PHYSICSBOWL 2018

March 28 – April 13, 2018

40 QUESTIONS – 45 MINUTES

The sponsors of the 2018 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 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. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

Division 1 students will answer only questions 1 – 40. Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

Division 2 students will answer only questions 11 – 50. Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 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 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!

ATTENTION: All Division 1 students – START HERE.
All Division 2 students – Begin on *question #11*.

***** Treat $g = 10.0\ {}^{m}/_{s^2}$ for ALL questions #1 – #50.**

1. A quick Google search reveals that your phone operates at a frequency of 850 x 10^6 Hz. Which of the following choices best represents this frequency using metric prefixes?
(A) 850 μHz **(B)** 850 mHz **(C)** 850 kHz **(D)** 850 MHz **(E)** 850 GHz

2. A standard metal electroscope is positively charged. A person that is grounded (neutral charge) then touches the top portion of the electroscope with their finger. Which one of the following choices most correctly explains what happens when the finger touches the electroscope?
(A) The leaves of the electroscope come back together because excess protons conduct to the finger from the electroscope.
(B) The leaves of the electroscope come back together because electrons conduct to the electroscope from the finger.
(C) The leaves remain where they are as nothing occurs.
(D) The leaves of the electroscope move apart as electrons conduct from the electroscope to the finger.
(E) The leaves of the electroscope move apart as protons conduct from the finger to the electroscope.

3. Which of the following is *NOT* a vector quantity?
(A) Acceleration **(B)** Average velocity **(C)** Linear momentum **(D)** Potential energy **(E)** Force

4. A ball is thrown vertically downward with an initial speed of 12.0 m/s from a height of 10.0 m above the ground. Ignoring air resistance, what is the speed of the ball when it reaches the ground?
(A) 18.5 m/s **(B)** 14.6 m/s **(C)** 14.0 m/s **(D)** 12.8 m/s **(E)** 12.0 m/s

5. A particle travels at a constant speed around a circular path of radius *R*. If the particle makes one complete trip around the entire circle, what is the magnitude of the displacement for this trip?
(A) πR **(B)** $2R$ **(C)** $2\pi R$ **(D)** $4R$ **(E)** 0

6. What temperature on the Kelvin scale is equivalent to 37° Celsius?
(A) 310 K **(B)** 283 K **(C)** 256 K **(D)** 37 K **(E)** 19 K

7. What is the percent uncertainty in the measurement 2.54 ± 0.16 cm?
(A) 2.9% **(B)** 6.3% **(C)** 8.7% **(D)** 12.6% **(E)** 14%

8. An Olympic bobsled needs to negotiate a 100 m radius turn at 35 m/s without skidding. What minimum banking angle of the turn is needed for this to happen? (Ignore friction.)
(A) 21° **(B)** 31° **(C)** 41° **(D)** 51° **(E)** 61°

9. The mean diameter of the Earth is 12.76 x 10^3 km. What is the surface area of the Earth in m^2?
(A) 4.01 x 10^7 **(B)** 5.12 x 10^{14} **(C)** 1.09 x 10^{21} **(D)** 1.68 x 10^9 **(E)** 2.05 x 10^{15}

10. A 2.0 m long organ pipe which is open at both ends resonates at its fundamental frequency. Neglecting any end effects, what wavelength is formed by this pipe in this mode of vibration?
(A) 1 meter **(B)** 2 meters **(C)** 4 meters **(D)** 6 meters **(E)** 8 meters

All Division 2 students START HERE. Numbers 1 – 10 on your answer sheet should be blank. Your first answer should be for #11.

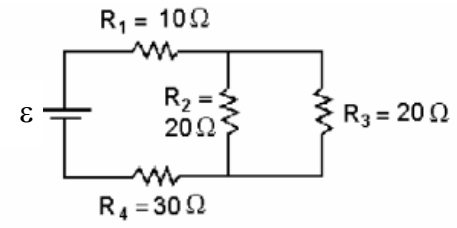
***** Treat $g = 10.0\ {}^{m}/_{s^2}$ for ALL questions #1 – #50.**

11. In a classroom demonstration, a teacher discussing the air in the room as an ideal gas slides a solid barrier of negligible thickness into place, cutting the room into two equal-sized volumes. What is the air pressure for the portion of the room in which the teacher is standing, assuming the original pressure in the whole room was P? Treat the room as a sealed container.

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

12. What is the equivalent resistance in the circuit that is shown at right?

(A) 55 Ω
(B) 80 Ω
(C) 50 Ω
(D) 45 Ω
(E) 75 Ω



13. An x-ray photon collides with a free electron, and the photon is scattered. During the collision:

(A) there is conservation of momentum but not energy
(B) there is conservation of neither momentum nor energy
(C) there is conservation of energy but not momentum
(D) there is conservation of both momentum and energy
(E) impossible to predict if momentum and energy are conserved without additional information

14. Three identical wood blocks are raced across three different flat surfaces, with the faces of the blocks on the surfaces. Each block is pulled horizontally with the same force F from one edge by a light string attached to the block. Block 1 is pulled on a frictionless surface. Block 2 is pulled on a surface with a nonzero kinetic friction coefficient, and a zero static friction coefficient. Block 3 is pulled on a surface with a nonzero static friction coefficient, and the same kinetic coefficient as for Block 2, where $\mu_k < \mu_s$. If each block starts from rest and is pulled until traveling the same fixed horizontal distance, which of the following choices correctly ranks the times (t_1, t_2, t_3) it takes for each block to traverse the distance?

(A) $t_1 < t_2 < t_3$ **(B)** $t_1 = t_2 = t_3$ **(C)** $t_1 < t_2 = t_3$ **(D)** $t_3 < t_2 < t_1$ **(E)** $t_2 < t_3 < t_1$

15. A sample of ideal gas is in a container at a temperature of 100 °C and a pressure of 2.5 atm. If the volume of the container is 0.025 m^3, approximately how many molecules of gas are in the container?

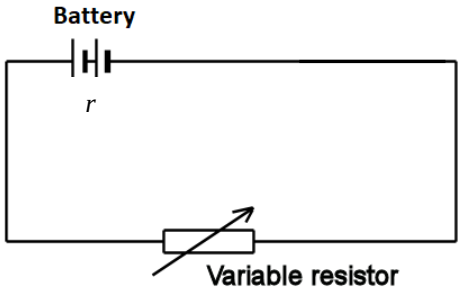
(A) 4.58×10^{24} **(B)** 1.23×10^{24} **(C)** 6.25×10^{23} **(D)** 4.53×10^{22} **(E)** 1.21×10^{22}

16. Determining the area under an object's acceleration vs. time graph for a fixed time interval will calculate

(A) the object's average velocity during the time interval
(B) the object's velocity at the end of the time interval
(C) the object's average speed during the time interval
(D) the object's change in velocity during the time interval
(E) the object's velocity at the time midway through the time interval

17. A thick-walled metal pipe of length 20.0 cm has an inside diameter of 2.00 cm and an outside diameter of 2.40 cm. What is the total surface area of the pipe, including the inside, outside, and ends, in cm^2?
(A) 276 **(B)** 277 **(C)** 278 **(D)** 279 **(E)** 282

18. The circuit shown contains a battery with an internal resistance, *r* connected to a variable resistor. When the resistance of the variable resistor is increased, which of the following statements is true?
(A) The terminal voltage increases.
(B) The current through the variable resistor in the circuit increases.
(C) The power dissipated by the internal resistance increases.
(D) The potential difference across the variable resistor decreases.
(E) None of the above statements are true.



19. Which of the following *could* produce an enlarged but inverted image of a real object?
(A) A converging lens placed at a distance greater than its focal length from the object.
(B) A converging lens placed at a distance less than its focal length from the object.
(C) A diverging lens placed at a distance less than the magnitude of its focal length from the object.
(D) A diverging lens placed at a distance greater than the magnitude of its focal length from the object.
(E) It is not possible to create the type of image desired.

20. A frictionless, solid disk pulley has a mass of 7.07 kg, a radius of 66.0 cm, and is free to rotate vertically about an axle. A rope is wrapped around the disk, a 1.53 kg mass is attached to the end of the rope, and the mass is allowed to fall vertically. What is the angular acceleration of the pulley?
(A) 4.58 rad/s^2 **(B)** 7.98 rad/s^2 **(C)** 9.87 rad/s^2 **(D)** 2.25 rad/s^2 **(E)** zero

Questions 21 & 22 relate to the following information

A small object is released from rest and reaches the ground in a time of 2.50 s. Neglect air resistance.

21. With what speed does the object reach the ground?
(A) 31.3 m/s **(B)** 25.0 m/s **(C)** 12.5 m/s **(D)** 10.0 m/s **(E)** 2.50 m/s

22. From what height above the ground was the object released?
(A) 6.25 m **(B)** 12.5 m **(C)** 25.0 m **(D)** 31.3 m **(E)** 62.5 m

23. Induced electric currents due to changing magnetic flux can be explained using which **<u>one</u>** of the following laws?
(A) Gauss's Law **(B)** Faraday's Law **(C)** Ohm's Law **(D)** Ampere's Law **(E)** Volta's Law

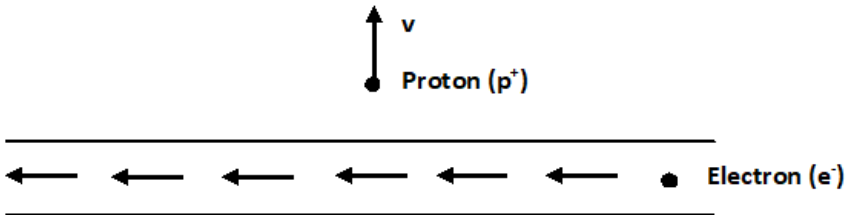
24. A small ball is thrown at an angle of 30.0^o above the horizontal ground with a speed of 20.0 m/s. What is the maximum height above the launch point to which the ball rises? Ignore air resistance.
(A) 2.5 m **(B)** 5.0 m **(C)** 10.0 m **(D)** 15.0 m **(E)** 20.0 m

25. In a circuit, the flow of electrons in a horizontal wire produces a constant current of 3.20 A for a time of 3.0 hours. Which of the following choices best represents the number of electrons that pass through a vertical cross-section of wire during this time?
(A) 9.6 **(B)** 6.00×10^{19} **(C)** 7.20×10^{22} **(D)** 2.16×10^{23} **(E)** 6.02×10^{23}

26. A simple pendulum consists of a mass *M* attached to a string of length *L* of negligible mass. For this system, when undergoing small oscillations
(A) the frequency is proportional to the amplitude.
(B) the period is proportional to the amplitude.
(C) the frequency is independent of the mass *M*.
(D) the frequency is independent of the length *L*.
(E) the frequency is inversely proportional to the length *L*

27. Electrons flow from right to left in a wire. A proton is directly above the wire and moving upward as shown. What is the direction of the magnetic force on the proton?

(A) to the left
(B) to the right
(C) into the plane of the page
(D) out of the plane of the page
(E) toward the wire



28. At the top of a high cliff, a small rock is dropped from rest. A ball is launched straight downward with an initial speed of 36.0 m/s at a time of 2.10 s after the rock was dropped from the same cliff. When the ball has fallen 28.0 m further than the initially dropped rock, what is the speed of the ball relative to the rock?
(A) 15.0 m/s **(B)** 16.0 m/s **(C)** 20.0 m/s **(D)** 21.0m/s **(E)** 36.0m/s

29. An object that is 8.60 cm tall is placed in front of a convex mirror. The resulting image is 7.60 cm tall, and 14.2 cm from the mirror. What is the focal length of the mirror?
(A) -122 cm **(B)** -105 cm **(C)** 14.0 cm **(D)** –16.9 cm **(E)** -4.2 cm

30. A radian per second is a unit of:
(A) angular displacement
(B) angular velocity
(C) angular acceleration
(D) angular momentum
(E) rotational kinetic energy

31. A standing transverse wave is formed on a tightly stretched string. The distance between a node and an adjacent antinode is:
(A) 1/8 wavelength
(B) 1/4 wavelength
(C) 1/2 wavelength
(D) 1 wavelength
(E) unable to be determined without more information.

32. For a negative point charge, the electric field vectors:
(A) circle the charge
(B) point radially in toward the charge
(C) point radially away from the charge
(D) pass directly through the charge
(E) cross at infinity

33. A torque of 150 Newton-meters causes the driveshaft of a car to rotate at 450 radians per second. How much power is produced by this torque?
(A) 53,300 W **(B)** 67,500 W **(C)** 70,000 W **(D)** 72,500 W **(E)** 75,000 W

34. For the hydrogen atom, which series describes electron transitions to the N=1 orbit, the lowest energy electron orbit?
(A) Lyman series **(B)** Balmer series **(C)** Paschen series **(D)** Curie series **(E)** Bohr series

35. 200 turns of wire are wrapped on a square frame with sides 18 cm. A uniform magnetic field is applied perpendicular to the plane of the coil. If the field changes uniformly from 0.50 T to 0 in 8.0 s, find the average value of the induced *emf*.
(A) 2.05 V **(B)** 4.05 V **(C)** 0.205 V **(D)** 0.405 V **(E)** 0.605 V

36. A 0.30 kg mass is suspended on a vertical spring. In equilibrium the mass stretches the spring 2.0 cm downward. The mass is then pulled an additional distance of 1.0 cm down and released from rest. What is the period of oscillation?
(A) 0.14 s **(B)** 0.28s **(C)** 0.024 s **(D)** 0.046 s **(E)** 0.064 s

37. An electron is traveling due north and has a speed of 4.0×10^5 m/s. It enters a region where the Earth's magnetic field has the magnitude 5.0×10^{-5} T to the north and directed downward at 45° below the horizontal. What is the magnitude of the force acting on the electron?
(A) 2.3×10^{-18} N **(B)** 3.2×10^{-18} N **(C)** 4.2×10^{-18} N **(D)** 2.5×10^{-19} N **(E)** 3.23×10^{-19} N

38. Why does the sky appear to be more blue when looking directly overhead than it does when looking toward the horizon?
(A) The atmosphere is denser at higher altitude than it is at the Earth's surface.
(B) The temperature of the upper atmosphere is higher than it is at the Earth's surface.
(C) There are fewer clouds directly overhead than near the horizon.
(D) The sunlight travels over a longer path at the horizon, resulting in more scattering.
(E) The sunlight entering the atmosphere from directly above undergoes greater refraction and dispersion.

39. A mass that is in simple harmonic motion obeys the following position versus time equation: $y = (0.50 \text{ m}) \sin(\pi/2\ t)$ where t is in seconds. What is the period of vibration of this mass?
(A) 1.0 s **(B)** 2.0 s **(C)** 3.0 s **(D)** 4.0 s **(E)** 5.0 s

40. Which of the following wavelengths (in nm) of electromagnetic radiation will produce photoelectrons of the least kinetic energy if the radiation is incident on a material with a work function of 4.80 eV?
(A) 992 **(B)** 496 **(C)** 248 **(D)** 124 **(E)** 62

IMPORTANT: All Division 1 students <u>STOP HERE</u>. Your last answer should be for #40. Numbers 41-50 should remain blank for Division 1 students.

All Division 2 students continue to Questions 41 – 50.

IMPORTANT: All Division 1 students, STOP HERE.
All Division 2 students, continue to questions #50.

41. An object of mass *m* is initially at rest. After this object is accelerated to a speed of 2.40 x 10^8 m/s, it collides with and sticks to a second object of mass *m* that is at rest. Immediately after the collision, what is the common speed of the two masses?
(A) 2.25 x 10^8 m/s **(B)** 1.80 x 10^8 m/s **(C)** 1.66 x 10^8 m/s **(D)** 1.50 x 10^8 m/s **(E)** 1.20 x 10^8 m/s

42. Two moles of an ideal gas absorbs 2100 J of heat during an isobaric process. If the gas changes temperature by 36 ℃ during the process, which one of the following choices could identify the gas?
(A) Carbon monoxide **(B)** Water vapor **(C)** Ammonia **(D)** Helium **(E)** Hydrogen sulfide

43. In August of 2017, the gravitational waves from the collision and merger of two neutron stars were detected. After their collision, several forms of electromagnetic radiation were subsequently detected. What was the first type of electromagnetic radiation detected after the gravitational waves were detected?
(A) Gamma rays **(B)** Visible light **(C)** Radio waves **(D)** X-rays **(E)** Microwaves

44. Which of the following terms/quantities is most closely associated with "the measure of resistance of an object to length change under lengthwise tension or compression"?
(A) Bulk modulus **(B)** Plastic deformation **(C)** Shear modulus **(D)** Elastic limit **(E)** Young's modulus

45. According to Lenz's law, the direction of an induced current in a conductor will be that which tends to produce which of the following effects?
(A) Enhance the effect which produces it.
(B) Produce a greater heating effect.
(C) Oppose the greatest voltage.
(D) Oppose the effect which produces it.
(E) Enhance the greatest voltage.

46. When an ideal gas is taken through an isochoric process,
(A) ΔU=0 **(B)** W=0 **(C)** Q=0 **(D)** ΔU=W **(E)** none of the above

47. The existence of the neutrino was proposed to explain
(A) alpha decay **(B)** gamma emission **(C)** beta decay **(D)** fission **(E)** fusion

48. A series RC circuit has a resistance of $2.00\ \Omega$ and a capacitance of $0.010\ F$. A student plots the natural log of the current in the circuit as a function of time while the capacitor is charging. Which one of the following choices best represents the numerical value associated with the slope of the resulting line?
(A) 0.02 **(B)** -0.02 **(C)** 50 **(D)** -50 **(E)** 0.5

49. A particle has a total energy of $500\ MeV$ and a linear momentum of $300\ \frac{MeV}{c}$. What is the mass of the particle?
(A) $800\ \frac{MeV}{c^2}$ **(B)** $583\ \frac{MeV}{c^2}$ **(C)** $400\ \frac{MeV}{c^2}$ **(D)** $267\ \frac{MeV}{c^2}$ **(E)** $200\ \frac{MeV}{c^2}$

50. Two spheres are heated to the same temperature and allowed to radiate energy to identical surroundings. The spheres have the same emissivity, but one sphere has twice the diameter of the other. If the smaller sphere radiates energy at a rate *P*, at what rate will the larger sphere radiate energy?
(A) *P* **(B)** *2 P* **(C)** *4 P* **(D)** *8 P* **(E)** *16 P*

IMPORTANT: All Division 2 students STOP HERE. Your last answer should be for #50.