PHYSICSBOWL 2011

MARCH 30 – APRIL 13, 2011

40 QUESTIONS – 45 MINUTES

The sponsors of the 2011 PhysicsBowl, including the **American Association of Physics Teachers,** are providing some of the prizes to recognize outstanding high school physics students and their teachers through their performance on this year's contest.

- ▪ Schools compete in one of 15 regions, each with two divisions.

  - o *Division 01* is for students *taking physics for the first time* (even if that first course is AP Physics).

  - o *Division 02* is for students taking a second (or more) course in physics or anyone wishing a challenge.

- • A school's team score in each division is the sum of the *five* highest student scores in that division.

- • A school may compete in either or both divisions.

INSTRUCTIONS

Answer sheet: Write and bubble-in the following **REQUIRED** information on your answer sheet:

- • Your *Name*

- • Your *School's CEEB code* (given to you by your teacher)

- • Your *Teacher's AAPT Teacher code* (given to you by your teacher – only *one* code per school!)

- • Your *Region* (given to you by your teacher)

- • Your *Division* (01 for first-year physics students, 02 for students in a second physics course)

If ALL of this information is not properly bubbled, you will be disqualified from individual awards as your official score will be a zero.

Your answer sheet will be machine graded. Be sure to use a *#2 pencil*, fill the bubbles completely, and make no stray marks on the answer sheet.

Questions: The test is composed of 50 questions; however, students will be required to answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the number of the question on the test.

Division 01 students will answer only questions 1 – 40. Numbers 41 – 50 on the answer sheet should remain blank for all Division 01 students.

Division 02 students will answer only questions 11 – 50. Numbers 1 – 10 on the answer sheet should remain blank for all Division 02 students.

Calculator: A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

Formulas and constants: Only the formulas and constants provided with these instructions may be used.

Time limit: *45 minutes.*

Score: Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared, from the end of the test forward, until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner, and you should consider them carefully.

Good Luck!

*** Treat $g = 10\,^m/_{s^2}$ for ALL questions #1 – #50.

1. Which one of the following choices best represents the average mass of an adult human male?

   (A) $1.0 \times 10^{-2}\ kg$
   (B) $1.0 \times 10^{-1}\ kg$
   (C) $1.0 \times 10^{1}\ kg$
   (D) $1.0 \times 10^{2}\ kg$
   (E) $1.0 \times 10^{3}\ kg$

2. Albert Einstein's most famous equation is $E = mc^2$. The unit for the quantity represented by E can be written as which one of the following options?

   (A) seconds   (B) newtons   (C) kilograms   (D) meters   (E) joules
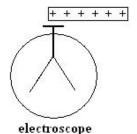
3. The distance of one thousand meters can be written as one kilometer. Which one of the following choices best represents a distance of one million meters?

   (A) one gigameter   (B) one megameter   (C) one micrometer   (D) one nanometer   (E) one terameter

4. The following two measurements of length are recorded from an experiment: $L_1 = 4.57 \times 10^3\ m$ and $L_2 = 2.130 \times 10^2\ m$. Using the rules of significant digits, what is the sum $(L_1 + L_2)$ of these measurements?

   (A) $5 \times 10^3\ m$ (B) $4.8 \times 10^3\ m$ (C) $4.78 \times 10^3\ m$ (D) $4.783 \times 10^3\ m$ (E) $6.70 \times 10^3\ m$

5. A positively charged rod is brought near a metal electroscope that is initially uncharged. As shown in the figure, the rod does not touch the electroscope. There is no charge transfer between the electroscope and rod, but the leaves of the electroscope move apart from each other when the rod is brought near the top of the electroscope. Which one of the following choices is the best explanation for this phenomenon?

   electroscope

   (A) Protons are repelled by the rod into the leaves of the electroscope.
   (B) Electrons are attracted out of the leaves of the electroscope toward the rod.
   (C) Protons are repelled into the leaves of the electroscope and electrons are attracted out of the leaves of the electroscope.
   (D) Positively charged electrons are repelled by the rod into the leaves of the electroscope.
   (E) Positively charged electrons are repelled into the leaves of the electroscope and regular electrons are attracted out of the leaves of the electroscope.

Questions 6 – 7 deal with the following information:

A ball of mass $m = 0.100\ kg$ is launched straight upward so that it rises to a maximum height of $12.0\ m$ above the launch point. Ignore air resistance.

6. When the ball reaches its maximum height, which one of the following choices best represents the magnitude of the net force acting on the ball?

(A) $0\ N$ (B) $0.100\ N$ (C) $1.00\ N$ (D) $10.0\ N$ (E) $12.0\ N$

7. Approximately how much time does it take the ball to reach the maximum height from its launch?

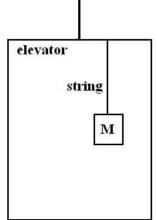(A) $0.65\ s$ (B) $1.10\ s$ (C) $1.20\ s$ (D) $1.55\ s$ (E) $2.40\ s$

8. An object moves along a horizontal line with increasing speed. Which one of the following choices could represent the signs of the velocity and of the acceleration for the object to achieve this motion?

	Velocity	Acceleration
(A)	Zero	Zero
(B)	Positive	Zero
(C)	Positive	Negative
(D)	Negative	Positive
(E)	Negative	Negative

9. Which one of the following choices best represents the speed of $60.0\ \frac{miles}{hr}$ rewritten in units of $\frac{km}{day}$?

(A) 2300   (B) 1440   (C) 900   (D) 4.00   (E) 1.56

10. A string of negligible mass connects an object of mass $M = 10\ kg$ to the ceiling of an elevator. The elevator experiences a constant downward speed of 3.0 $^m/_s$.
Let T represent the magnitude of the force on the mass M by the string (tension), G represent the magnitude of the gravitational force by the Earth acting on the mass M hanging in the elevator, and F represent the magnitude of the net force acting on the mass M. Which one of the following choices describes the relationships between these forces?

(A) $F < T < G$
(B) $F = G = T$
(C) $F < G < T$
(D) $F = T < G$
(E) $F < T = G$

ATTENTION: All Division 01 students, continue to question #40.
All Division 02 students, START HERE. Numbers 1 – 10 on your answer sheet should be blank. Your first answer should be for #11.
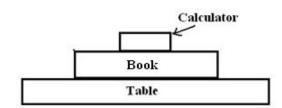
*** Treat $g = 10 \, ^m/_{s^2}$ for ALL questions #1 – #50.

11. The largest particle accelerator in the world is called the LHC. What does LHC stand for?

(A) Large Hadron Conductor
(B) Light Hadron Container
(C) Light Hadron Collider
(D) Large Hadron Container
(E) Large Hadron Collider

12. A 5.0 kg mass moves along the x-axis. At one instant of time, the mass has position 2.0 m, velocity 3.0 $^m/_s$, and acceleration 4.0 $^m/_{s^2}$. What is the net force acting on the mass at this instant of time?

(A) 0 N　　　　(B) 10.0 N　　　　(C) 15.0 N　　　　(D) 20.0 N　　　　(E) 22.5 N

13. A physics book sits at rest on a table. On top of the book is a calculator, also at rest. Which one of the following choices is the Newton's Third Law pair force to the force that the table exerts on the book?
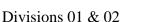
(A) The contact force on the table by the book.
(B) The gravitational force on the book by the Earth.
(C) The gravitational force on the combination of the book and calculator by the Earth.
(D) The contact force on the book by the calculator.
(E) The contact force on the table by the ground supporting it.

14. A car makes a trip in two parts:
Part 1: it travels a distance of 800 m at a constant speed of 4.0 $^m/_s$.
Part 2: it travels a distance of 1200 m at a constant speed of 20.0 $^m/_s$.
What is the average speed of the car for the entire two-part trip?

(A) 7.7 $^m/_s$　　　(B) 10.4 $^m/_s$　　　(C) 12.0 $^m/_s$　　　(D) 13.6 $^m/_s$　　　(E) 17.3 $^m/_s$

15. A 4.0 kg object is pushed to the right on a rough surface by a horizontal force of 15 N as shown. During the push, the object accelerates uniformly to the right at 2.50 $^m/_{s^2}$. What must be the magnitude of the force of friction also acting on the object during the push?

(A) 0 N　　　　(B) 5 N　　　　(C) 10 N　　　　(D) 15 N　　　　(E) 25 N

16. Which one of the following is NOT a vector quantity?
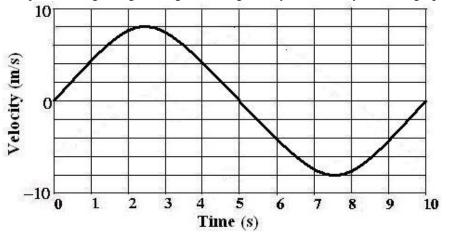
(A) Linear momentum　　　　　　　　　(D) Instantaneous acceleration
(B) Electric field　　　　　　　　　　　(E) Kinetic energy
(C) Average velocity

17. A new radio station broadcasts its signal with a wavelength of $3.40\ m$. At what frequency is this station broadcasting?

(A) $1.76 \times 10^8\ Hz$　　　(B) $8.82 \times 10^7\ Hz$　　　(C) $100\ Hz$　　　(D) $0.294\ Hz$　　　(E) $1.13 \times 10^{-8}\ Hz$

Questions 18 – 19 deal with the following information:

The motion of an object moving along a straight line is given by the velocity vs. time graph shown.

18. Which one of the following choices best represents the average acceleration of the object during the time interval from $t = 4.0\ s$ to $t = 9.0\ s$?

(A) $0.80\ m/_{s^2}$　　　(B) $0\ m/_{s^2}$　　　(C) $-0.80\ m/_{s^2}$　　　(D) $-1.6\ m/_{s^2}$　　　(E) $-3.2\ m/_{s^2}$

19. Which one of the following choices best represents the instantaneous acceleration of the object at the time of $t = 5.0\ s$?

(A) $0\ m/_{s^2}$　　　(B) $-1.6\ m/_{s^2}$　　　(C) $-2.0\ m/_{s^2}$　　　(D) $-3.2\ m/_{s^2}$　　　(E) $-4.0\ m/_{s^2}$

20. The transistor is a solid piece of semiconducting material with many applications in electronics. The initial development of transistors and the Nobel Prize awarded for its invention occurred closest to which calendar year?
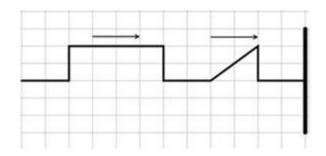
(A) 1890　　　　(B) 1920　　　　(C) 1950　　　　(D) 1980　　　　(E) 2005

21. Which one of the following choices best represents the time it takes for light coming from the Moon's surface to reach the Earth?
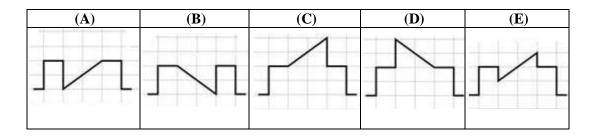
(A) 0.001 s (B) 0.10 s (C) 1.0 s (D) 10.0 s (E) 1 minute

22. Three moles of an ideal gas occupy a container of volume $2.5 \times 10^{-2} \ m^3$. The pressure inside this container is $5.00 \times 10^5 \ Pa$. Which one of the following choices best represents the temperature of the gas?

(A) 225 K   (B) 500 K   (C) 775 K   (D) 1500 K   (E) 50800 K

23. A string, clamped at both ends, has its tension fixed. A wave generator vibrates the string with a frequency f producing waves of wavelength λ which have speed v. The frequency of the wave generator now is doubled to $2f$. Which one of the following choices best describes the new values of the wavelength of waves produced and the speed of the waves on the string?

	Wavelength	Wave speed
(A)	½ λ	v
(B)	½ λ	$2v$
(C)	λ	$2v$
(D)	λ	v
(E)	2λ	$4v$

24. Two wave pulses travel to the right toward a rigid boundary as shown. After reflection of the triangular pulse, the pulses will interfere. Which one of the following pictures best represents the superposition of the pulses when the centers of the individual pulses coincide?

(A)	(B)	(C)	(D)	(E)

25. The product (3 Teslas)×(2 meters)×(4 meters/second) is equivalent to which one of the following?

(A) 24 Amperes   (B) 24 Coulombs   (C) 24 Watts   (D) 24 Ohms   (E) 24 Volts

26. During the New Moon phase of the lunar cycle, approximately what percent of the Moon's surface receives light from the Sun?

(A) 0 %   (B) 25.0 %   (C) 50.0 %   (D) 75.0 %   (E) 100 %

27. The density of a solid cubic block is given as $\rho = 0.750 \ ^g/_{cm^3}$. This block is dropped into a large swimming pool filled with water. When equilibrium is established and all motion stops, which choice best describes the location of the block? The block is very small in comparison to the pool.

(A) The block is resting at the bottom of the pool.
(B) The block is completely submerged, but stops 75 % of the way to the bottom of the pool.
(C) The block is completely submerged, but stops 25 % of the way to the bottom of the pool.
(D) The block is floating with 75 % of its volume under the water's surface.
(E) The block is floating with 25 % of its volume under the water's surface.

28. A person throws an object of mass M straight upward with an initial non-zero speed v. The object rises to a maximum height H above the launch point. The person now throws an object of mass $\frac{1}{2}M$ straight upward with initial speed $2v$. In terms of H, to what maximum height does the object of mass $\frac{1}{2}M$ rise above the launch point? Ignore air resistance.

(A) $8\,H$ (B) $4\,H$ (C) $2\,H$ (D) $\sqrt{2}\,H$ (E) H

29. An electron moves with speed $1.00 \times 10^3 \ ^m/_s$ as it enters a region of space that has only a uniform magnetic field. The electron is accelerated because of this field with a constant magnitude of $8.00 \times 10^5 \ ^m/_{s^2}$ for the entire time of 1.00×10^{-3} s that it is in the field. With what speed would the electron exit the field? Ignore gravity.

(A) $1.80 \times 10^3 \ ^m/_s$
(B) $1.41 \times 10^3 \ ^m/_s$
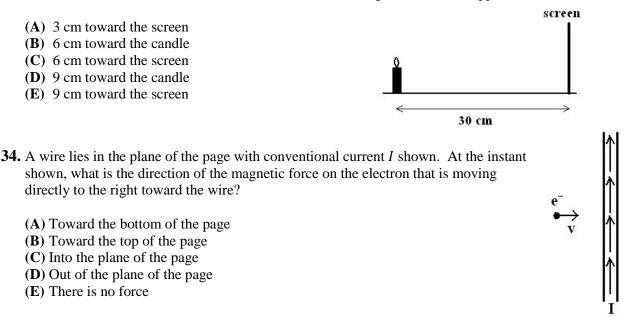(C) $1.00 \times 10^3 \ ^m/_s$
(D) $2.00 \times 10^2 \ ^m/_s$
(E) It depends on the initial angle of the electron's velocity with respect to the magnetic field.

30. Two cars travel to the right, each starting from rest, along a straight road. Car A has twice the acceleration of Car B. After traveling a distance d, Car A has speed v. When Car B has traveled the same distance d, what is its speed in terms of v?

(A) $\frac{1}{4}v$ (B) $\frac{1}{2}v$ (C) $\frac{\sqrt{3}}{2}v$ (D) $\frac{\sqrt{2}}{2}v$ (E) v

31. Approximately how much energy is required to transform a 20.0 g cube of ice at a temperature of $-10.0\,°C$ into liquid water at a temperature of 10.0 °C?

(A) 840 J   (B) 1300 J   (C) 1700 J   (D) 7900 J   (E) 46000 J

32. An ideal green pigment is mixed with an ideal red pigment. After mixing, which one of the following choices best represents the color of the pigment produced?

(A) Blue   (B) Cyan   (C) Magenta   (D) Yellow   (E) Black

33. For the set-up shown of a candle and screen placed 30 cm apart, there are two locations at which a thin converging lens can be placed to produce a focused real image. One real image of the candle appears on the screen when the lens is located 12 cm from the candle. From this location, how does this lens now have to be moved in order to make the second real image of the candle appear on the screen?
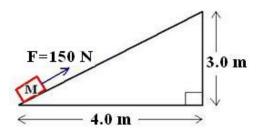
(A) 3 cm toward the screen
(B) 6 cm toward the candle
(C) 6 cm toward the screen
(D) 9 cm toward the candle
(E) 9 cm toward the screen

screen

30 cm

34. A wire lies in the plane of the page with conventional current I shown. At the instant shown, what is the direction of the magnetic force on the electron that is moving directly to the right toward the wire?

(A) Toward the bottom of the page
(B) Toward the top of the page
(C) Into the plane of the page
(D) Out of the plane of the page
(E) There is no force

e^-
v
I

35. Mary rides her bicycle directed due South. She applies the brakes quickly bringing the bicycle to rest with the wheels rolling without slipping on the ground. Which one of the following choices best represents the direction of the angular acceleration of the bicycle's front wheel while it is slowing to rest from Mary's point of view?

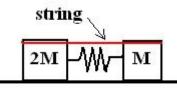(A) Into the ground   (B) North   (C) South   (D) East   (E) West

36. For the inclined plane shown, a force of 150 N applied parallel to the incline's surface is needed to pull the object of mass $M = 10.0 \ kg$ along the entire length of the incline's surface at a constant speed. What is the actual mechanical advantage (AMA) for this scenario?

F=150 N
M
4.0 m
3.0 m

(A) $^2/_3$ (D) $^3/_5$
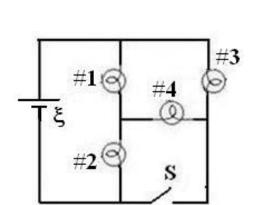(B) $^3/_2$ (E) $^5/_3$
(C) $^2/_5$

37. Two blocks sit on a horizontal frictionless surface connected to an ideal spring. Initially everything is at rest and there is a string compressing the mass-spring system from equilibrium. At some time after the string is cut, the block of mass $2M$ reaches its maximum kinetic energy K. What maximum kinetic energy does the block of mass M attain in terms of K?
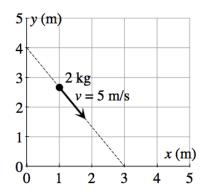

string

2M ⟋⟍⟋⟍ M

(A) $\frac{1}{4}K$ (B) $\frac{1}{2}K$ (C) K (D) $2K$ (E) $4K$

38. For the circuit shown, the four light bulbs have identical resistance, all wires have zero resistance, and the battery is assumed to be ideal with emf ξ. When the switch, S, in the circuit is closed, a wire of zero resistance is added into the circuit. Which of the light bulbs will be dimmer after the switch is closed?

(A) Only bulb #2
(B) Only bulb #4
(C) Only bulbs #1 and #4
(D) Only bulbs #2, and #4
(E) Only bulbs #1, #2, and #4

39. An object with mass M moves due East on a frictionless horizontal surface with a speed of V. A second object of mass $\frac{1}{2}M$ has a speed of $3V$. The two objects collide and stick together. If the objects are moving due South after the collision, with what speed are they moving?

(A) $\frac{5}{3}V$ (B) $\frac{1}{3}V$ (C) $\frac{\sqrt{5}}{3}V$ (D) $\frac{4\sqrt{2}}{3}V$ (E) $\frac{\sqrt{33}}{3}V$

40. A 2.0 kg particle travels at a constant speed of 5.0 m/s along the line shown in the figure. What is the magnitude of the particle's angular momentum calculated from the origin?

(A) $10\ kg \cdot m^2/s$
(B) $24\ kg \cdot m^2/s$
(C) $30\ kg \cdot m^2/s$
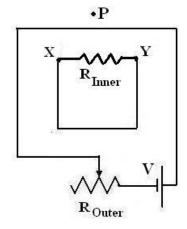(D) $32\ kg \cdot m^2/s$
(E) $40\ kg \cdot m^2/s$

IMPORTANT: All Division 01 students <u>STOP HERE</u>.   **Your last answer should be for #40. Numbers 41-50 should remain blank for Division 01 students.**

All Division 02 students continue to Questions 41 – 50.

ATTENTION: All Division 01 students, <u>STOP HERE</u>.
                 All Division 02 students, continue to question #50.

41. For the figure shown, the variable resistance of the outer circuit, R_{Outer}, is decreasing at a constant rate. While this is occurring, in which direction is the magnetic field associated with the outer circuit at the point P in the plane of the circuit and in which direction is the conventional current through the resistor R_{Inner} in the smaller interior circuit? The two circuits lie on a flat table.

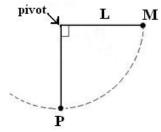|	**Magnetic Field at P**	**Current through R_{Inner}**
(A)	Into the page	From X to Y
(B)	Into the page	From Y to X
(C)	Into the page	There is no current.
(D)	Out of the page	From X to Y
(E)	Out of the page	From Y to X

42. A parallel-plate capacitor of capacitance C has an insulating dielectric material of constant κ filling the entire region between its plates. This capacitor now is connected to a battery of voltage V and is fully charged before the battery is disconnected. The capacitor stores energy U.
Using insulating gloves, a person now removes the dielectric from the capacitor. After equilibrium is established following the removal of the dielectric, which one of the following choices best represents the energy stored by the capacitor in terms of U?

(A) $\kappa^2\,U$ (B) $\kappa\,U$ (C) U (D) U/κ (E) U/κ^2

43. A standing wave is created in an air-filled tube open at both ends when a tuning fork of frequency $552\ Hz$ is placed near one of the open ends. A tuning fork of frequency $644\ Hz$ produces the next highest harmonic for this tube. What is the length of the open tube? Assume room temperature.

(A) $0.46\ m$ (B) $0.92\ m$ (C) $1.59\ m$ (D) $1.85\ m$ (E) $3.70\ m$

44. One mole of a monatomic ideal gas undergoes an isobaric expansion. In the process, the temperature of the gas increases from 300 K to 500 K. Which one of the following choices best represents the amount of work done by the gas on the surroundings?

(A) $665\ J$ (B) $1110\ J$ (C) $1660\ J$ (D) $2490\ J$ (E) $4160\ J$

45. An object is placed in front of a thin converging lens resulting in a focused image forming on a screen. If the bottom half of the lens were covered with black paper, what happens to the image on the screen?

(A) There is no change of any kind to the image.
(B) Only the top half of the object is focused into an image on the screen.
(C) Only the top half of the object is focused into an image on the screen and it now is half the size.
(D) The image is fully formed, only it now is half as large.
(E) The image is fully formed, only it is dimmer.

46. A hollow conducting sphere in static equilibrium is isolated in deep space with a net excess charge $+Q$ on it. What is the electric potential (assuming $V(r \to \infty) = 0$) at the position labeled P shown in the interior of the figure? The sphere has radius $R = 3a$ and the point of interest is at a location $r = 2a$ from the center of the sphere at an angle of $60°$ with respect to the $+x$-axis.

(A) 0   (B) $kQ/(2a)$ (C) $kQ/(3a)$ (D) $kQ/(4a)$ (E) $\sqrt{3}kQ/(4a)$

47. A simple pendulum of length L has a point mass M released from rest from the horizontal position shown. In the absence of air resistance and friction, the mass swings through the arc of a circle. Let T represent the magnitude of the force from the string on the mass (tension), G represent the magnitude of the gravitational force acting on the mass by the earth, and F represent the magnitude of the net force acting on the mass. Which one of the following choices describes the relationship among these forces when the mass swings at the bottom of the arc (point P)?

(A) $G < F < T$
(B) $F < G = T$
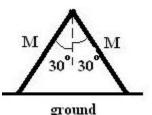(C) $F < G < T$
(D) $T < F < G$
(E) $G = F < T$

48. An electromagnetic wave has a magnetic field given by the expression (in Cartesian coordinates) $\vec{B}(x, y, z, t) = (6.0 \times 10^{-6}) \cos(2.21 \times 10^7 z - 6.63 \times 10^{15} t) \, \hat{x}$. At time $t = 0$ and position $x = y = z = 0$, what is the direction of the electric field associated with this wave?

(A) $+ x$ (B) $- x$ (C) $+ y$ (D) $- y$ (E) $+ z$

49. An inverted "V" in static equilibrium is made from two uniform beams each of mass $M = 12 \, kg$. Each beam of the "V" has the same length and makes an angle of $30°$ with the vertical as shown in the diagram. Which one of the following choices best represents the magnitude of the static friction force acting on the left leg of the "V" from the level ground? The coefficient of static friction between each beam and the ground is $\mu_s = 0.76$.

(A) 26.3 N   (B) 34.6 N   (C) 45.6 N   (D) 69.3 N   (E) 91.2 N

50. A person sets a one-meter long stick so that it makes a $30°$ angle with the x-axis. An observer in a space ship moving along the x-axis measures the angle of the stick to be $60°$ with the x-axis. With what speed is the space ship moving in terms of the speed of light, c?

(A) $\frac{1}{2}c$ (B) $\frac{\sqrt{2}}{3}c$ (C) $\frac{3}{4}c$ (D) $\frac{2}{\sqrt{5}}c$ (E) $\frac{2\sqrt{2}}{3}c$

IMPORTANT: All Division 02 students <u>STOP HERE</u>. Your last answer should be for #50.