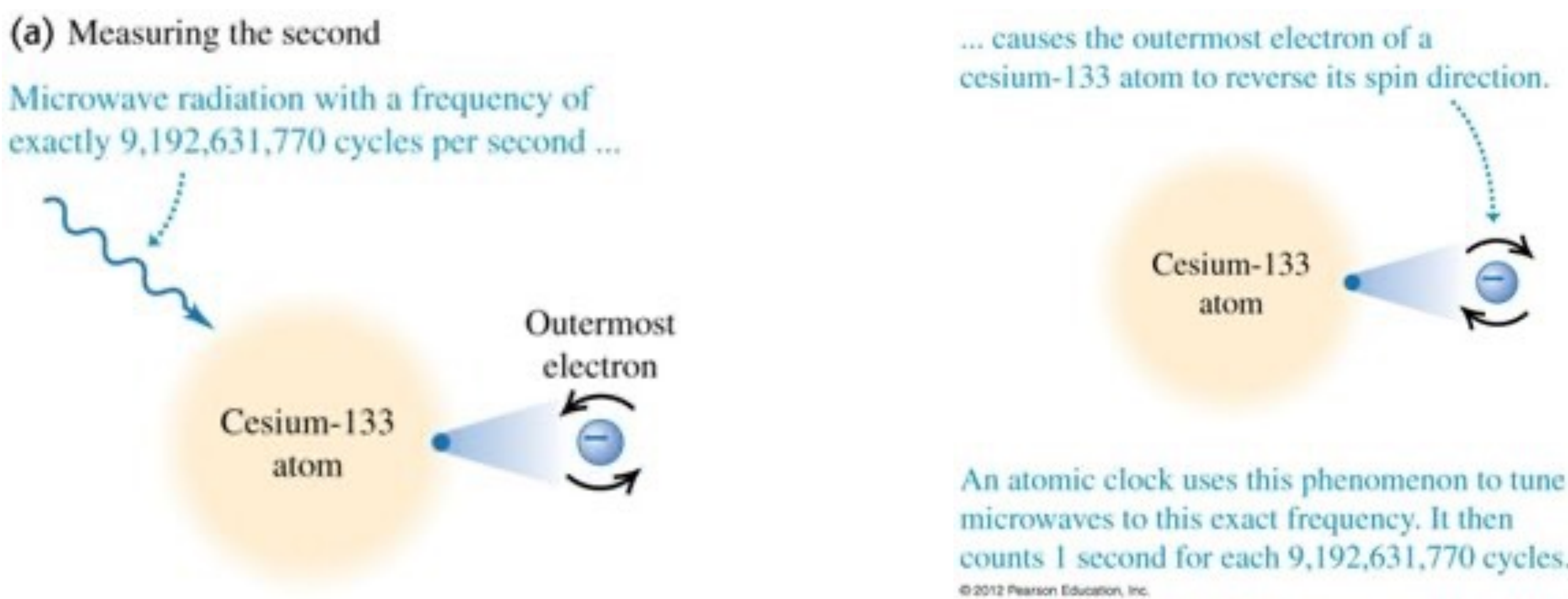
- The *International Standard*, or SI (Système International) Units
- TIME: in second (s, ms, …)
- LENGTH: in meter (m, cm, mm,…)
- MASS: in kilogram (kg, g, …)

Imperial metric (commonly used in the US)

Inches, feet, miles, gallons, pounds, …

Time (Second)

Starting 1967, defined using an atomic clock



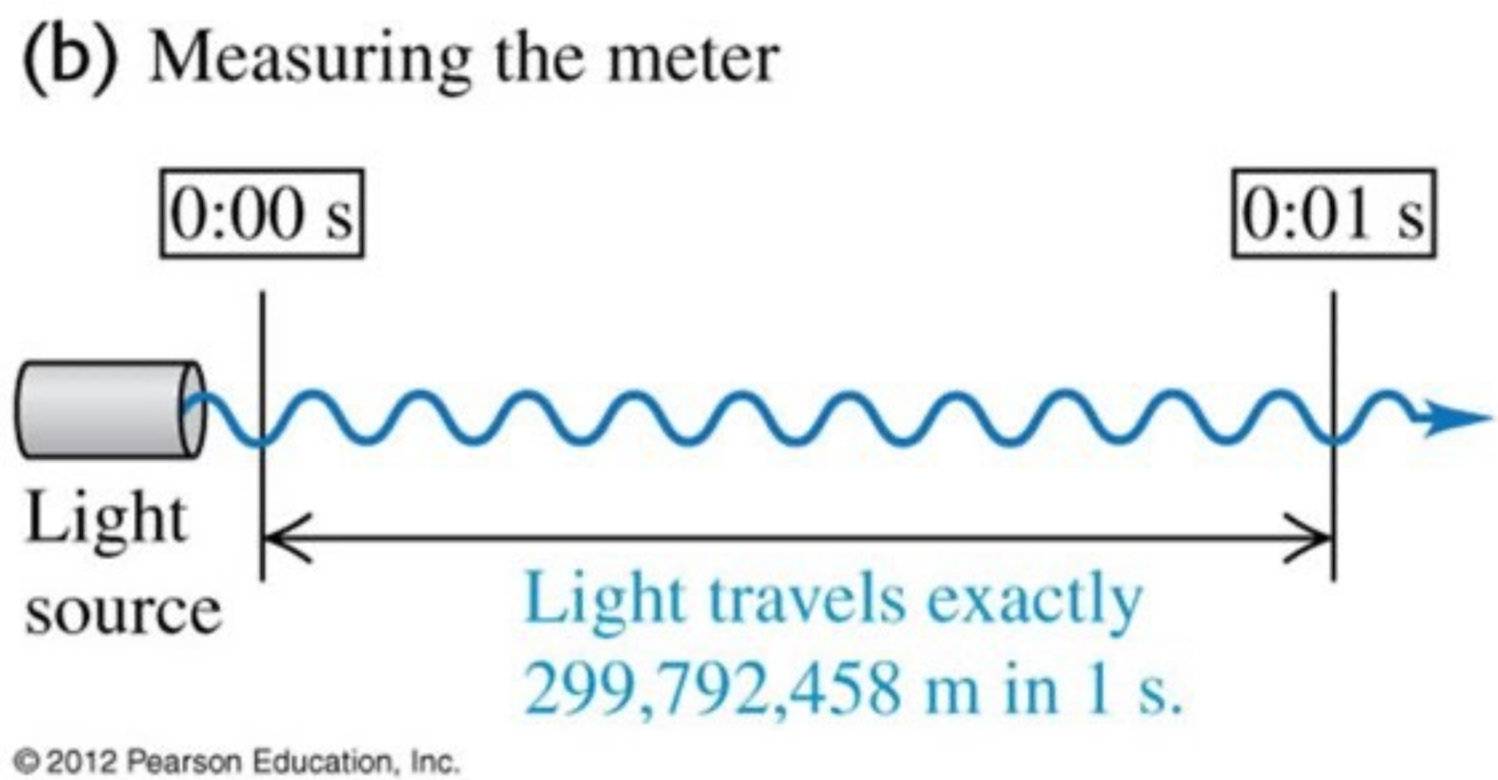
"One second is defined as "9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cesium 133 atom".

SI Brochure (2019)

Length (Meter)

Starting 1983, the meter is defined based on the speed of light

$$c = 299,792,458 \text{m/s}$$



Mass (Kilogram)

Previously defined on the mass of a metal cylinder kept at the International Bureau of Weight and Measures in France

Since 2018, kilogram is defined based on the *Planck's constant*

$$h = 6.62607015 \times 10^{-34} kg \cdot m^2/s$$

Uncertainty and Significant Figures

What is the difference among the following representations of π ?

1. 3.14 means between 3.135 and 3.145, or 3.14 ± 0.005
2. 3.1416 means 3.1416 ± 0.00005
3. 22/7 rational number usually means exact, misleading here, not exact!

Question: what is the difference between 3 and 3.00 ?

(Be careful about the number of significant figures)

What are the problems with the following representation?

$$2.01\underbrace{7676}\pm 0.0\underbrace{132}$$

smaller than error,
meaningless!

Error estimation cannot be so accurate!
Usually take 1, at most 2 sig. fig.

Note: Uncertainty Propagation in Calculations

Multiplication or division:
Result may have no more significant figures than the starting number with the fewest significant figures:

$$\frac{0.745 \times 2.2}{3.885} = 0.42$$

$$1.32578 \times 10^{7} \times 4.11 \times 10^{-3} = 5.45 \times 10^{4}$$

Addition or subtraction:
Number of significant figures is determined by the starting number with the largest uncertainty (i.e., fewest digits to the right of the decimal point):

$$27.153 + 138.2 - 11.74 = 153.6$$

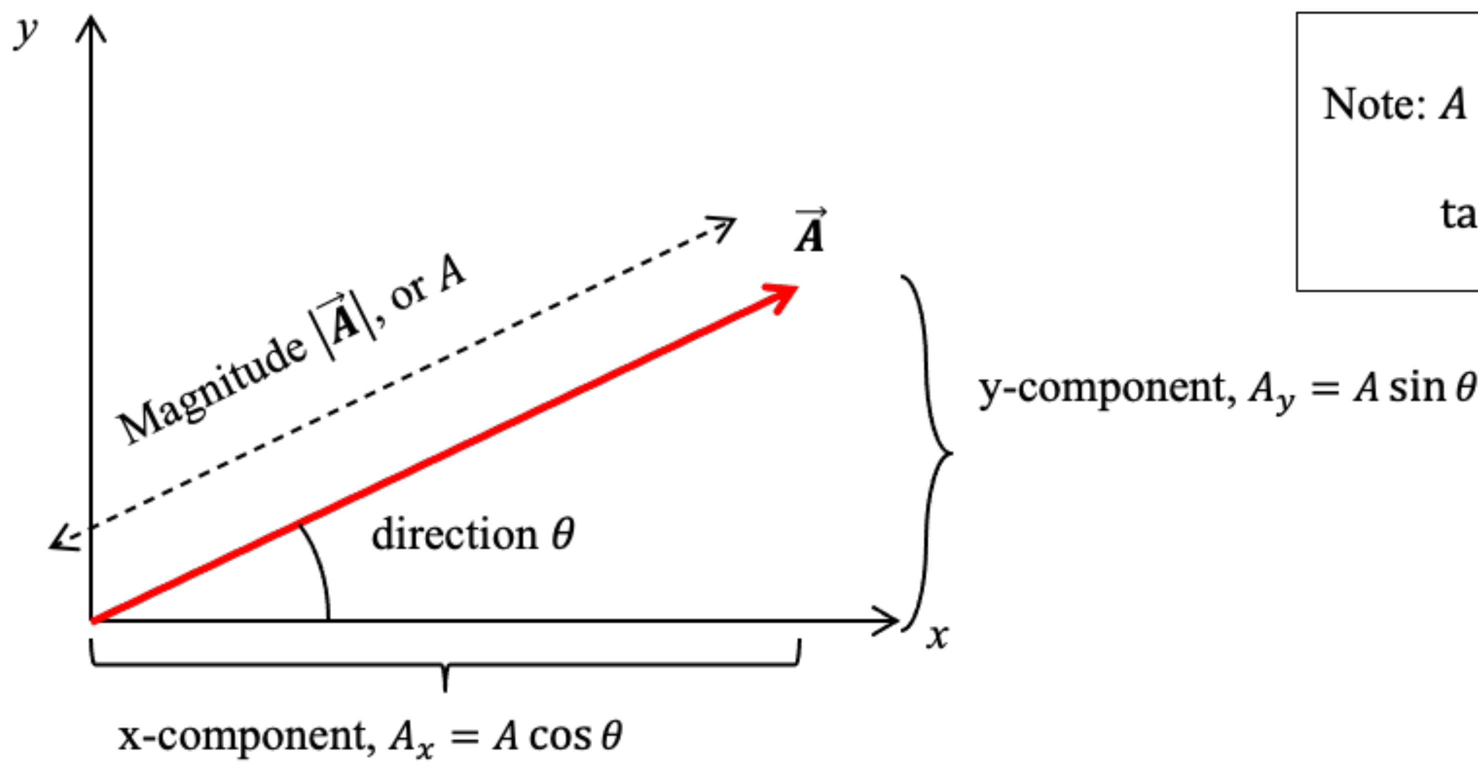
Question: What is the density (in kg/m^3) of a rock of mass 1.80 kg and volume $6.0 \times 10^{-4}\ m^3$?

(a) $3 \times 10^3\ kg/m^3$, (b) $3.0 \times 10^3\ kg/m^3$, (c) $3.00 \times 10^3\ kg/m^3$, (d) $3.000 \times 10^3\ kg/m^3$

Vector

Vector

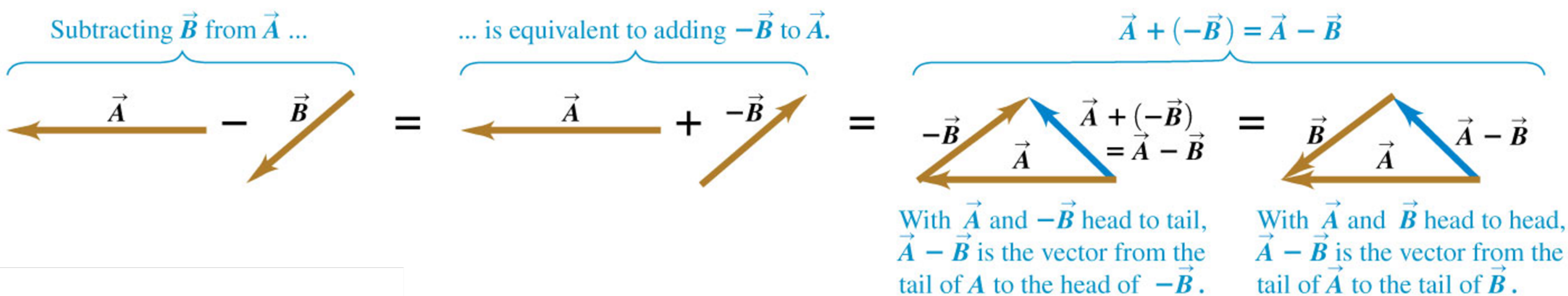
An "arrow" in space, has magnitude (length) and direction
e.g. in 2D Cartesian coordinates



Note: $A = \sqrt{A_x^2 + A_y^2}$ (Pythagoras thm)

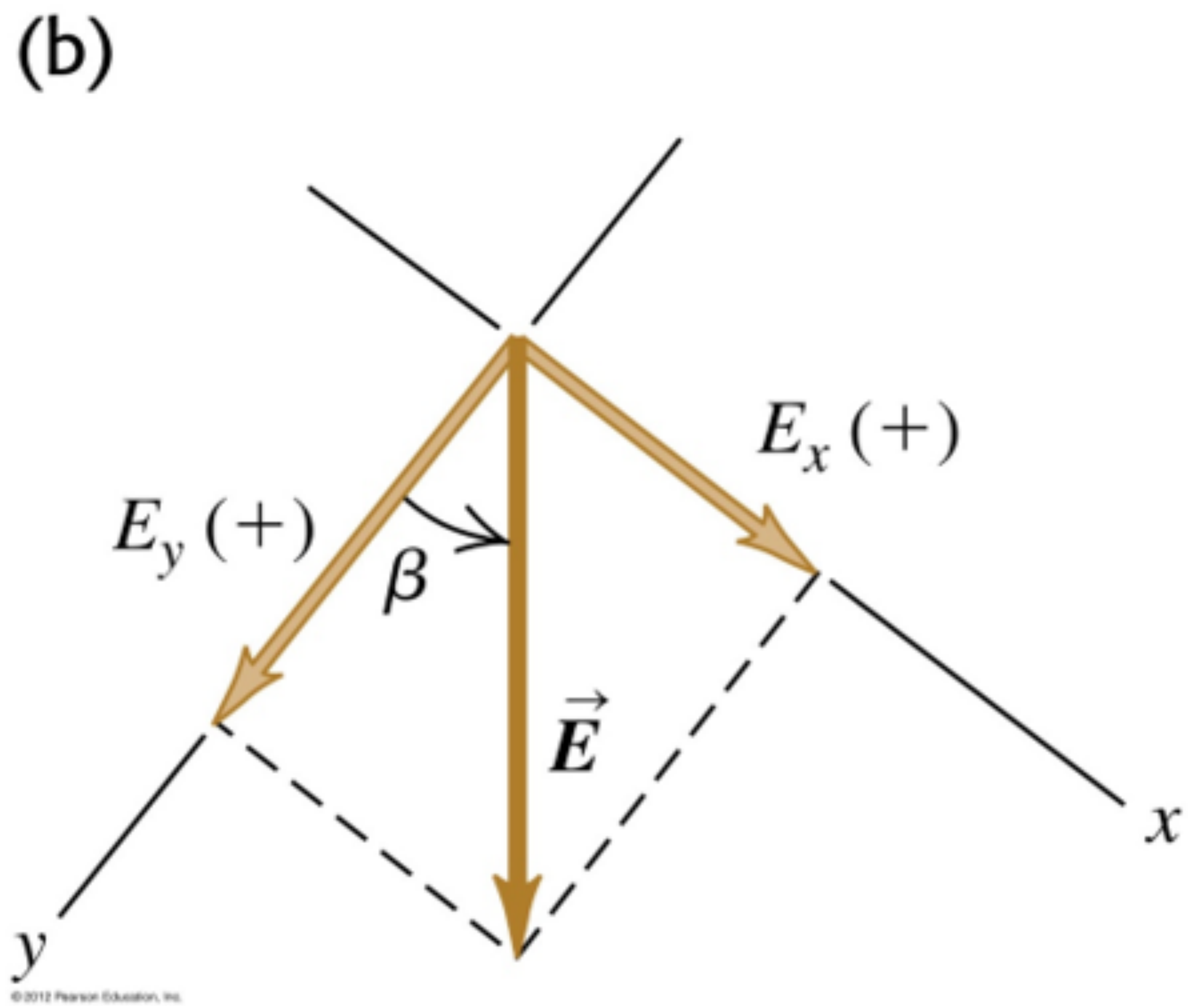
$\tan\theta = \frac{A_y}{A_x}$

Subtraction



Q1.1

What are the *x*- and *y*-components of the vector $\vec{E}$?



A. $E_x = E \cos \beta$, $E_y = E \sin \beta$

B. $E_x = E \sin \beta$, $E_y = E \cos \beta$

C. $E_x = -E \cos \beta$, $E_y = -E \sin \beta$

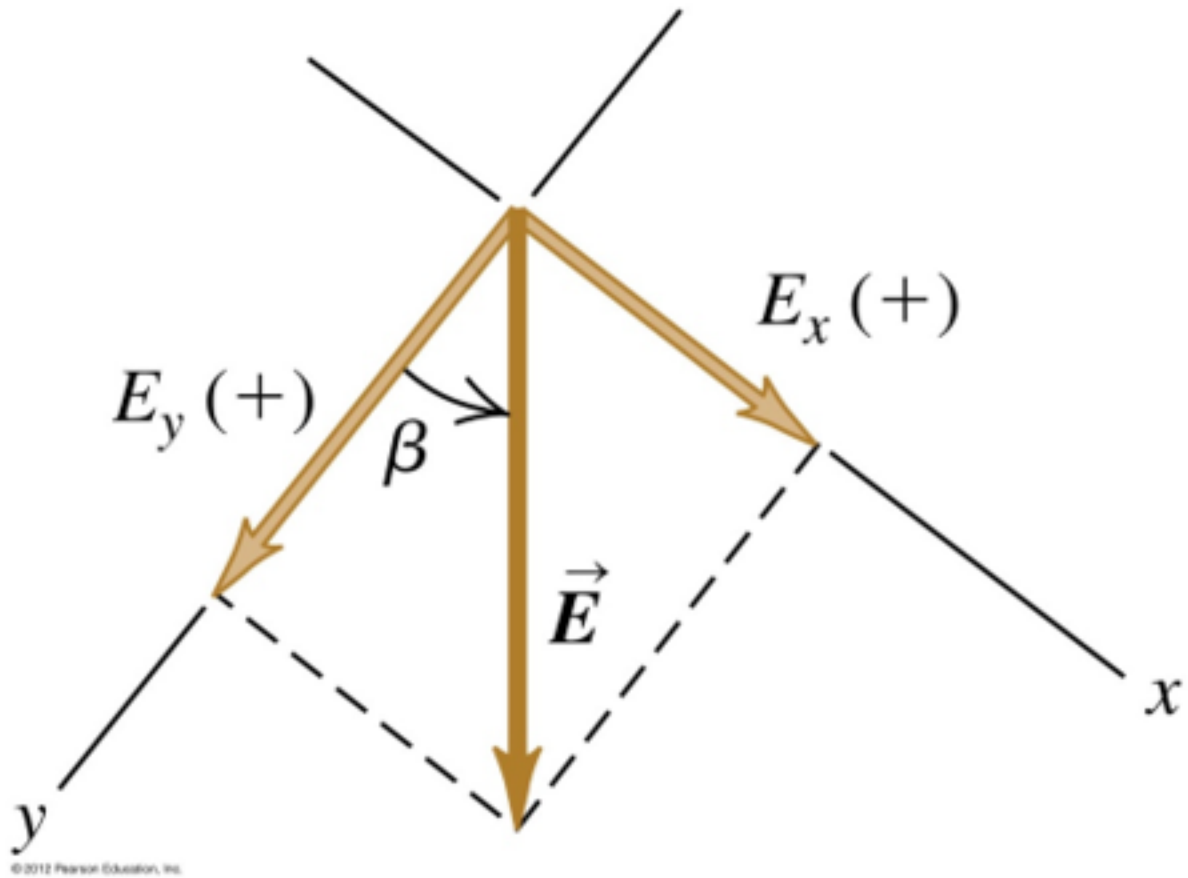
D. $E_x = -E \sin \beta$, $E_y = -E \cos \beta$

E. $E_x = -E \cos \beta$, $E_y = E \sin \beta$

Q1.1

What are the x- and y-components of the vector $\vec{E}$?

(b)



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Q1.2

Which of the following statements is correct for *any* two vectors $\vec{A}$ and $\vec{B}$?

A. The magnitude of $\vec{A}+\vec{B}$ is $A + B$

B. The magnitude of $\vec{A}+\vec{B}$ is $A - B$

C. The magnitude of $\vec{A}+\vec{B}$ is greater than or equal to $|A - B|$

D. The magnitude of $\vec{A}+\vec{B}$ is greater than the magnitude of $\vec{A}-\vec{B}$

E. The magnitude of $\vec{A}+\vec{B}$ is $\sqrt{A^2 + B^2}$

Q1.2

Which of the following statements is correct for *any* two vectors $\vec{A}$ and $\vec{B}$?

A. The magnitude of $\vec{A} + \vec{B}$ is $A + B$

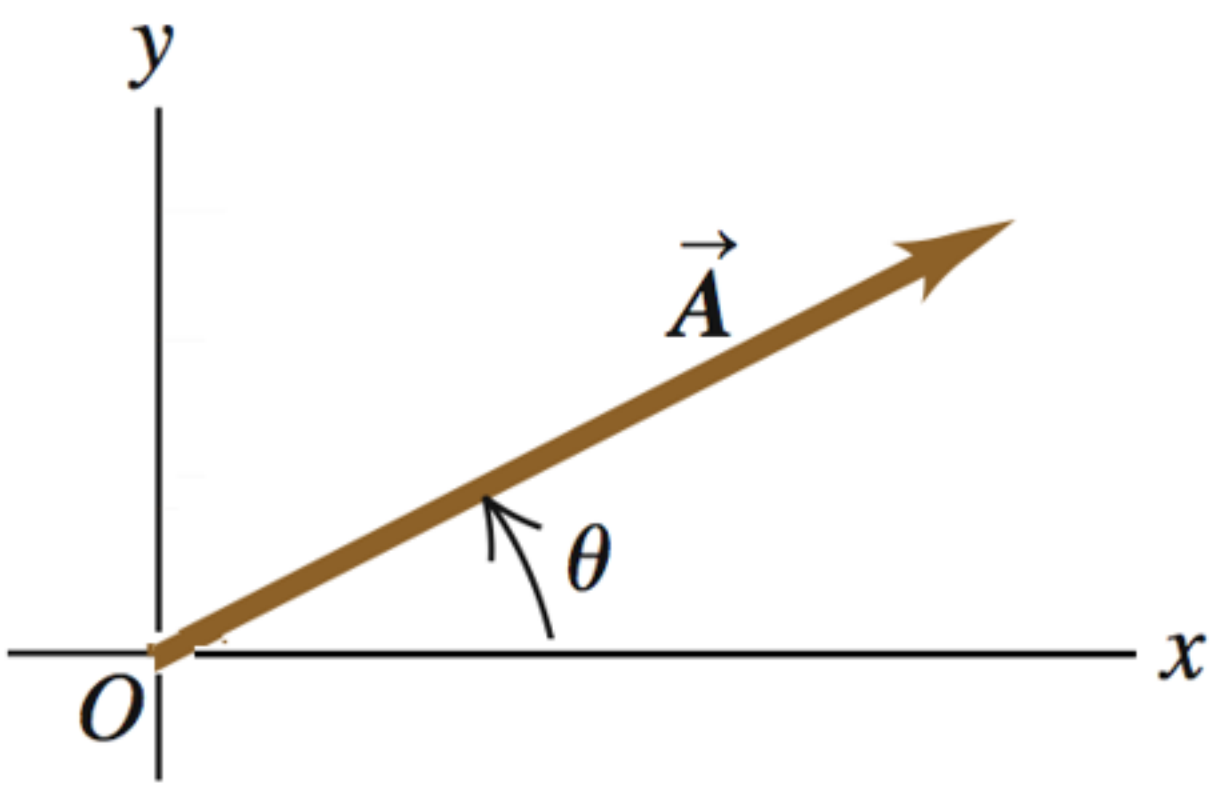
B. The magnitude of $\vec{A} + \vec{B}$ is $A - B$

C. The magnitude of $\vec{A} + \vec{B}$ is greater than or equal to $|A - B|$

D. The magnitude of $\vec{A} + \vec{B}$ is greater than the magnitude of $\vec{A} - \vec{B}$

E. The magnitude of $\vec{A} + \vec{B}$ is $\sqrt{A^2 + B^2}$

Q1.3



The angle θ is measured counterclockwise from the positive *x*-axis as shown. For which of these vectors is θ greatest?

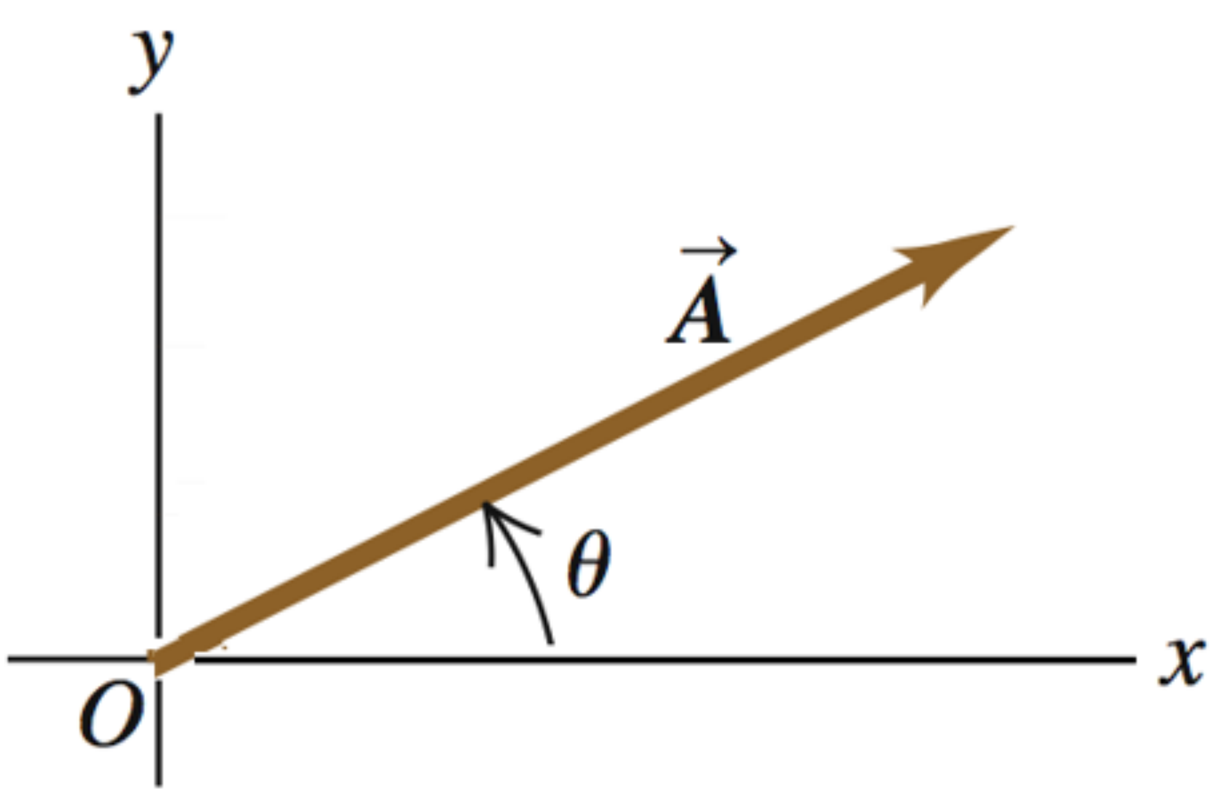
A. $24\hat{\boldsymbol{i}} + 18\hat{\boldsymbol{j}}$

B. $-24\hat{\boldsymbol{i}} - 18\hat{\boldsymbol{j}}$

C. $-18\hat{\boldsymbol{i}} + 24\hat{\boldsymbol{j}}$

D. $-18\hat{\boldsymbol{i}} - 24\hat{\boldsymbol{j}}$

Q1.3



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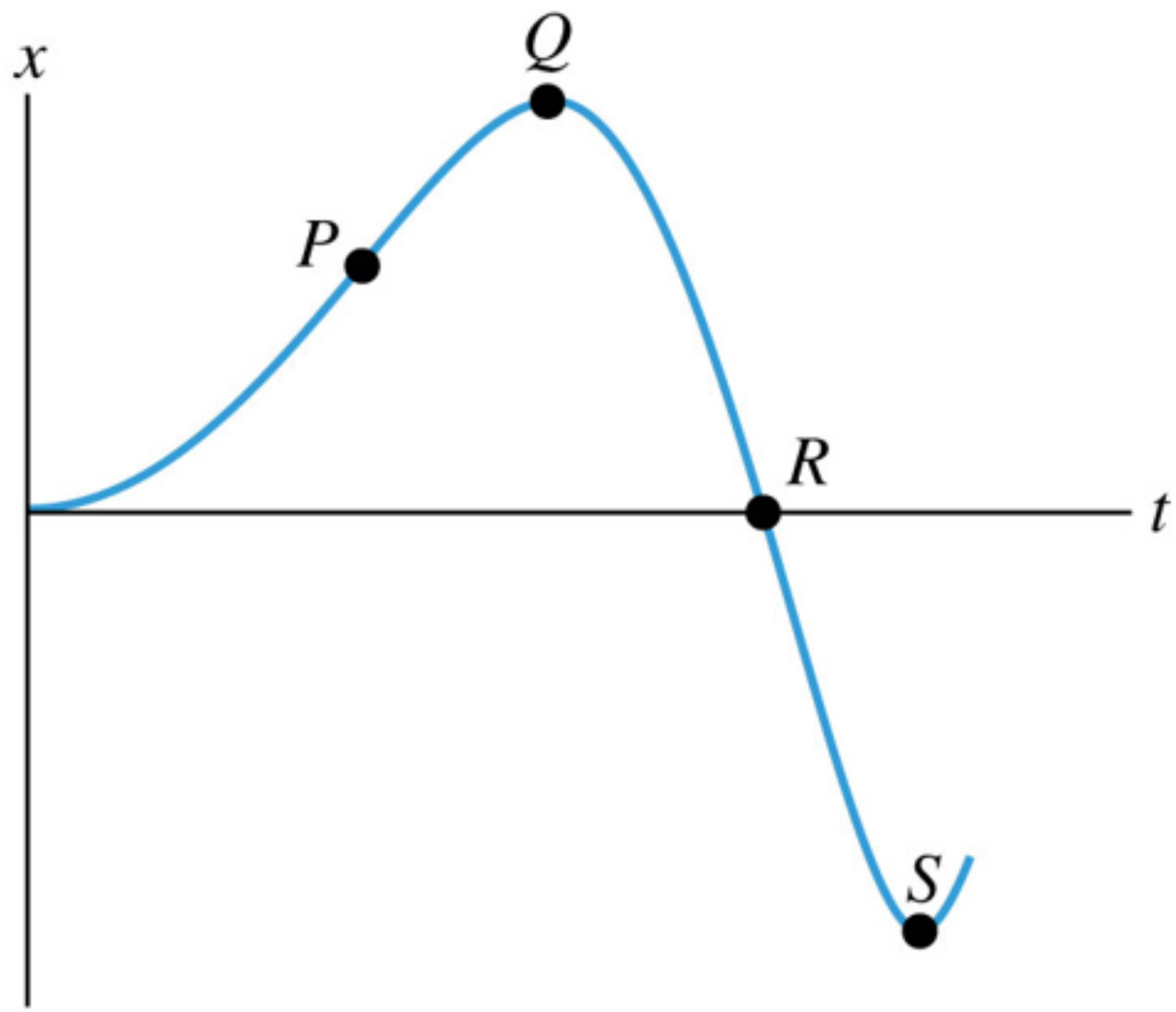
Motion in 2D

Q2.3



This is the *x*-*t* graph of the motion of a particle. Of the four points *P, Q, R,* and *S*, the acceleration a_x is greatest (most positive) at

A. point *P.*

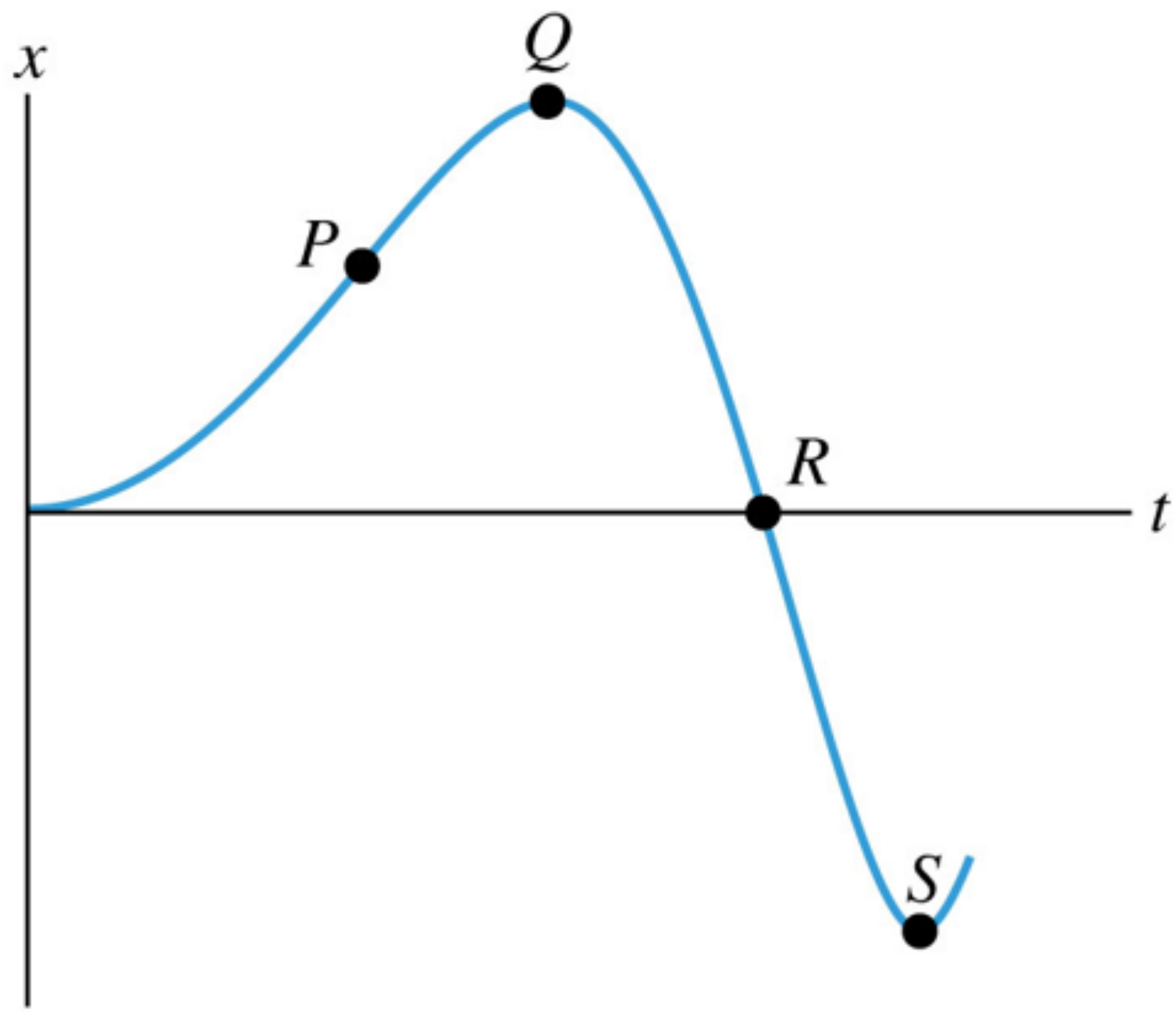
B. point *Q.*

C. point *R.*

D. point *S.*

E. not enough information in the graph to decide

Q2.3



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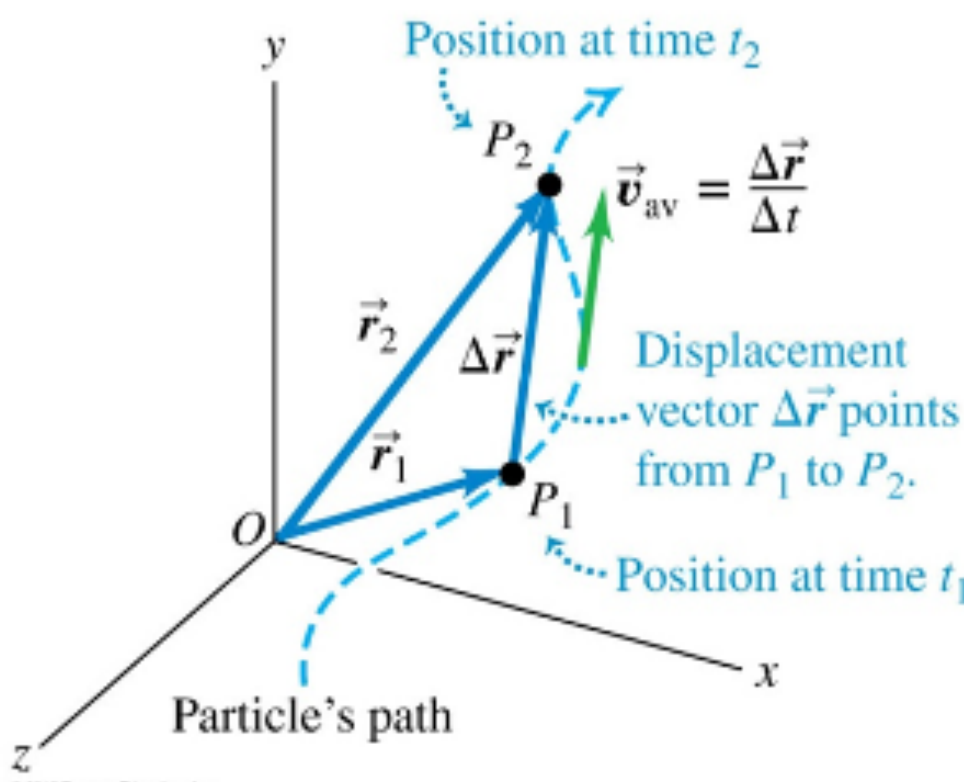
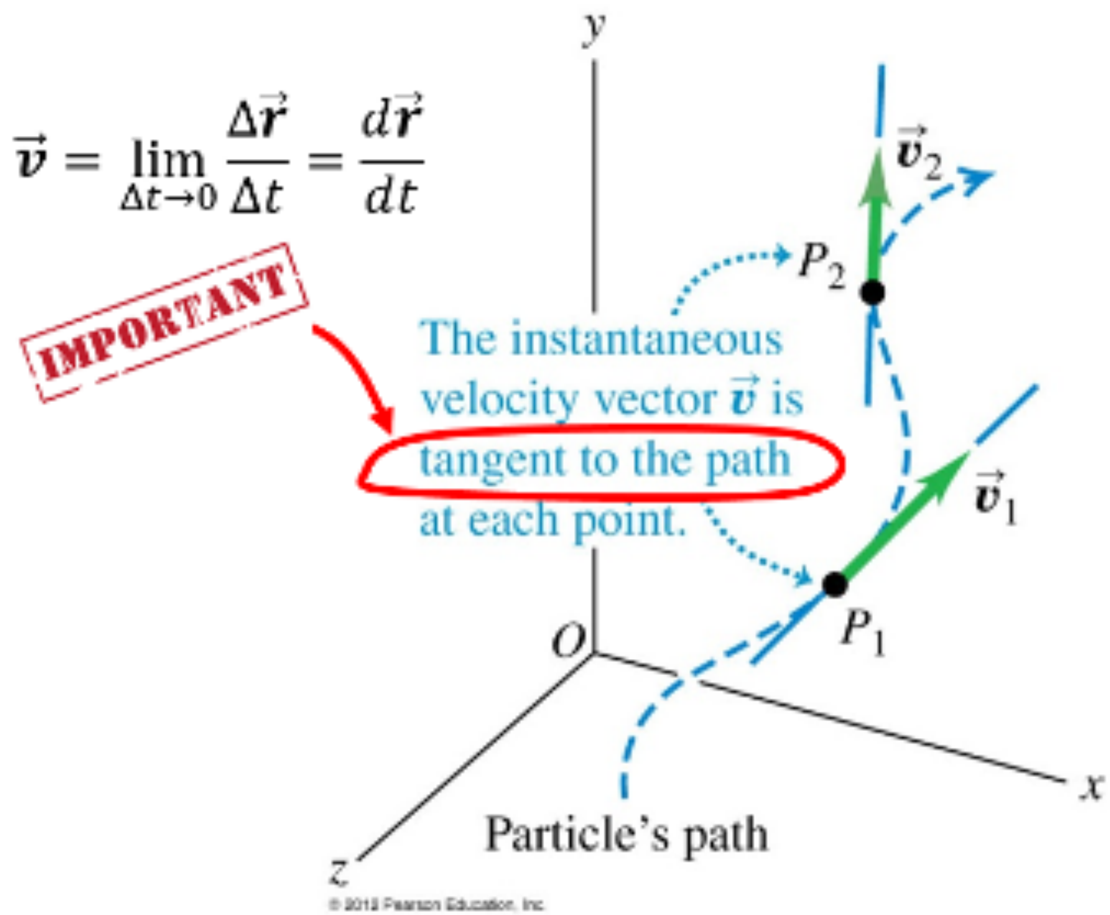
Displacement and velocity vectors

Distance and speed – scalars

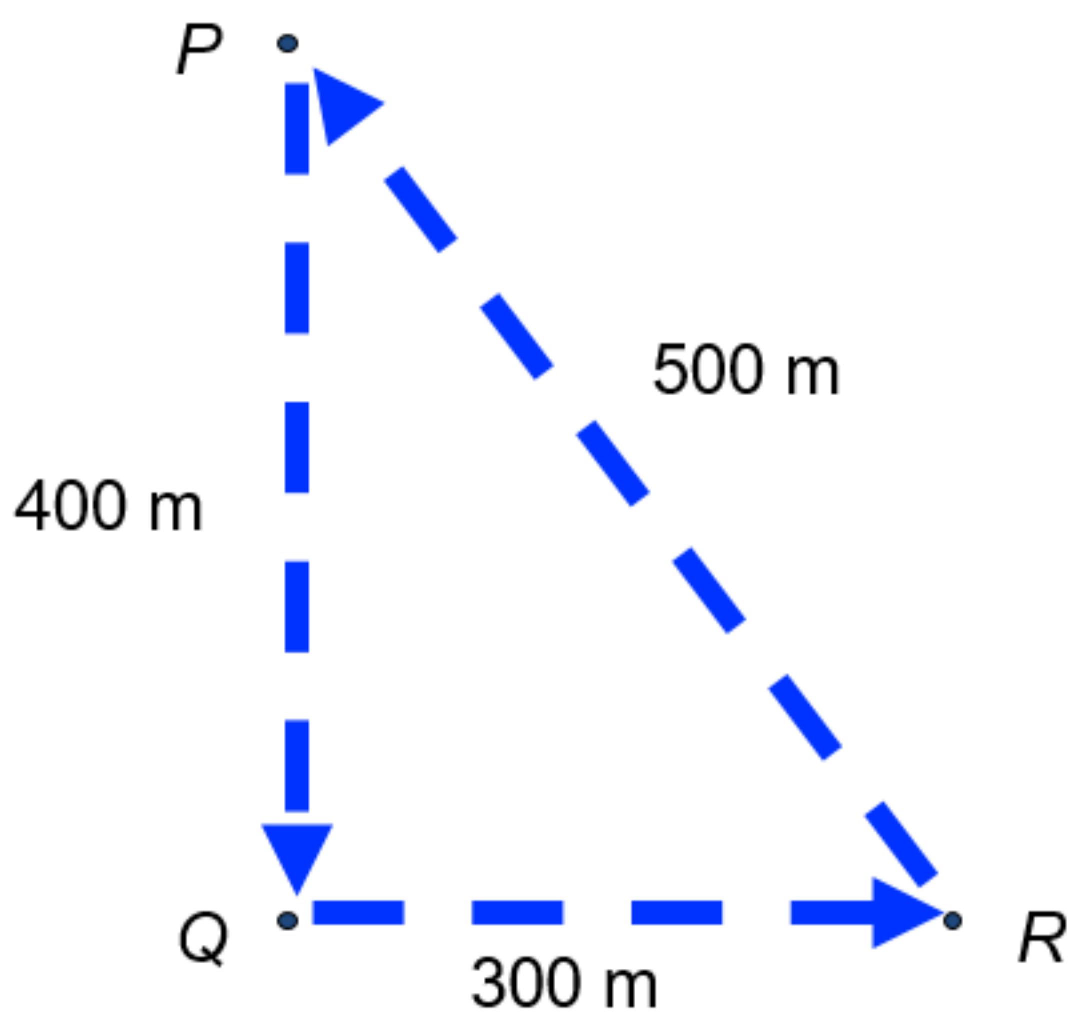
Displacement and velocity – vectors





Q3.1

A bicyclist starts at point *P* and travels around a triangular path that takes her through points *Q* and *R* before returning to point *P*. What is the magnitude of her net displacement for the entire round trip?



A. 100 m

B. 200 m

C. 600 m

D. 1200 m

E. zero

Q3.1

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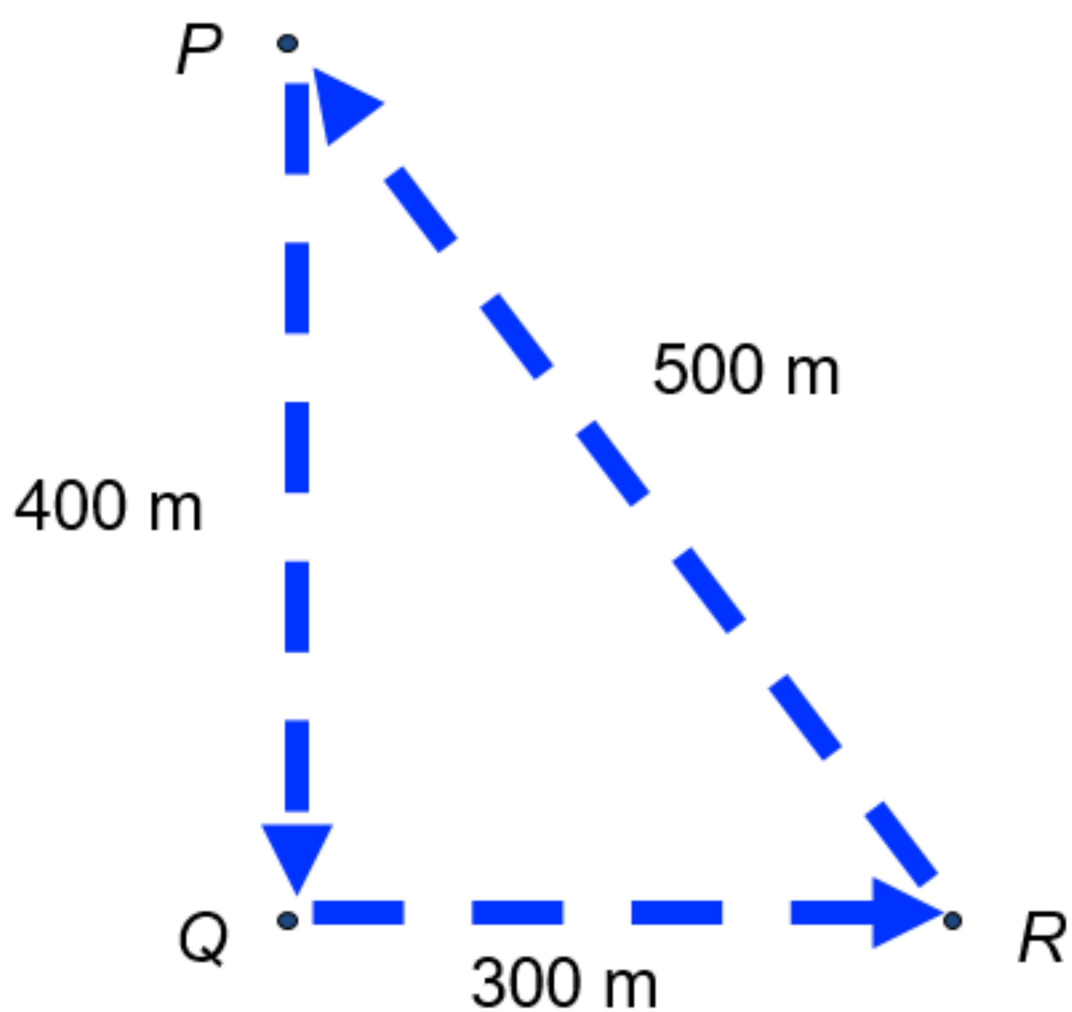

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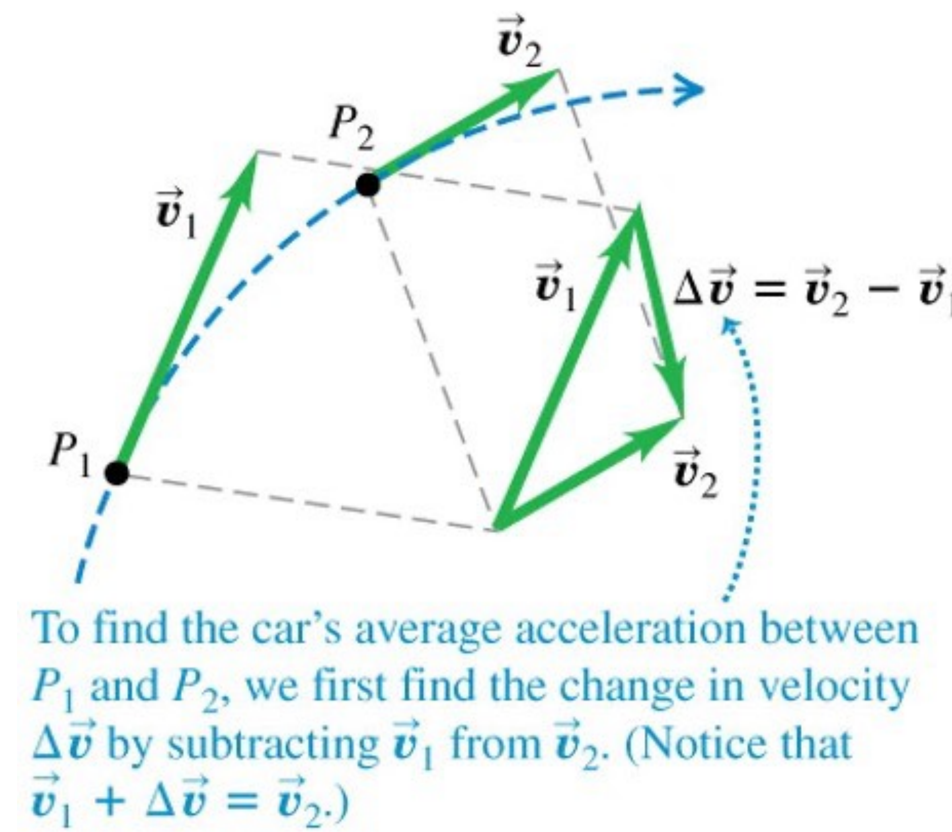
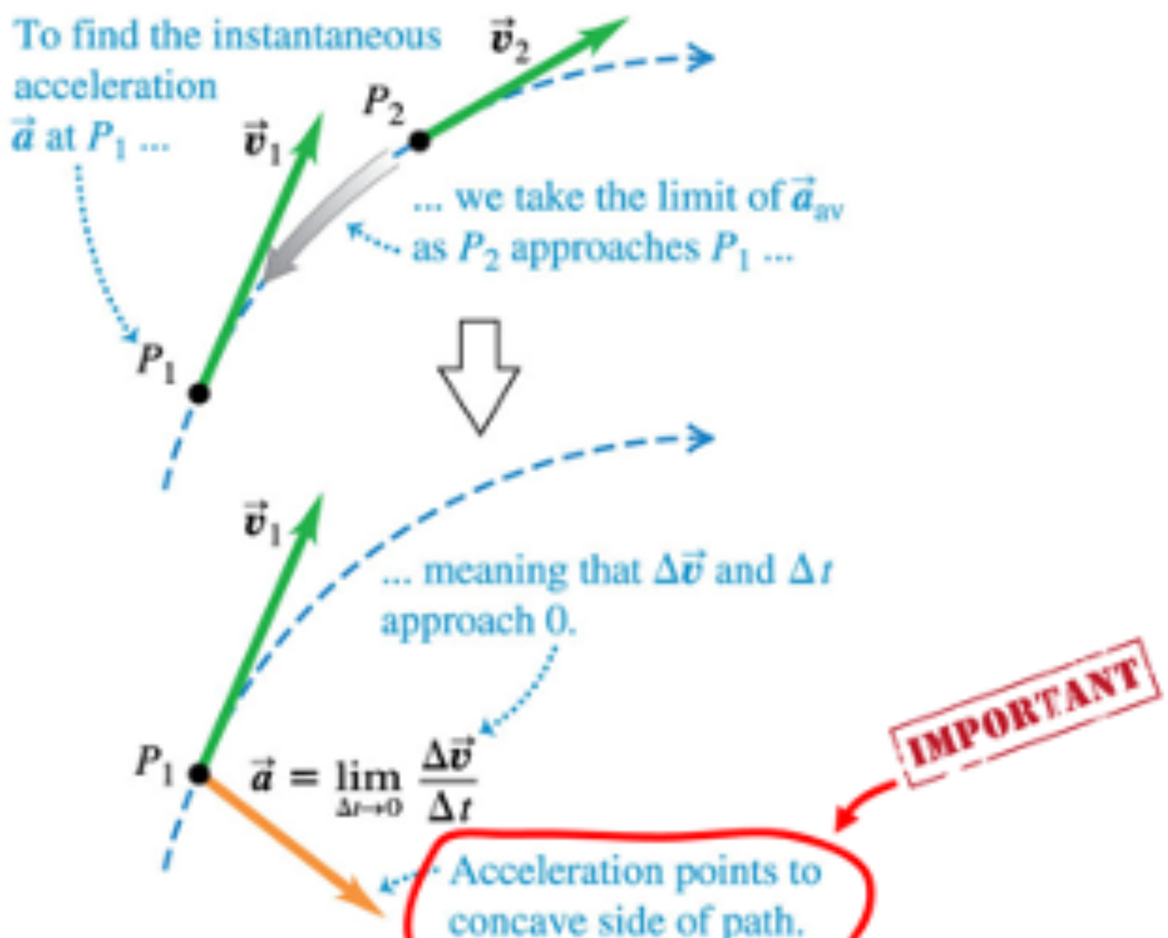
Acceleration vector

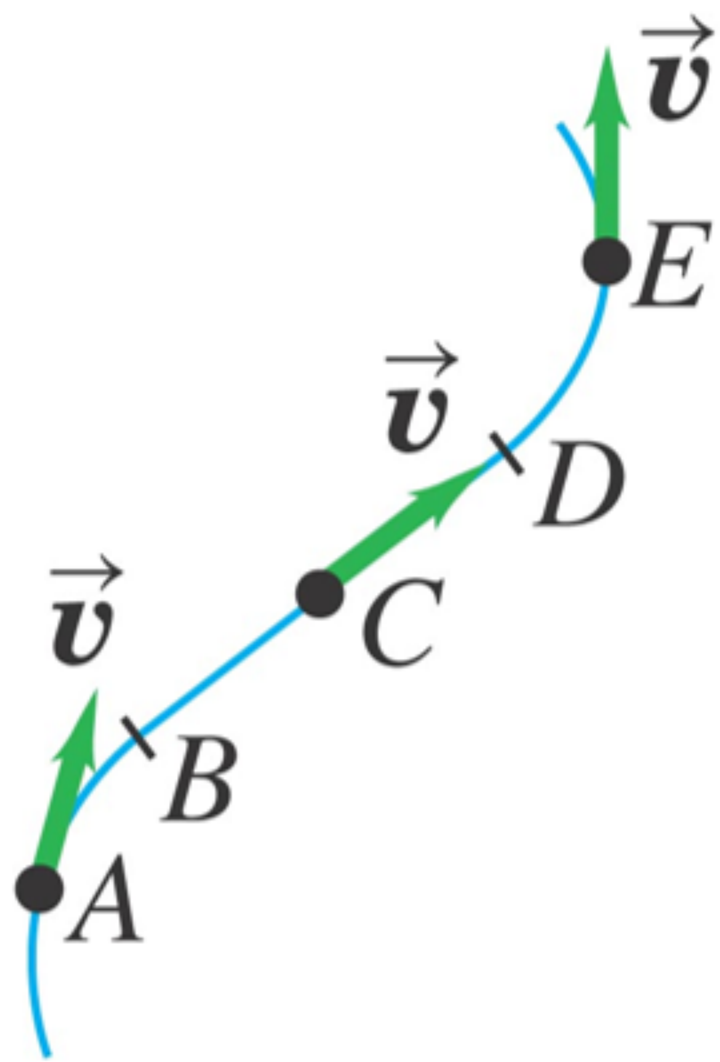




$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

Q3.3

The motion diagram shows an object moving along a curved path at constant speed. At which of the points *A*, *C*, and *E* does the object have *zero* acceleration?



A. point *A* only

B. point *C* only

C. point *E* only

D. points *A* and *C* only

E. points *A*, *C*, and *E*

Q3.3

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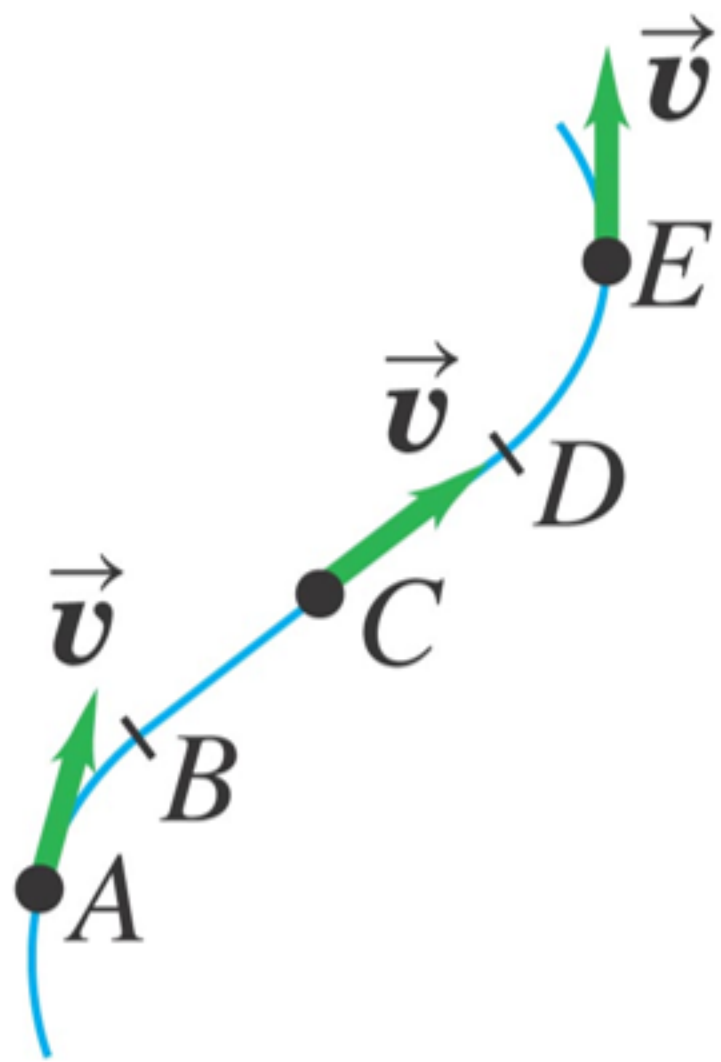


A. point *A* only

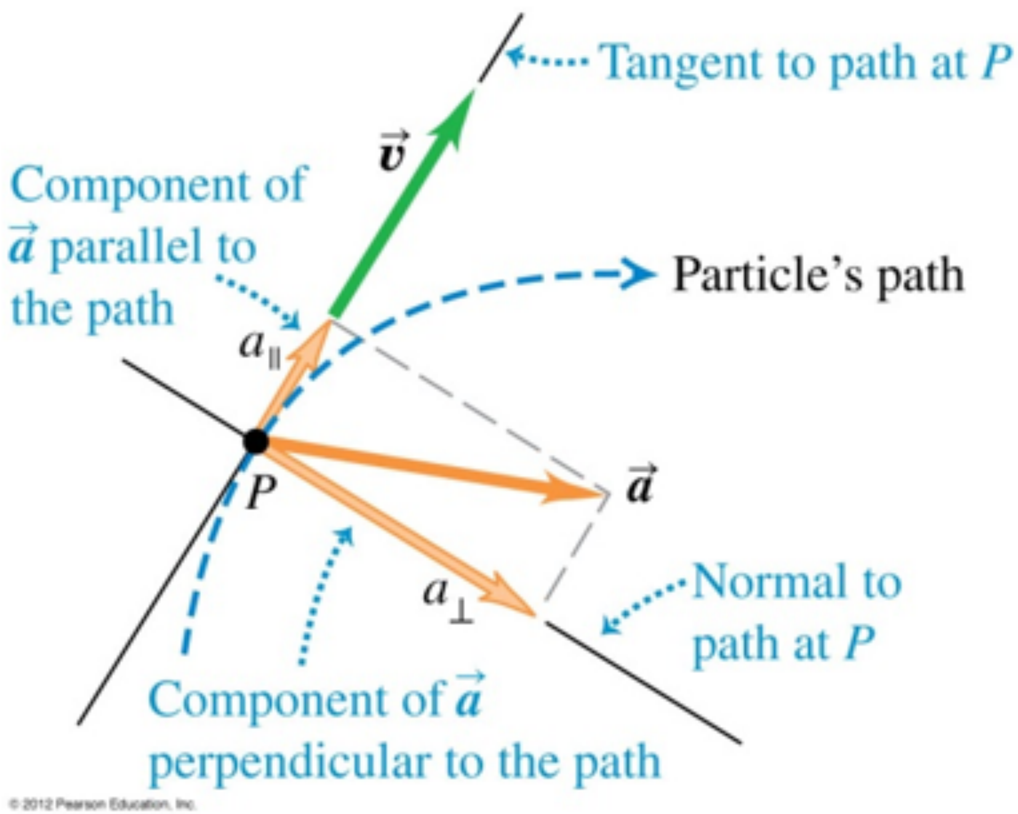
B. point *C* only

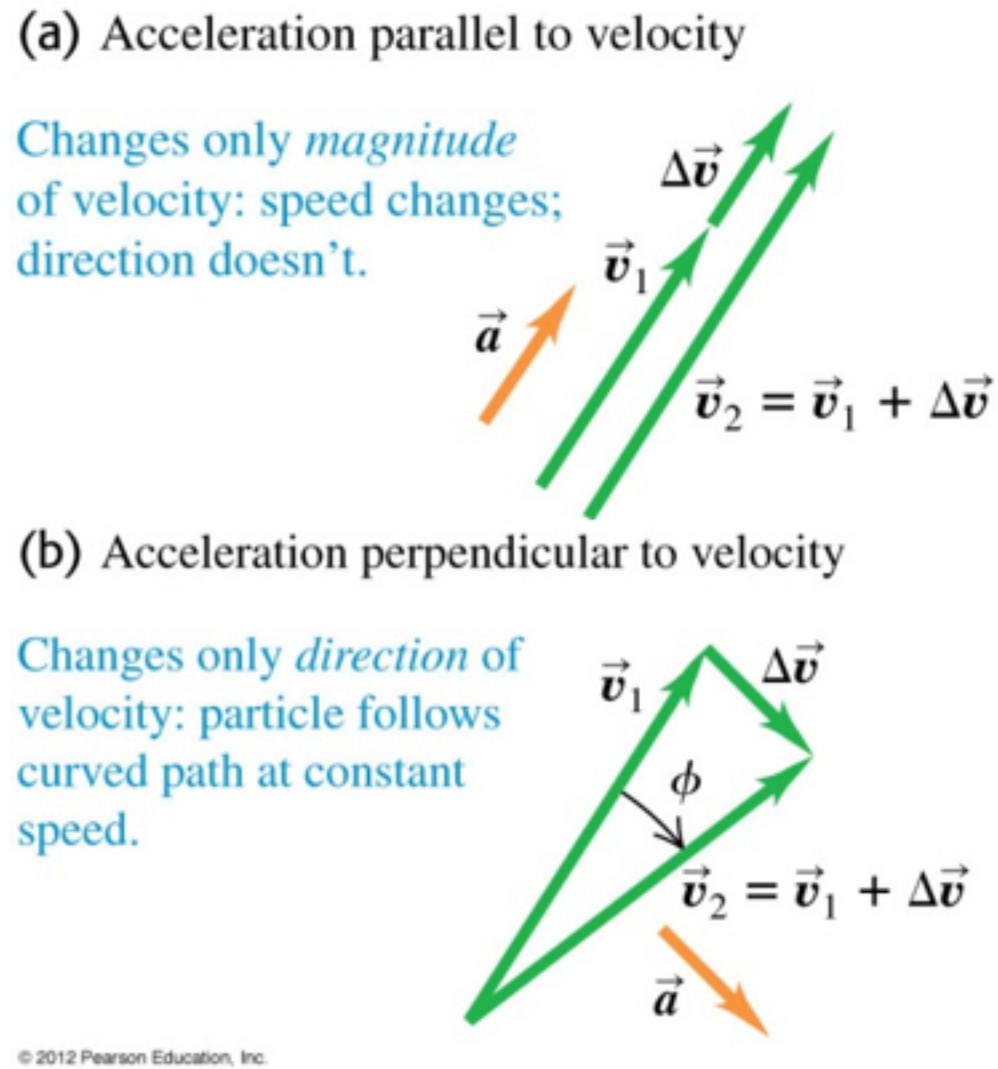
C. point *E* only

D. points *A* and *C* only

E. points *A*, *C*, and *E*

Resolve into parallel (or tangential) $a_{\parallel}$, and perpendicular (or radial) $a_{\perp}$ components



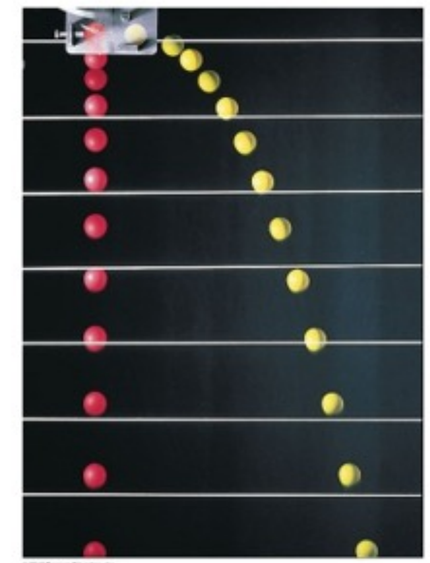


Projectile

Principle: x and y motions are independent

Vertical motion of red and yellow balls are identical – at the same height at any time

$\vec{\boldsymbol{a}} = a_x\hat{\imath} + a_y\hat{\jmath} = -g\hat{\jmath}$, i.e., $a_x = 0, a_y = -g$



Recall from high school: rectilinear motion with uniform acceleration a

$$v = v_0 + at$$
$$x - x_0 = v_0 t + \frac{1}{2}at^2$$
$$v^2 = v_0^2 + 2a(x - x_0)$$

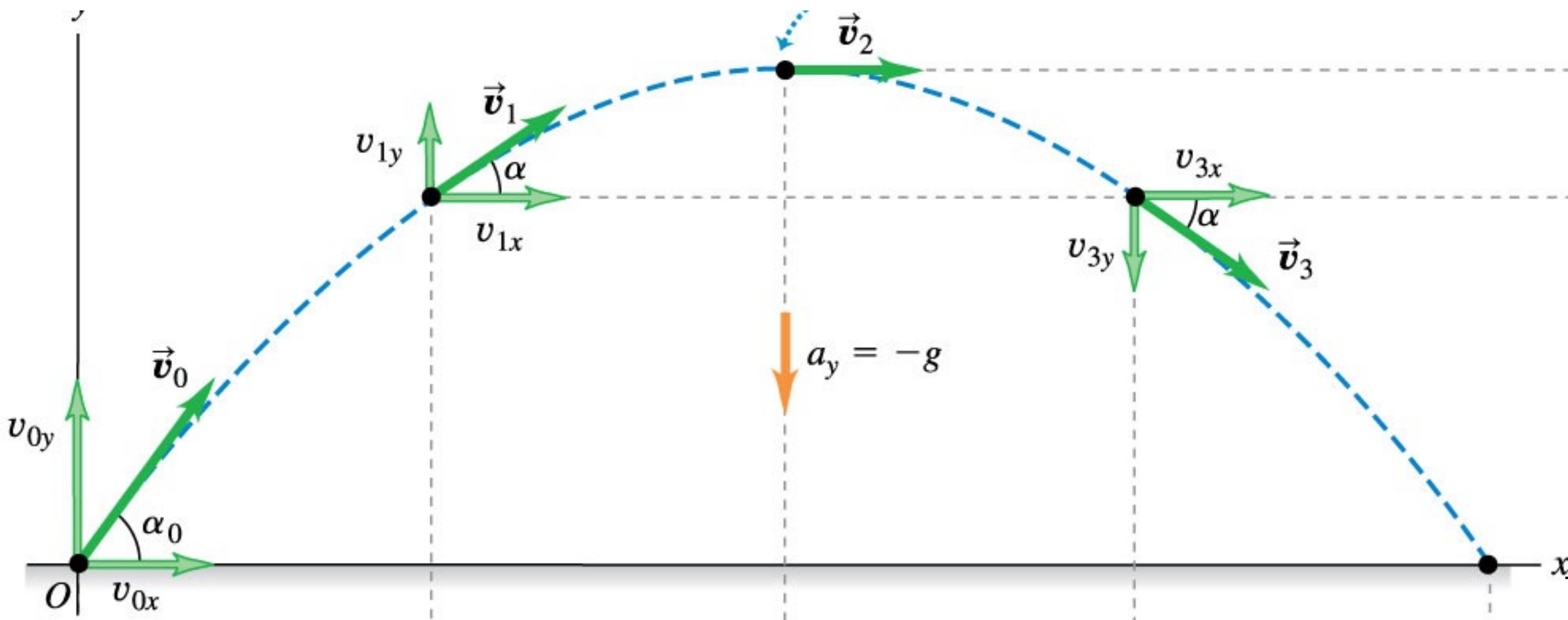
Trajectory: $x(t) = v_0 \cos\alpha_0\, t,\ y(t) = v_0 \sin\alpha_0\, t - \frac{1}{2}gt^2$

Eliminate $t \Longrightarrow \quad y = (\tan\alpha_0)x - \dfrac{g}{2v_0^2\cos^2\alpha_0}x^2$

i.e. $y = bx - cx^2$ a parabola 抛物線

A typical projectile: at the top, $0 = v_y = v_0 \sin\alpha_0 - gT$

$\Rightarrow T = v_0 \sin\alpha_0 / g$



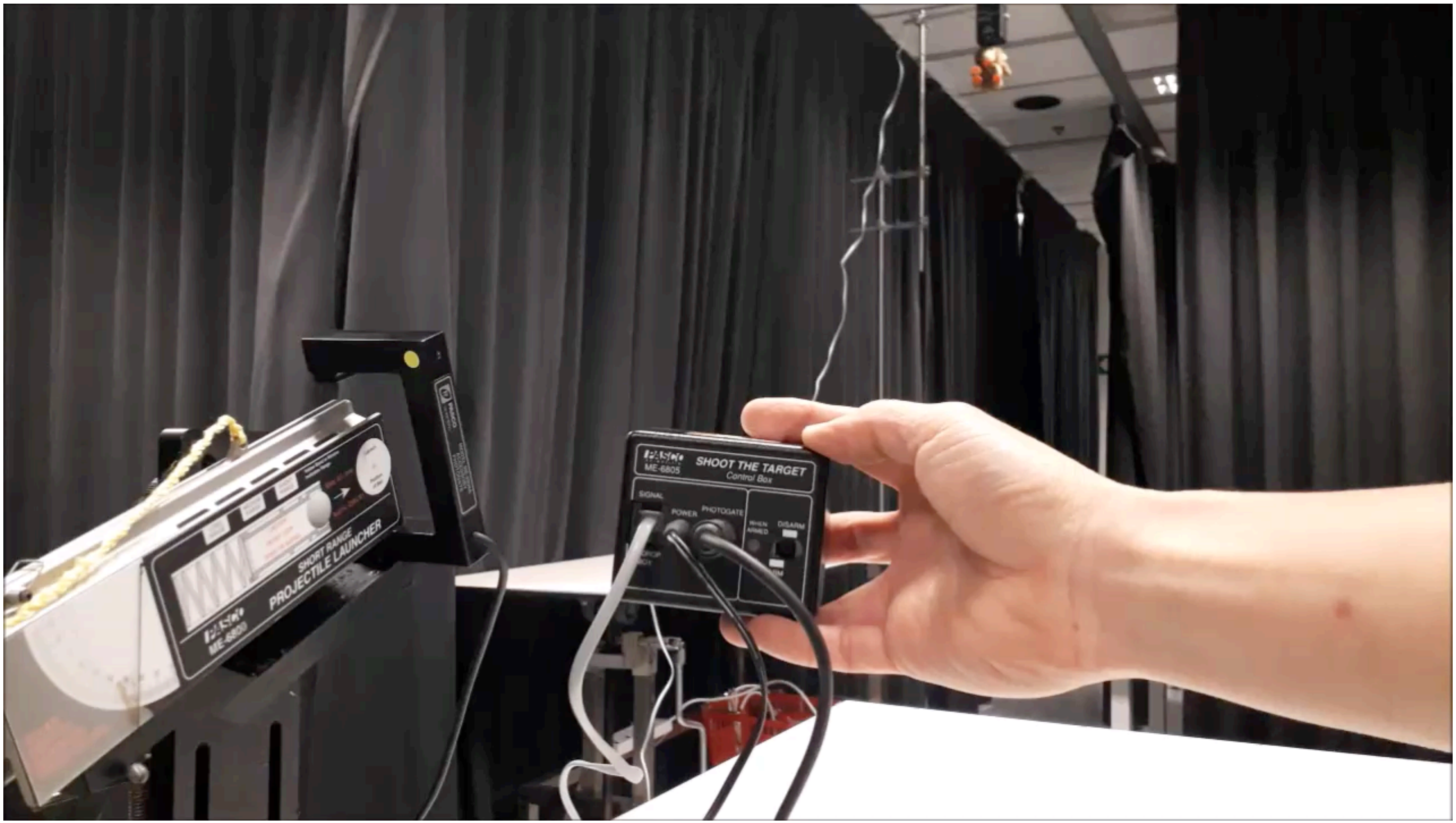
y motion with uniform downward acceleration g,
max. height

$$= v_0 \sin\alpha_0\, T - \tfrac{1}{2} g T^2$$

$$= \frac{v_0^2 \sin^2\alpha_0}{2g}$$

x motion, no acceleration, range $= v_0 \cos\alpha_0\,(2T) = 2v_0^2 \sin\alpha_0 \cos\alpha_0 / g$

Demonstration: a ball fired at the same instant when the monkey is dropped
Ball *always* hit the monkey, *AMAZING!!*
See textbook for a proof.


SHORT RANGE
PROJECTILE LAUNCHER
PASCO
ME-6800
PASCO
ME-6805
SHOOT THE TARGET
Control Box
SIGNAL
POWER
PHOTOGATE
DISARM

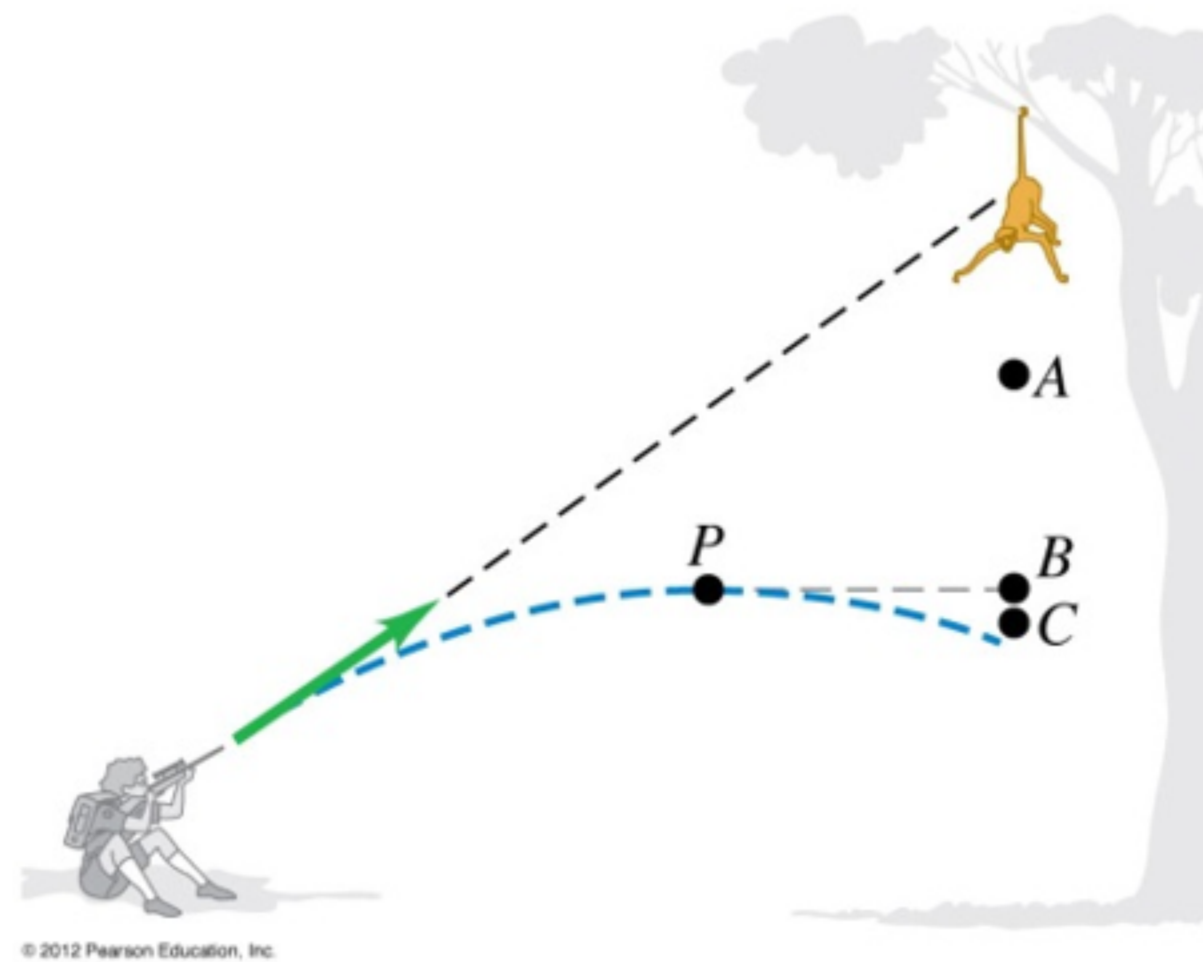
Question

When the ball is at its highest point P, the monkey will be at

(i) point A (higher than P)

(i) point B (at the same height as P)

(i) C (lower than P)



Q3.10

A projectile is launched at a 30° angle above the horizontal. Ignore air resistance. The projectile's acceleration is greatest

A. at a point between the launch point and the high point of the trajectory.

B. at the high point of the trajectory.

C. at a point between the high point of the trajectory and where it hits the ground.

D. misleading question—the acceleration is the same (but nonzero) at all points along the trajectory

E. misleading question—the acceleration is zero at all points along the trajectory

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