PHYSICSBOWL 2023

March 22 – April 14, 2023

40 QUESTIONS – 45 MINUTES

The 2023 PhysicsBowl, organized by the **American Association of Physics Teachers**, is an opportunity to recognize outstanding high school physics students and their teachers through their performance on this year's contest.

- Schools compete in one of <u>two</u> divisions, each with <u>nineteen</u> regions.
  - *Division 1* is for students *taking physics for the first time* (even if that first course is AP Physics).
  - *Division 2* is for students taking a second (or more) course in physics OR anyone wanting a challenge.
- A school's team score in each division is the sum of the ***<u>five</u>*** highest student scores in that division.
- A school may compete in either or both divisions.

INSTRUCTIONS

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

- Your *<u>Name</u>*
- Your *<u>Teacher's AAPT Teacher code</u>* (given to you by your teacher – only ***one*** code per school!)
- Your *<u>Region</u>* (given to you by your teacher)
- Your *<u>Division</u>* (1 for first-year physics students, 2 for students in a 2nd physics course OR wanting a challenge)

If this information is not properly bubbled, ***you will be disqualified,*** as your official score will be a zero.

Your *<u>School's CEEB code</u>* (given to you by your teacher), though not required, is helpful in the event of a disqualification for identifying your school.

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 answer only 40 questions.

> **Division 1 students will answer only questions 1 – 40.** Do not answer questions 41 – 50.
>
> **Division 2 students will answer only questions 11 – 50.** Do not answer questions 1 – 10.

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 the contest may be used.

Time limit: *<u>45 minutes.</u>*

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!

DIVISION 1 STUDENTS

START HERE.

DIVISION 2 STUDENTS

Go to question #11 on page 4.

Treat $g = 10.0\ \frac{m}{s^2}$ for ALL questions.

1. Earth satellites such as the International Space Station orbit at altitudes that are mainly above Earth's atmosphere. A simple and accurate way to comprehend the orbit of these satellites is to view them as
   a. balanced between gravitational and centripetal forces.
   b. beyond the main pull of Earth's gravity.
   c. in mechanical equilibrium with a net force of zero.
   d. having sufficient tangential velocities to fall around rather than into Earth.
   e. All of the above.

2. To break a board, a typical karate chop delivers 3000 N of force to the board. The force that the board exerts on the hand during the chop is
   a. less than 3000 N. b. 3000 N. c. greater than 3000 N.
   d. dependent upon the type of wood.
   e. dependent upon the speed of the karate chop.

3. All of the following are base units of the SI system except:
   a. kilogram b. kelvin c. meter d. volt e. candela

4. The speed of sound in air depends upon
   a. frequency b. wavelength c. amplitude
   d. speed of the sound source e. temperature of the air

5. There are 6.02×10^{23} carbon atoms (Avogadro's number) in 12.0 g of carbon. If you could count one atom each second, how much time would it take to count the atoms in 1.0 g of carbon?
   a. 1.59×10^{15} days b. 1.59×10^{15} weeks c. 1.59×10^{15} years
   d. 1.59×10^{18} weeks e. 1.59×10^{18} years

6. Consider one horizontal circular path that a ball makes on the inside surface of a cone. In this situation, the normal force on the ball
   a. is mg.
   b. is always greater than mg.
   c. may be greater or less than mg.
   d. is always less than mg.
   e. depends upon the speed of the ball.

7. A Boeing 737 jet is landing with a speed of 69 m/s. The jet touches down and has 750 m of runway in which to reduce its speed to 6.1 m/s. What is the average acceleration, assumed to be uniform, of the plane during landing?
    a. $-0.32\ \frac{m}{s^2}$ b. $-3.2\ \frac{m}{s^2}$ c. $-6.3\ \frac{m}{s^2}$ d. $-32\ \frac{m}{s^2}$ e. $-63\ \frac{m}{s^2}$

8. What does a Venturi meter measure?
    a. fluid pressure b. fluid density c. fluid speed
    d. fluid flow e. fluid temperature

9. A force applied to a rocket gives it an upward acceleration equal to 2 times the acceleration of gravity. The magnitude of the force is equal to:
    a. One-half the weight of the rocket
    b. The weight of the rocket
    c. Two times the weight of the rocket
    d. Three times the weight of the rocket
    e. Four times the weight of the rocket

10. A 0.200 kg mass attached to the end of a spring moves up and down through 10 cycles in 6.50 s. What is the force constant of the spring
    a. 18.7 N/m b. 4.67 N/m c. 22.8 N/m d. 5.95 N/m e. 12.0 N

DIVISION 1 STUDENTS

Continue

Answer questions #11 through #40.

DIVISION 2 STUDENTS

START HERE

Numbers 1 – 10 on your answer sheet should be blank. Your first answer should be for #11.

Treat $g = 10.0\ \frac{m}{s^2}$ for ALL questions.

11. A block of wood is floating on water. If you push down on the block until it is completely submerged, the buoyant force acting on it
    a. increases.
    b. decreases.
    c. stays the same.
    d. is dependent upon the type of wood.
    e. is dependent upon the depth to which the block is pushed.

12. On December 21, 1968, NASA launched Apollo 8. This was the first manned mission to the moon, and after 68 hours, went into orbit around the moon but never landed on the surface. That was reserved for Apollo 11. During one five-minute portion of the launch, Apollo 8 increased its speed from 7,600 to 10,800 meters per second. What was the acceleration of Apollo 8 during this time period?
    a. $8.92\ \frac{m}{s^2}$ b. $53.3\ \frac{m}{s^2}$ c. $64.0\ \frac{m}{s^2}$ d. $10.7\ \frac{m}{s^2}$ e. $18.7\ \frac{m}{s^2}$

13. An older and heavier sister can balance on a seesaw with her younger and lighter brother. This can happen because of balanced
    a. forces. b. torques. c. momenta. d. energies. e. inertia.

14. Any atom that emits an alpha particle or a beta particle
    a. always becomes an atom of a different element.
    b. may become an atom of a different element.
    c. becomes a different isotope of the same element.
    d. increases its mass.
    e. becomes highly reactive.

15. If the sun collapsed suddenly to become a black hole, the Earth would
    a. continue in its present orbit.
    b. fly off tangential to the current orbital path.
    c. likely be pulled into the black hole.
    d. be pulled apart by tidal forces.
    e. Both C & D.

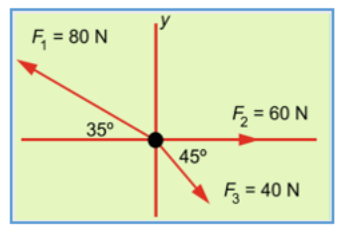
16. On October 4, the 2022 Nobel Prize in Physics was awarded to three individuals, Alain Aspect, John F. Clauser, and Anton Zeilinger, for experiments with entangled photons. In how many other categories are Nobel Prizes awarded?
    a. One   b. Two   c. Three   d. Four   e. Five

17. A person has a height 1.8 m. Beginning directly under a streetlight that is 6 m above the ground, they walk away from their starting position at 7 m/s. Find the speed at which the top of the person's shadow moves.
    a. 6 m/s.   b. 8 m/s   c. 10 m/s   d. 12 m/s   e. 14 m/s

18. A curious physics student drops a rock from a cliff that is 5.0 m above a pond. The rock hits the water with velocity v and then sinks to the bottom with the constant velocity v. It reaches the bottom of the pond 5.0 s after it is dropped. Find the depth of the lake
    a. 10 m   b. 20 m   c. 30 m   d. 40 m   e. 50 m

19. A hot air balloon is moving up at 10 m/s. At a height of 100 m above the ground, a package is released from the balloon. How much time does it take the package to reach the ground after being released?
    a. 4.58 s   b. 5.58 s   c. 4.24 s   d. 5.24 s   e. 4.64 s

20. Three vector forces F_1, F_2, and F_3 act on a particle that has a mass of 3.00 kg as shown in in the diagram at right. What is the particle's acceleration?
    a. 9.49 m/s^2 b. 9.59 m/s^2 c. 9.69 m/s^2
    d. 9.79 m/s^2 e. 9.89 m/s^2



21. A crate slides down a ramp with a rough surface that is inclined to the horizontal at 30°. If 70% of the initial potential energy is dissipated during the descent, find the coefficient of sliding friction
    a. 0.20   b. 0.30   c. 0.40   d. 0.50   e. 0.60

22. LaGrange Point 2 is a location in space where the gravitational attraction of the sun is equal to the gravitational attraction of the Earth. The sun is 1.5 X 10^8 km from Earth, and it has a mass that is 3.24 X 10^5 times that of Earth. How far from Earth, along a line to the sun, must an object be located to be in this location?
    a. 1.50 X 10^6 km   b. 1.83 X 10^6 km   c. 1.53 X 10^6 km
    d. 3.26 X 10^6 km   e. 3.06 X 10^6 km

23. A pendulum clock has a period of 1.0 s and gives the correct time on the ground at a certain location. It is then moved to the top of a building that is 320 m high. How much time will the pendulum lose in 1 day at this height?
    a. 2.25 s   b. 2.88 s   c. 3.42 s   d. 3.94 s   e. 4.32 s

24. An M-80 (BIG firecracker) is detonated in a valley formed between two parallel mountains. The first echo is heard 2.0 s after the detonation and the second echo is heard 2.0 s after the first one. What is the width of the valley?
    a. 340 m   b. 740 m   c. 1080 m   d. 1360m   e. 1700 m

25. A spark is produced between two insulated surfaces, maintained at a constant potential difference of 5.0 X 10^6 V. The energy output is 10^{-5} J. How many electrons have been transferred in the spark?

    a. 1.25 X 10^7 b. 1.20 X 10^7 c. 1.35 X 10^7 d. 1.25 X 10^6 e. 1.25 X 10^8

26. Atoms in a solid are not stationary. They vibrate about their equilibrium positions. Typically, the frequency of vibration is about 2.0 X 10^{12} Hz, and the amplitude is about 1.1 X 10^{-11} m. For a typical atom, what is its maximum speed?

    a. 108 m/s b. 10.8 m/s c. 128 m/s d. 12.8 m/s e. 138 m/s

27. A pendulum has a length of 2.00 m and has a mass attached to its end. The mass is pulled back 60.0° from the vertical before being released and allowed to swing downward. If the string breaks under a tension of more than 20 N, what is the maximum amount of mass that can be attached to string to allow the mass to swing without breaking the string?

    a. 0.8 kg b. 1.0 kg c. 1.2 kg d. 1.4 kg e. 1.6 kg

28. On November 16, 2022, the Artemis 1 rocket lifted off from Launch Pad 39 at Cape Canaveral, FL for its trip to the moon. To lift off, the engines supplied 8.8 million pounds (4.0 x 10^7 N) of thrust. Which of the following does NOT express this thrust force?

    a. 4.0 x 10^{10} mN
    b. 4.0 x 10^4 kN
    c. 4.0 x 10^1 MN
    d. 4.0 x 10^{-3} GN
    e. 4.0 x 10^{-5} TN

29. Small particles with a mass of 0.10 kg are allowed to fall from a height of 1.6 m before colliding with the pan of a balance. The collisions occur at 441 particles/min, what will the balance register if the collisions of the particles are perfectly elastic?

    a. 0.43 kg b. 0.53 kg c. 0.73 kg d. 0.83 kg e. 0.93 kg

30. Earth rotates once every 23 h 56 min around an axis that runs from the North to South Pole. What is the angular velocity of the Earth?

    a. 7.29 X 10^{-5} rad/s b. 7.59 X 10^{-5} rad/s c. 7.09 X 10^{-5} rad/s
    d. 4.37 X 10^{-3} rad/s e. 4.37 X 10^{-5} rad/s

31. When riding the *Wild Thing* roller coaster, the passengers feel 50% heavier than their actual weight as the car goes through a dip with a 30 m radius of curvature. What is the car's speed at the bottom of the dip?

    a. 14.3 m/s b. 11.1 m/s c. 12.3 m/s d. 10.1 m/s e. 15.0 m/s

32. As an airplane is flying, it is determined that the airflow speed past the lower surface of the wing is 100 m/s. What speed of airflow over the upper surface of the wing would give a pressure difference of 1000 Pa? 1.293 $\frac{kg}{m^3}$ is the density of the air.

    a. 102 m/s b. 103 m/s c. 105 m/s d. 108 m/s e. 111 m/s

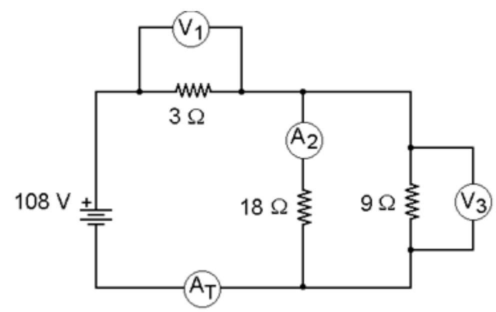
33. A high-voltage power transmission line is to supply power at 104 kW. The electricity travels through 30 km of cable that has a resistance $0.7\frac{\Omega}{km}$. Find the rate of energy loss if the power is transmitted at 100 kV.

    a. 4.2%　　b. 4.9%　　c. 2.1%　　d. 9.8%　　e. 6.4%

34. A sample of an ideal gas is being held at a constant pressure. What happens to the internal energy of the gas if 10 J of heat energy are transferred to the gas?

    a. Increases by 10 J　　b. Increases by <10 J　　c. Increases by >10 J
    d. Remains unchanged　　e. More information is needed

35. Before testing the circuit shown at right, and taking the current and voltage readings, a student is asked to predict what the meters will read at each location indicated. What will be the ammeter reading at A_2?



    a. 2.0 A　　b. 12 A　　c. 8.0 A
    d. 6.0 A　　e. 4.0 A

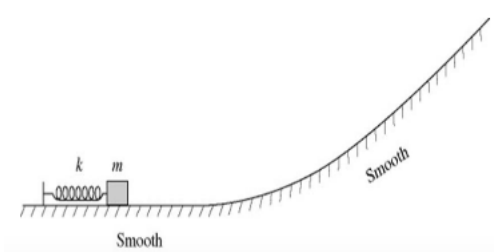
36. Light is refracted when it passes from air into glass. Which of these wave properties changes?

    a. Speed only　　b. Wavelength only　　c. Frequency only
    d. Both speed and wavelength　　e. Both speed and frequency

37. Imagine that you're standing on the surface of a planet that shrinks to 1/10 of its original diameter with no change in mass. Your weight on the shrunken planet would be

    a. 1/100 as much.　　b. 1/10 times as much.　　c. 10 times as much.
    d. 100 times as much.　　e. 1000 times as much.

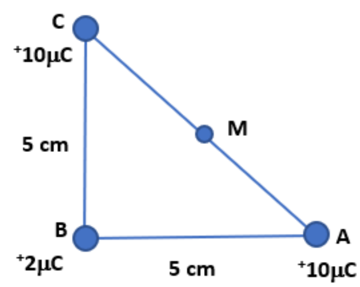
38. A box of mass *m* is pressed against (but is not attached to) an ideal spring of force constant *k* and negligible mass. The spring is compressed a distance *x*. After it is released, the box slides up a frictionless incline as shown in the diagram at right and eventually stops. If we repeat this experiment with a box of mass *2m*



    a. the lighter box will go twice as high up the incline as the heavier box.
    b. just as it moves free of the spring, the lighter box will be moving twice as fast as the heavier box.
    c. both boxes will have the same speed just as they move free of the spring.
    d. both boxes will reach the same maximum height on the incline.
    e. just as it moves free of the spring, the heavier box will have twice as much kinetic energy as the lighter box.

39. A 20 L tank of oxygen has a pressure of 0.30 atm and a temperature of 300 K. A 30 L tank of nitrogen has a pressure of 0.60 atm and a temperature of 300 K. The oxygen is transferred to the nitrogen tank where the two mix. What is the pressure of the mixture if its temperature stays at 300 K?
   a. 0.70 atm   b. 0.75 atm   0.78 atm   d. 0.80 atm   e. 0.90 atm

40. Three charges are located at the vertices of a right triangle as shown at right. What is the magnitude of the resultant electric field at the midpoint, *M*, on a line between *A* and *C*?
   a. 1.44×10^7 N/C
   b. 1.84×10^7 N/C
   c. 1.14×10^7 N/C
   d. 2.64×10^7 N/C
   e. 1.04×10^7 N/C



DIVISION 1 STUDENTS

STOP HERE

Your last answer should be for #40. Numbers 41-50 should remain blank for Division 1 students.

DIVISION 2 STUDENTS

CONTINUE

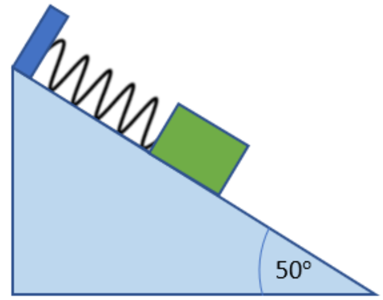
Answer questions #41 through #50.

Treat $g = 10.0\ \frac{m}{s^2}$ for ALL questions.

41. For a particular conductor, the magnetic flux density and current are at right angles to one another. The component of force acting on the conductor is
   a. BIL cos θ   b. BIL sin θ   c. BIL tan θ   d. BL sin θ   e.BL cos θ

42. A satellite with a mass of 2500 kg is in orbit around Earth. If a second satellite with a mass 5000 kg, is to be placed at the same orbital distance from Earth, the second satellite must have a speed which is:
   a. half the speed of the lighter satellite.
   b. twice the speed of the lighter satellite.
   c. the same speed as the lighter satellite.
   d. four times the speed of the lighter satellite.
   e. dependent upon the location from which it is launched.

43. A block with a mass of 1.5 kg is at rest on a ramp as shown at right. The ramp is angled at 50° to the horizontal and has a rough surface with coefficients of static and kinetic frictions that are μ_s=0.65 and μ_k=0.3, respectively. The block is being held in place by a spring with k=40 N/m. What is the minimum distance the spring must be stretched in order for the block to be at rest?



a. 0.043 m b. 0.053 m c. 0.13 m
d. 0.17 m e. 0.21 m

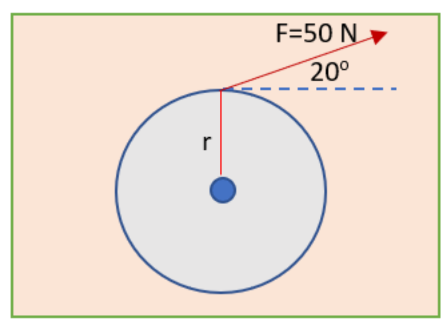
44. Two quantities are found to be inversely proportional to one another. When analyzing this relationship, a graph between y and $\frac{1}{x}$ is plotted. This graph would show:

a. a straight line bisecting the *y-axis.*
b. a straight line through the origin.
c. a parabolic curve.
d. a hyperbolic curve.
e. a straight line bisecting the $\frac{1}{x}$ *-axis.*

45. An electron moves in a circle with radius 1.9 m in a magnetic field of 3.0 X 10^{-5} T. What is the frequency with which this electron revolves around the circle?

a. 8.4 X 10^5 Hz b. 6.4 X 10^5 Hz c. 9.4 X 10^5 Hz
d. 8.4 X 10^4 Hz e. 6.4 X 10^4 Hz

46. A thin cylindrical wheel has a of radius of 40 cm and is allowed to spin on a frictionless axle. The wheel, which is initially at rest, has a force of 50 N applied at 20° from the perpendicular to its radius as shown. The wheel has a moment of inertia of 20 kg·m^2. What is the wheel's angular speed after 3.0 s?



a. 1.82 rad/s b. 2.00 rad/s c. 2.42 rad/s
d. 2.82 rad/s e. 3.00 rad/s

47. A small rocket with a mass of 5000 kg is to be launched vertically. What rate of ejection of gas, with an exhaust speed 1000 m/s, is necessary to provide the thrust to impart an initial upward acceleration of 2 g?

a. 50 kg/s b. 100 kg/s c. 150 kg/s d. 200 kg/s e. 250 kg/s

48. The focal lengths of the objective and eyepiece convex lenses are in the ratio 8:1 for a particular telescope. The telescope is pointed at a building that is 10 km from the telescope and is 100 m tall. What is the distance to the image?

a. 56.2 m b. 156.2 m c. 98.4 m d. 142 m e. 33. 4 m

49. A circuit consists of a resistor, capacitor, and inductor connected in series to an AC source. As the source frequency increases, the current in the circuit decreases. Which statement about the circuit is NOT correct as the source frequency increases?

   a. The impedance of the circuit increases.
   b. The circuit is said to become more capacitive than inductive.
   c. The phase angle for the circuit becomes more positive.
   d. The inductive reactance increases.
   e. The total power from the source decreases

50. An electron (e^-) is moving and has kinetic energy of 1.00 MeV. It makes a head-on collision with a positron (e^+) that is at rest. In the collision the two particles annihilate each other and are replaced by two photons (γ) of equal energy, each traveling at angles θ to the electron's original direction of motion. The reaction is $e^- + e^+ \rightarrow 2\gamma$. Determine the angle of emission θ of each photon.

   a. 15.3° b. 25.3° c. 35.3° d. 45.3° e. 55.3°