PHYSICSBOWL 2022

March 23 – April 15, 2022

40 QUESTIONS – 45 MINUTES

The 2022 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 two divisions, each with nineteen 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 ***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 *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* (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 *School's CEEB code* (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: *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!

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. A 20,000 kg truck is traveling at 25 km/hr. At what speed does a 1000 kg car need to travel to have the same kinetic energy as the truck?
   a. 112 km/hr b. 132 km/hr c. 102 km/hr d. 79.0 km/hr e. 89.0 km/hr
2. Who was the *last* person to walk on the Moon?
   a. Buzz Aldrin b. Eugene Cernan c. Neil Armstrong
   d. Sally Ride e. Gus Grissom
3. Two bodies of equal mass are moving in circular paths at equal speed. The first body moves in a circle whose radius is twice that of the second. The ratio of the radial acceleration of the first body to that of the second is:
   a. 1 to 4 b. 1 to 3 c. 1 to 2 d. 1 to 1 e. 1 to 0.5
4. A bullet with a mass of 5.0 g is fired horizontally into a 2.0 kg wooden block which is resting on a horizontal table. The bullet stops in the block and the block and bullet combination move 2.0 m. The coefficient of kinetic friction between the block and surface of the table is 0.2. Find the initial speed of the bullet.
   a. 1123 m/s b. 1134 m/s c. 1132 m/s d. 113.2 m/s e. 113.4 m/s
5. A car is moving along a straight horizontal road at a speed of 20 m/s. The brakes are applied and a constant force of 5000 N brings the car to a stop in 10 s. What is the mass of the car?
   a. 1250 kg b. 2500 kg c. 5000 kg d. 7500 kg e. 10,000 kg
6. Two forces have magnitudes of 11.0 N and 5.0 N. The magnitude of their sum could NOT be equal to which of the following values?
   a. 16.0 N b. 9.0 N c. 7.0 N d. 5.0 N e. 6.0 N
7. Which of the following colors of visible light has the longest wavelength?
   a. Violet b. Yellow c. Blue d. Green e. Red

8. An increase in the translational motion of the molecules of a gas confined in a steel tank will be observed in one of the following ways. It will produce an increase in:
    a. the temperature of the gas only.
    b. the pressure of the gas only.
    c. both the temperature and pressure of the gas.
    d. the temperature of the gas and a decrease in its pressure.
    e. the volume of the gas.

9. When descending mountain roads, large trucks pulling a heavy load can burn up the brakes. Once the brakes are no longer useful, the driver may need to guide the truck up a "runaway truck lane" on the side of the road. The runaway truck lane is directed uphill and often has a thick layer or sand or gravel or both on the surface. Which of the following is **one** of the reasons the truck will stop?
    a. An increase in kinetic energy
    b. A decrease in potential energy
    c. A decrease in fuel
    d. A transfer of energy to the gravel on the track of the runaway truck lane
    e. The change in temperature of the engine

10. A 4.0 kg mass at the end of a spring moves with simple harmonic motion on a horizontal frictionless table with a period of 2.0 s and an amplitude of 2.0 m. Determine the maximum force exerted on the spring.
    a. 25.1 N b. 158 N c. 39.5 N d. 63.0 N e. 79.0 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.

The following information is to be used for Questions 11 & 12:

The James Webb Space Telescope was launched on December 25, 2021 and arrived at its destination, LaGrange Point 2, on January 24, 2022. This point is approximately 1,500,000 km from the Earth and it is where the telescope will orbit the sun.

11. What was James Webb's former occupation?
    a. Astronomer
    b. Telescope designer/engineer
    c. Silicon valley entrepreneur and financier of the telescope project
    d. Space shuttle astronaut/pilot
    e. NASA Administrator

12. How long will it take the radio signal sent by the James Webb Space Telescope to reach the Earth?
    a. 0.005 s b. 0.05 s c. 5 s d. 50 s e. 5000 s

13. A car engine moves a piston with a circular cross-section of 7.500 cm in diameter a distance of 3.250 cm to compress the gas in the cylinder. By what amount is the gas decreased in volume?
    a. 143.6 cm^3 b. 153.6 cm^3 c. 662.7 cm^3 d. 682.7 cm^3 e. 88.36 cm^3

14. A fisherman watches a dolphin leap out of the water at an angle of 35^o above the horizontal. The horizontal component of the dolphin's velocity is 7.7 m/s. Find the magnitude of the vertical component of the velocity.
    a. 4.4 m/s b. 6.3 m/s c. 11 m/s d. 5.4 m/s e. 3.2 m/s

15. Two simple pendula are 60 cm and 63 cm in length. They hang vertically, one in front of the other. If they are set in motion simultaneously, find the time taken for one to gain a complete cycle of oscillation on the other.
    a. 15.4 s b. 15.7 s c. 31.5 s d. 62.4 s e. 79.7 s

16. If a copper wire is stretched to make it 0.1% longer, what is the percentage change in its resistance?
    a. 0.01% b. 0.1% c. 0.2% d. 0.4% e. 0.5%

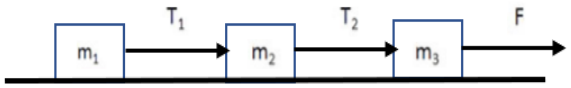
17. A block of wood initially at rest slides down an inclined plane. Neglecting friction, the kinetic energy of the block at the bottom of the plane is:
    a. all converted into heat.
    b. less than its kinetic energy at the top of the plane.
    c. dependent on the materials of which the block is made.
    d. dependent on the materials of which the inclined plane is made.
    e. equal to its potential energy (with respect to the bottom of the plane) when it was at the top of the plane.

18. In the last one second of a free fall, an apple traveled three-fourths of its total path. From what height did the apple fall?
    a. 10 m b. 15 m c. 20 m d. 25 m e. 30 m

19. A helicopter with a mass of 700 kg will hover when its rotating blades move through an area of 50 m^2. Find the average speed imparted to the air (density of air = 1.3 kg/m^3)
    a. 7.66 m/s b. 10.4 m/s c. 16.5 m/s d. 38.0 m/s e. 44.1 m/s

20. A refrigerator has a mass of 150 kg and rests in the open back end of a delivery truck. If the truck accelerates from rest at 1.5 m/s^2, what is the minimum coefficient of static friction between the refrigerator and the bed of the truck that is required to prevent the refrigerator from sliding off the back of the truck?
    a. 0.08 b. 0.10 c. 0.12 d. 0.15 e. 0.18

21. Three blocks (m_1=1 kg, m_2=2 kg, m_3=3 kg) connected by cords are pulled by a constant force, F, of 18 N on a frictionless horizontal table. T_2 is the tension in the rope between m_2 and m_3. What is T_2?



    a. 3 N b. 6 N c. 9 N d. 12 N e. 15 N

22. An object starting from rest moves on a circular path with a radius 40 cm and a constant tangential acceleration of 10 cm/s^2. How much time is needed after the motion begins for the centripetal acceleration of the object to be equal to the tangential acceleration?
    a. 0.2 s b. 1.0 s c. 1.2 s d. 1.8 s e. 2.0 s

23. The distance between the electron and the proton in the hydrogen atom is about 0.53×10^{-10} m. By what factor is the electrical force between the electron and proton stronger than the gravitational force between them?
    a. 1.3×10^{39} b. 2.3×10^{39} c. 3.3×10^{39} d. 4.3×10^{39} e. 5.3×10^{39}

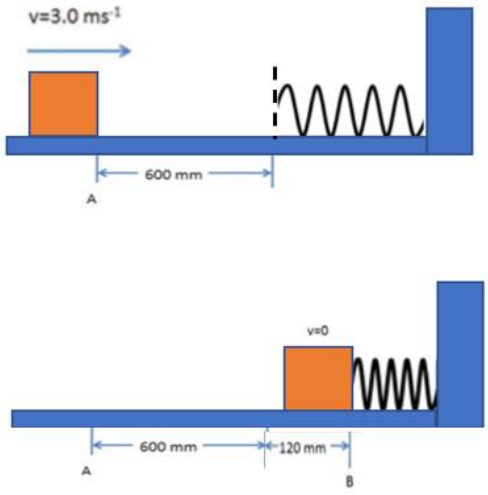
24. A 3.00 kg bucket of water is raised with an upward acceleration of 2.20 m/s^2 from a well by means of an attached rope. What is the tension in the rope?
    a. 30.2 N b. 33.3 N c. 36.6 N d. 39.0 N e. 43.2 N

25. Two light waves, initially emitted in phase, will interfere constructively with maximum amplitude if the path-length difference between them is:
    a. 1.5 wavelengths
    b. one wavelength
    c. one-half wavelength
    d. one-quarter wavelength
    e. one-eighth wavelength

26. For an object moving in uniform circular motion, the magnitude of the centripetal acceleration is given by $a_c = v^2/r$, where v is the speed of the object, and r is the radius of the circle. The "jerk" is the rate of change of acceleration. For uniform circular motion, the magnitude of the jerk is given by:
    a. zero b. v^2/r c. $v^2 r$ d. v^3/r e. v^3/r^2

27. A machine gun fires 100 g bullets at a speed of 1000 m/s. The person holding the machine gun in their hands can exert an average force of 150 N against the gun. If the gun is to remain stationary, what is the maximum number of bullets that can be fired per minute?
    a. 10 b. 15 c. 30 d. 60 e. 90

28. A spring with spring constant k = 20 kN/m, is used to stop a 50 kg box that is sliding on a horizontal surface. The spring is initially in its equilibrium state. At position *A*, shown in the top diagram, the box has a speed of 3.0 m/s. The compression of the spring when the box is instantaneously at rest (position *B* in the bottom diagram) is 120 mm. Determine the coefficient of kinetic friction between the box and the surface.
    a. 0.125
    b. 0.230
    c. 0.245
    d. 0.280
    e. 0.315



29. A cyclist, using a power meter while on a training ride, checks and sees that she is doing work at the rate of 500 W. How much average force does her foot exert on the pedals when she is traveling at 8.0 m/s?
    a. 31 N b. 63 N c. 80 N d. 320 N e. 710 N

30. A ticker tape timer is operating at 60 Hz. It was used to analyze the motion of a battery-powered car. The following displacements were measured for five intervals on the ticker tape.

	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5
Displacement	0.055 m	0.065 m	0.055 m	0.070 m	0.060 m

What is the average speed of the car?

a. 0.612 m/s b. 3.66 m/s c. 0.366 m/s d. 0.947 m/s e. 6.32 m/s

31. Water drips from the nozzle of a shower onto the floor 2.45 m below. The drops fall at regular intervals of time, the first drop striking the floor at the instant the third drop begins to fall. Measured from the shower head, what is the location of the second drop when the first drop strikes the floor.

a. 0.313 m b. 0.613 m c. 0.938 m d. 1.25 m e. 1.563 m

32. A star initially has a radius of 6×10^8 m and a period of rotation about its axis of 30 days. Eventually, it collapses to form a neutron star with a radius of only 1×10^4 m and a period of 0.1 s. Assuming that the mass has not changed, find the ratio of initial and final angular momentum of the star.

a. 15.92 b. 214.6 c. 103.1 d. 442.1 e. 138.9

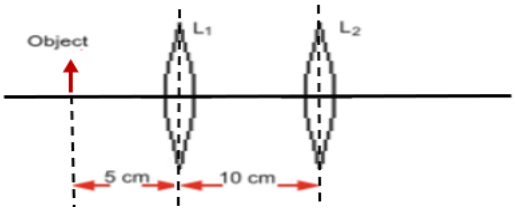
33. For ordinary conversation, a sound level meter reads 60 dB. What is the intensity of this sound wave?

a. 6.0×10^{-6} W/m^2 b. 1.0×10^{-4} W/m^2 c. 6.0×10^{-4} W/m^2
d. 1.0×10^{-6} W/m^2 e. 1.0×10^{-8} W/m^2

34. A tiny ball with a mass of 0.6 g carries a charge of magnitude 8 μC. It is suspended by a thread in a downward directed electric field of intensity 300 N/C. What is the tension in the thread if the charge on the ball is positive?

a. 2.40×10^{-3} N b. 6.00×10^{-3} N c. 8.40×10^{-3} N
d. 6.00×10^{-2} N e. 6.24×10^{-3} N

35. A combination of two thin convex lenses is placed as shown at right. An object is placed 5 cm in front of L_1 which has a focal length of 10 cm. L_2 is 10 cm behind L_1 and has a focal length of 12 cm. How far from L_2 is the final image for this lens combination?



a. 8 cm b. 15 cm c. 22 cm d. 24 cm e. 30 cm

36. A thick glass plate has parallel sides. A beam of white light is incident on one side at an angle between 0° and 90° with the normal. Which color emerges from the other side first?

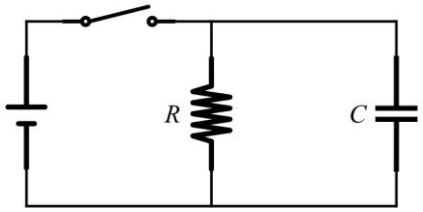
a. All of them b. red c. green d. violet e. None of them

37. A car and a truck are both traveling with a constant speed of 20 m/s. The car is 10 m behind the truck. The truck driver suddenly applies his brakes, causing the truck to slow to a stop at the constant rate of 2 m/s^2. Two seconds later, the driver of the car applies their brakes and just manages to avoid a rear-end collision. Determine the constant rate at which the car slowed.

a. 3.33 m/s^2 b. 4.33 m/s^2 c. 1.33 m/s^2 d. 3.03 m/s^2 e. 3.93 m/s^2

38. In the circuit shown below, the voltage source, switch, capacitor and connecting wires have no resistance. Let ΔV_R and ΔV_C represent the potential differences across the resistor and the capacitor, respectively. The capacitor is initially uncharged. Which of the following choices correctly compares these potential differences immediately after the switch is closed and after the circuit has reached steady state.

	Switch Closed	Steady State
a.	$\Delta V_R = \Delta V_C$	$\Delta V_R = \Delta V_C$
b.	$\Delta V_R > \Delta V_C$	$\Delta V_R = \Delta V_C$
c.	$\Delta V_R = \Delta V_C$	$\Delta V_R < \Delta V_C$
d.	$\Delta V_R > \Delta V_C$	$\Delta V_R < \Delta V_C$
e.	$\Delta V_R < \Delta V_C$	$\Delta V_R > \Delta V_C$



39. A radioactive carbon-14 nucleus decays into a beta particle, an antineutrino, and a nitrogen-14 nucleus. In a particular decay, the beta particle has momentum, *p*, and the nitrogen nucleus has momentum of magnitude *4p/3* at an angle of 90^o to *p*. At what angle (with respect to the beta particle) do you expect the antineutrino to be emitted?

a. 53^o b. 37^o c. 90^o d. 127^o e. 33^o

40. An Olympic ice skater in Beijing spins at 4π rad/s with her arms extended. If her moment of inertia with arms folded is 80% of that with arms extended, what is her angular velocity when she folds her arms?

a. π rad/s b. 2π rad/s c. 3π rad/s d. 5π rad/s e. 6π rad/s

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.

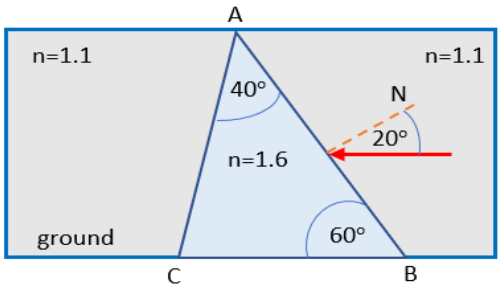
41. A weather balloon is loosely filled with 2.0 m^3 of helium at 1.0 atm and 27 °C. The balloon is then released. When it has reached an elevation of 7000 m, the pressure has dropped to 0.41 atm and the balloon has expanded. If the temperature at this elevation is −31 °C, what is the new volume of the balloon?

    a. 2.7 m^3 b. 3.2 m^3 c. 3.9 m^3 d. 4.6 m^3 e. 5.1 m^3

42. Three resistors of 4 Ω, 6 Ω, and 12 Ω are connected in parallel. This parallel arrangement is then connected in series with a 1-Ω and a 2-Ω resistor. A potential difference of 120 V is applied across the ends of the circuit. What will be the potential drop across the part of the circuit connected in parallel?

    a. 12 V b. 48 V c. 24 V d. 36 V e. 72 V

43. A triangular glass prism (n = 1.6) is immersed in a liquid (n = 1.1) as shown. A laser light is incident as shown on face *AB* making an angle of 20° with the normal (*N*). Calculate the angle that the ray emerging from *AC* makes with the ground when it leaves *AC* and strikes the ground.



    a. 28.1° b. 30.3° c. 33.8° d. 36.1° e. 18.9°

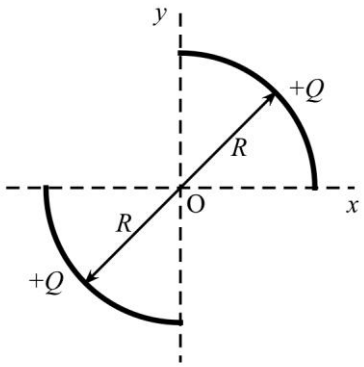
44. How long would it take 4.0×10^{20} nuclei to decay to 1.0×10^{19} atoms if their half-life was 14.7 years?

    a. 29.4 years b. 58.8 years c. 78.2 years d. 147 years e. 161 years

45. An electric field of 1500 V/m and a magnetic field act on an electron moving with a speed of 3000 m/s. If the resultant force is to be zero, what should be the strength of the magnetic field?

    a. 0.35 T b. 0.50 T c. 0.72 T d. 0.81 T e. 0.96 T

46. Each of the two curved rods shown in the picture form one-quarter of a circle with a radius *R*. Both rods carry a uniformly-distributed electric charge +*Q*. Which of the following choices correctly expresses the net electric field and net electric potential at the origin? Assume $V \to 0$ as $r \to \infty$.

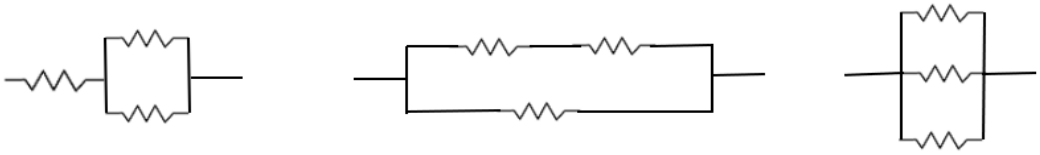


	Electric Field	Electric Potential
a.	zero	zero
b.	zero	$\frac{2kQ}{R}$
c.	$\frac{2kQ}{R^2}$	zero
d.	$\frac{\sqrt{2kQ}}{R^2}$	$\frac{2kQ}{R}$
e.	$\frac{2kQ}{R^2}$	$\frac{2kQ}{R}$

47. A shipping box in a warehouse has a mass of 2.00 kg and slides down an inclined plane that makes an angle of 30° with the horizontal. The coefficient of kinetic friction between the box and the plane surface is 0.866. How much force (parallel to the incline) should be applied to the box so that it moves down the plane at constant speed?

a. 5.00 N b. 6.50 N c. 3.80 N d. 4.60 N e. 11.0 N

48. The diagram below shows combinations X, Y, and Z of three identical resistors. What is the correct order of the **total** resistance of the combinations going from **lowest** resistance to **highest** resistance?



Combination X **Combination Y** **Combination Z**

a. Y, X, Z b. Z, X, Y c. X, Y, Z d. Z, Y, X e. Y, Z, X

49. If the Earth suddenly stopped in its orbit, and the orbit is assumed to be circular, how much time would elapse before it falls into the Sun?

a. 147 minutes b. 1.22 days c. 64.5 days d. 228 days e. 2.34 years

50. An ideal gas system, with an initial volume of 1.0 m^3 at standard temperature and pressure, undergoes the following three-stage cycle: Stage 1 – an isothermal expansion to twice its original volume. Stage 2 – a process by which its volume remains constant, its pressure returns to its original value and 104 J of heat is added to the system. Stage 3 – an isobaric compression to its original volume, with 3×10^4 J of heat being removed from the system. Calculate the work done on the system during Stage 3.
    a. -7.005×10^4 J
    b. -1.013×10^4 J
    c. -1.013×10^5 J
    d. -7.050×10^5 J
    e. -2.030×10^5 J