PHYSICSBOWL 2025

March 19 – April 4, 2025

40 QUESTIONS – 45 MINUTES

The 2025 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.

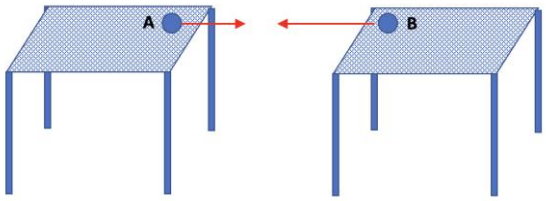
DIVISION 2 STUDENTS

Go to question #11 on page 4.

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

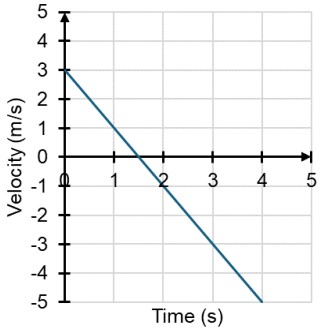
1. Your sister is 50 m ahead of you and walking at a speed of 1 m/s away from you. You run to catch up to her at a speed of 2.5 m/s. How much time does it take for you to catch her?
   a. 14 s b. 20 s c. 33 s d. 72 s e. 125 s

2. Two identical balls **A** and **B** are aimed at each other and roll off the edges of two identical horizontal tabletops at exactly the same time. Each ball has sufficient velocity to land under the opposite table, but ball **B** has a greater initial velocity than ball **A**. What will happen as they fall?



   a. Ball **B** will pass over the top of ball **A** as they fall.
   b. Ball **A** will pass over the top of ball **B** as they fall.
   c. The two balls will collide as they fall.
   d. The two balls may collide only if their velocities are exactly the right values.
   e. Ball **B** will hit the floor before ball **A**.

3. Which of the following mathematical expressions matches the velocity-time graph shown at right?
   a. $v(t) = (-2\ \text{m/s})\ t + (3\ \text{m/s})$
   b. $v(t) = (1.25\ \text{m/s}^2)\ t + (-3\ \text{m/s})$
   c. $v(t) = (2\ \text{m/s}^2) + (-3\ \text{m/s})$
   d. $v(t) = (-2\ \text{m/s}^2)\ t + (3\ \text{m/s})$
   e. $v(t) = (-3\ \text{m/s})\ t + (2\ \text{m/s})$



4. NASA launched Apollo 8 on December 21, 1968. What was unique about this mission?
   a. It was the first mission to land on the moon without a crew.
   b. It was the first mission to fly to the moon with a crew.
   c. It was longest mission to the moon.
   d. It was the shortest mission to the moon.
   e. It was a one-way mission to the moon.

5. A simple pendulum is hanging from the ceiling of a train car. It is observed to hang at 10^o to the right of vertical. Which of the following could describe this observation?
    a. The train car is at rest.
    b. The train car is accelerating to the left.
    c. The train car is moving with constant velocity to the left.
    d. The train car is accelerating to the right.
    e. The train car is moving with constant velocity to the right.

6. Which of the following two quantities have the same dimensions?
    a. Work and torque
    b. Power and moment of inertia
    c. Work and angular displacement
    d. Force and angular momentum
    e. Power and radius of circular motion

7. A researcher is measuring the average speed of a moving object over a known distance. The distance, d=5.0 m, is measured with an uncertainty of ±0.1 m, and the time t=1.00 s is measured with an uncertainty of ±0.02 s. All uncertainties are independent and random. What is the uncertainty in measured average speed?
    a. ±0.04 m/s
    b. ±0.08 m/s
    c. ±0.12 m/s
    d. ±0.14 m/s
    e. ±0.18 m/s

8. A swimmer is swimming in a slowly moving stream. Which of the following is NOT true?
    a. To have the largest speed relative to shore, the swimmer should swim downstream.
    b. To have the smallest speed relative to shore, the swimmer should swim upstream.
    c. The swimmer can achieve the same speed relative to shore swimming upstream or downstream.
    d. To cross the river in the shortest amount of time the swimmer should swim perpendicularly across the stream.
    e. The swimmer's speed relative to shore will depend on the speed of the stream's current.

9. A shopping cart with a speed of v_0 is brought to rest by an applied force. If the time interval over which the force is applied is increased, then bringing the cart to rest requires
    a. a smaller force.
    b. the same force.
    c. a larger force.
    d. another applied force acting in the same direction as the original applied force.
    e. a frictional force opposing the cart's motion.

10. An impulse of 10 N•s is acting on a 5 kg object. By how much will the object's velocity change?
    a. $0\,\frac{m}{s}$ b. $0.5\,\frac{m}{s}$ c. $2.0\,\frac{m}{s}$ d. $2.5\,\frac{m}{s}$ e. $5.0\,\frac{m}{s}$

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.

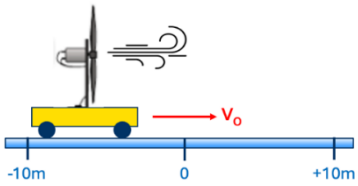
11. A solid disk of mass 5 kg and radius of 0.4 m is released from rest and rolls without slipping down a 5 m long incline that makes a 30° angle from the horizontal. What will be the linear velocity of the disk's center of mass at the bottom of the incline.
    a. $2.2\ \frac{m}{s}$ b. $4.2\ \frac{m}{s}$ c. $5.7\ \frac{m}{s}$ d. $7.0\ \frac{m}{s}$ e. $8.3\ \frac{m}{s}$

12. A simple pendulum consists of a small mass *m* attached to a massless string of length *L*. It is displaced to an angle θ_o from the vertical and released from rest. Assume no air resistance. At the lowest point of its swing, the pendulum bob collides elastically with another stationary bob of equal mass *m*, which is free to move after the collision. What is the maximum angle θ_f the original pendulum bob reaches after the collision?
    a. $\theta_f = \theta^o$ b. $\theta_f = \theta^o/4$ c. $\theta_f = \theta^o/2$ d. $\theta_f = 0$ e. $\theta_f = 2\theta^o$

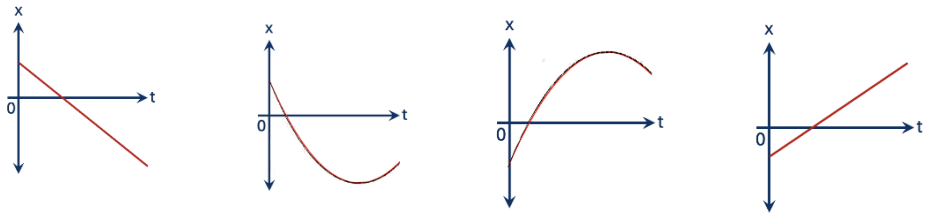
13. A box of mass *m* is given an initial speed *v* and slides along a horizontal surface. The coefficient of kinetic friction between the box and the surface is μ. The box stops after sliding a distance *d*. The stopping distance, *d*, would be doubled if which of the following quantities were doubled?
    a. only the mass of the box.
    b. only the initial speed of the box.
    c. only the coefficient of friction between the box and the surface.
    d. only the mass of the box and the coefficient of friction between the box and the surface.
    e. only the initial speed of the box and the coefficient of friction between the box and the surface.

14. Which of the following scientists is credited with first introducing the concept that energy is quantized, laying the foundation for quantum mechanics?
    a. Niels Bohr
    b. Erwin Schrödinger
    c. Max Planck
    d. Albert Einstein
    e. Louis de Broglie

15. A fan cart with an initial velocity is located on a level track with an initial position as shown. The cart's fan is blowing air to the right. Which of the following *position versus time* graphs corresponds to the cart's subsequent motion?



a. b. c. d.



16. A 50-kg person stands on a bathroom scale inside of an elevator. The scale reads 400 N. Which of the following could describe how the elevator is moving?
    a. The elevator is moving up while decreasing speed at a rate of 2 $\frac{m}{s^2}$.
    b. The elevator is moving up while increasing speed at a rate of 2 $\frac{m}{s^2}$.
    c. The elevator is moving up at a constant speed of 2 $\frac{m}{s}$.
    d. The elevator is moving down while decreasing speed at a rate of 2 $\frac{m}{s^2}$.
    e. The elevator is moving down at a constant speed of 2 $\frac{m}{s}$.

17. The sun radiates approximately 4×10^{26} W of power. It has a surface temperature of 5800K. If the temperature were twice as high (11600 K), how much power would it radiate?
    a. The same amount, 4×10^{26} W
    b. 2X as much
    c. 4X as much
    d. 8X as much
    e. 16X as much

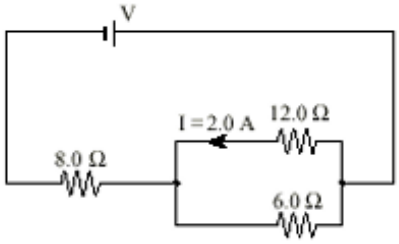
18. A particle with a mass of 10.0 g has an elastic, head-on collision with a second particle, also with a mass of 10.0 g, on frictionless, horizontal surface (such as an air hockey table). The collision has a coefficient of restitution, e = 1.0. Determine the percent loss of kinetic energy in the collision.
    a. 0% b. 25% c. 50% d. 75% e. 100%

19. Which of the following Physics Nobel Laureates does not have degree in physics?
    a. Albert Einstein
    b. Guglielmo Marconi
    c. Riccardo Giacconi
    d. George Smith
    e. Peter Higgs

20. A bike and rider with a combined mass of 70 kg ride through a curve of radius of 20 m at a speed of 11 $\frac{m}{s}$. The road is wet and the coefficient of static friction between the road and the tires is 0.50. Which of the following correctly explains whether the bike and rider will slip and why.
    a. The bike slips because the maximum speed the bike can go around the curve without slipping is 10 m/s.
    b. The bike slips because the force the tires exert on the road is greater than the friction component of the force the road exerts on the tires.
    c. The bike does not slip because the maximum speed the bike can go around the curve without slipping is 15 m/s.
    d. The bike does not slip because the force the tires exert on the road is less than the friction component of the force the road exerts on the tires.
    e. The bike does not slip because the coefficient of static friction is too large.

21. An object with a mass of 0.250 kg is moving through space with a linear velocity only and a kinetic energy of 1.000 J. Determine the magnitude of the momentum of this object as it is moving through space with a linear velocity.
    a. p= 0.500 $\frac{kg\ m}{s}$
    b. p= 0.707 $\frac{kg\ m}{s}$
    c. p= 1.000 $\frac{kg\ m}{s}$
    d. p= 0.250 $\frac{kg\ m}{s}$
    e. p= 1.414 $\frac{kg\ m}{s}$

22. What is the voltage, *V*, of the power supply shown in this circuit?
    a. 24 V
    b. 30 V
    c. 52 V
    d. 72 V
    e. 96 V



23. A ball is launched at 20° above the horizontal on a flat horizontal field. At what other launch angle (with respect to the horizontal) would the ball have the same horizontal range if fired at the same speed?
    a. 30° b. 45° c. 60° d. 70° e. 80°

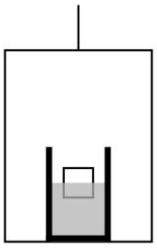
24. A mass on a spring executes simple harmonic motion with an amplitude of 10.0 cm and a period of 2.0 s. The average velocity of the mass over one complete oscillation is …
    a. 0.0 $\frac{cm}{s}$ b. 5.0 $\frac{cm}{s}$ c. 10.0 $\frac{cm}{s}$ d. 15.0 $\frac{cm}{s}$ e. 20.0 $\frac{cm}{s}$

25. An ideal atomic gas is a hypothetical gas model where atoms are considered as non-interacting, point-like particles that move randomly and collide elastically. What is the adiabatic index of an ideal diatomic gas?
    a. 1.00 b. 1.29 c. 1.33 d. 1.40 e. 1.67

26. Auroras produced in the Earth's atmosphere often occur following a phenomenon known as a CME, which is an abbreviation for …
    a. Carbon Molecule Excitation
    b. Celestial Magnetic Event
    c. Coronal Mass Ejection
    d. Cosmic Microwave Energy
    e. Coupled Monopolar Electromagnetism

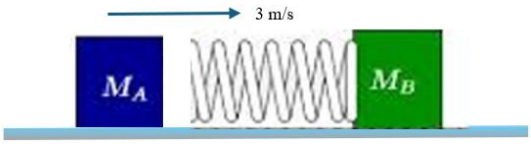
27. A block of wood is given a certain speed at the bottom of a rough ramp. The block slides a certain distance up the ramp and returns to the point from which it was launched. Let t_{up} represent the time it takes the block to travel up the ramp to its highest point and t_{down} represent the time it takes the block to travel down the ramp to the bottom. Let a_{up} represent the magnitude of the block's acceleration while traveling up the ramp and a_{down} represent the block's acceleration while traveling down the ramp. Which of the following correctly compares these quantities?
    a. $t_{up} > t_{down}$ and $a_{up} < a_{down}$
    b. $t_{up} < t_{down}$ and $a_{up} > a_{down}$
    c. $t_{up} = t_{down}$ and $a_{up} = a_{down}$
    d. $t_{up} > t_{down}$ and $a_{up} > a_{down}$
    e. $t_{up} < t_{down}$ and $a_{up} < a_{down}$

28. A container filled with water is placed in an elevator. When the elevator is at rest, a small block floats in the water with 50% of its volume submerged. If the elevator accelerates up with a constant acceleration of $0.1g$, what percentage of the block's volume will be submerged? Treat water as an incompressible fluid.



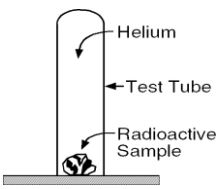
    a. 5%
    b. 45%
    c. 50%
    d. 55%
    e. e. 95%

29. M_A has a mass of 10 kg and slides to the right at 3 m/s across a level, frictionless surface towards M_B that has a mass of 6 kg and is initially at rest. There is a massless, ideal spring with k=540 N/m on the left side of M_B. The spring is initially compressed and held so that it will not release until the impact with M_A. After the collision, M_A is a rest. How far was the spring compressed from its natural length in meters?



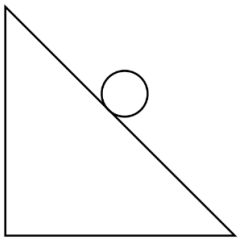
    a. 0.333 b. 0.200 c. 0.250 d. 0.111 e. 0.063

30. The diagram on the right shows an inverted test tube over a sample of a radioactive material. Helium has collected in the test tube. The presence of helium indicates that the sample is most probably undergoing the process of
    a. alpha decay b. neutron decay c. beta decay
    d. proton decay e. gamma emission



31. A mass, m =1.0 kg, is pulled on a horizontal table by a force F = 2 N, directed to the right. A small kinetic friction force $F_{friction}$ = 1 N acts on the mass while it is being pulled and the mass accelerates to the right with an acceleration, $a_1 = 1\ \frac{m}{s^2}$. The system then undergoes two changes:
i) m_1 is doubled
ii) $F_{friction}$ is doubled
Which of the following statements about the new acceleration, a_2, is correct?
    a. The magnitude of a_2 increases by a factor of 2.
    b. The magnitude of a_2 decreases by a factor of 0.5.
    c. $0 > a_2 < a_1$.
    d. $0 > a_1 < a_2$.
    e. $a_2 = 0\ \frac{m}{s^2}$.

32. In the diagram on the right, a ball is rolling down an incline. The direction of the normal force that the incline exerts on the ball is…

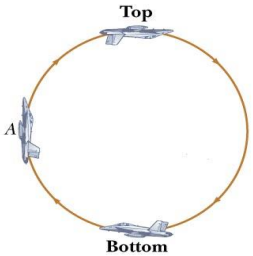


    a. perpendicular to the surface.
    b. about 75 degrees measured from the surface.
    c. parallel to the surface.
    d. about 115 degrees measured from the surface.
    e. about 180 degrees measured from the surface.

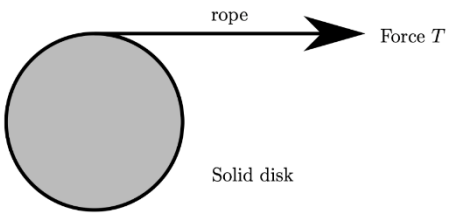
33. A sealed cylindrical container of height h is divided into two equal volumes by a frictionless, thermally insulated piston of negligible mass. The lower half of the container contains n moles of an ideal monatomic gas at an initial temperature T_1 and pressure P_1. The upper half is initially evacuated (vacuum). The piston is released, allowing the gas to expand into the entire container. Assuming the process is adiabatic, and the gas reaches a new equilibrium state, what is the final temperature T_f of the gas?
    a. $T_f = T_1$ b. $T_f = T_1(\frac{1}{2})^{\frac{2}{3}}$ c. $T_f = T_1(\frac{1}{2})^{\frac{2}{5}}$ d. $T_f = \frac{T_1}{2}$ e. $T_f = 0$

34. A transverse standing wave containing four loops is created on a string that is fixed at both ends. The string has a linear density μ. A second string with the same length and a linear density of 4μ now replaces the first string. When placed under the same tension and vibrated at the same frequency, the standing wave produced on the second string will contain …
    a. 1 loop. b. 2 loops. c. 4 loops. d. 8 loops. e. 16 loops.

35. An airplane is flying in a vertical loop. At the bottom of the loop, the forces on the pilot are such that…
    a. $F_N > F_g$.
    b. $F_N = F_g$.
    c. $F_N < F_g$.
    d. F_N cannot be determined without knowing the plane's speed.
    e. F_g decreases.

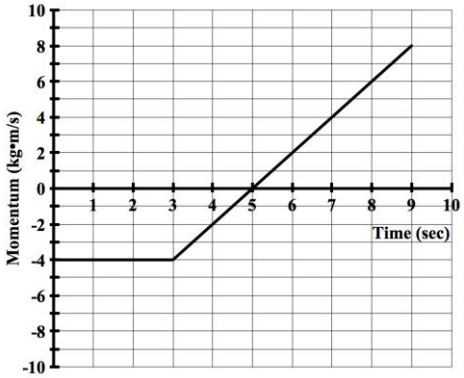


36. A solid disk of mass, *M*, moment of inertia, *I*, and radius, *R*, is at rest with its circular face on a horizontal, frictionless table as shown in this overhead view. A rope is wrapped around the disk tightly and pulled with a force of *T*. The disk moves linearly and rotationally as the force, *T*, accelerates the disk along the table. After the disk has accelerated some distance, determine the ratio of the translational Kinetic Energy to the total Kinetic Energy of the disk. ($KE_{translational}$ /KE_{total})



   a. I/MR^2
   b. MR^2/I
   c. I^3/MR^2
   d. $I/(MR^2+I)$
   e. $MR^2/(MR^2+I)$

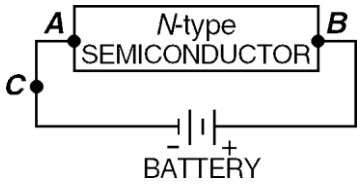
37. The graph shows the momentum of a particle as a function of time. What net impulse acted on the particle from t = 0.0 sec to t = 9.0 sec?



   a. 0.0 N•s
   b. 1.3 N•s
   c. 2.0 N•s
   d. 12 N•s
   e. 32 N•s

38. Which of the following statements about the electric field inside a charged conductor at electrostatic equilibrium is true?
   a. The strength increases uniformly with the distance from the center of the conductor.
   b. The strength decreases uniformly with the distance from the center of the conductor.
   c. The strength is a uniform, non-zero value everywhere.
   d. The strength is zero everywhere.
   e. The strength varies randomly from point to point.

39. The diagram shown on the right represents an *N*-type silicon semiconductor connected to a battery. A very small amount of antimony, which has five valence electrons, had previously been added to the silicon crystal. This process produced
   a. an excess of free protons.
   b. an excess of free electrons.
   c. more resistance.
   d. less resistance.
   e. a higher emf.



40. A container of ideal gas undergoes a Carnot heat engine cycle in the order shown below.

Process 1 – Reversible isothermal expansion
Process 2 – Reversible adiabatic expansion
Process 3 – Reversible isothermal compression
Process 4 – Reversible adiabatic compression

The gas has returned to its original state at the end of the cycle. Let Q_n represent the amount of heat exchanged on process *n*. Which of the following correctly calculates the efficiency of this engine?

a. $1 - Q_1 / Q_2$
b. $1 - Q_2 / Q_3$
c. $1 - Q_3 / Q_4$
d. $1 - Q_3 / Q_1$
e. $1 - Q_4 / Q_1$

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

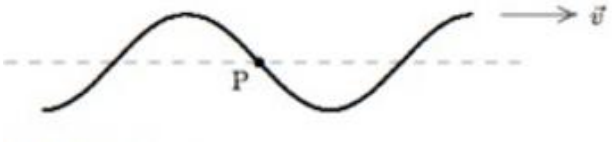
CONTINUE

Answer questions #41 through #50.

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

41. The transverse wave shown on the right is traveling from left to right in a string. The direction of the velocity of the string at point *P* is:

a. left
b. right
c. up
d. down
e. unknown



42. 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

43. An object is placed in front of a convex lens at a distance less than *F*. The image produced by the lens is…
    a. real, inverted, and smaller than the object.
    b. real, inverted, and larger than the object.
    c. virtual, upright, and larger than the object .
    d. virtual, upright, and smaller than the object.
    e. virtual, inverted, and larger than the object.

44. 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 3*V*. 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. $\frac{\sqrt{33}}{3}V$

45. The following expressions are non-mks units in physics. Identify the physical quantity that can be measured with the following units: (1) GeV, (2) GeV/c, (3) $\mathrm{GeV/c^2}$
    a. (1) Charge (2) Velocity (3) Mass
    b. (1) Energy (2) Linear Momentum (3) Mass
    c. (1) Mass (2) Angular Momentum (3) Torque
    d. (1) Energy (2) Angular Momentum (3) Charge
    e. (1) Energy (2) Linear Momentum (3) Torque

46. Two resistors are connected in parallel to an ideal voltage source using wires of negligible resistance. Resistor *B* produces thermal energy at four times the rate of resistor *A*. Which of the following could account for this difference?
    a. Resistor *B* has one-fourth the resistance of resistor *A*.
    b. Resistor *B* has one-half the resistance of resistor *A*.
    c. Resistor *B* has twice the resistance of resistor *A*.
    d. Resistor *B* has four times the resistance of resistor *A*.
    e. Resistor *B* has twice the potential difference of resistor *A*.

47. Which of the following statement(s) can be associated with Bohr's theory of the atom?
    I. An electron orbiting the nucleus can change its energy continuously.
    II. An electron orbiting the nucleus emits energy and falls into the nucleus.
    III. An electron orbits the nucleus without radiating energy and can change its energy only by a specific, quantized amount, when it moves between the orbits.
    IV. Electrons can only orbit the nucleus in specific circular orbits with fixed angular momentum and energy.
    a. I and II b. II and IV c. II and III d. III and IV e. I, II, III and IV

48. An incredibly energetic spaceship has a "proper length" of L = 200 m, as determined by an observer on board the ship. It is traveling at a speed 0.97c relative to the Earth. Assuming the spaceship travels parallel to its length L, what is the length of the spaceship as measured by a physicist that observes the ship from Earth?
    a. 200 m b. 194 m c. 48.6 m d. 206 m e. 97.0 m

49. Point charges $+q$ and $-q$ are fixed in place on the x-axis at $x = +d$ and $x = -d$, respectively. At $x = 0$, their net electric field _____ and their total electric potential _____.

	Net electric field	Total electric potential
a.	is zero	is zero
b.	points in the positive x-direction	is positive
c.	points in the negative x-direction	is negative
d.	points in the positive x-direction	is zero
e.	points in the negative x-direction	is zero

50. A waterproof speaker placed at the bottom of a swimming pool emits a sound wave that travels toward the surface of the water. In the water, the sound wave has a frequency, f_{water}, a wavelength, λ_{water}, and wave speed, v_{water}. When the sound wave enters the air, it has a frequency, f_{air}, a wavelength, λ_{air}, and a wave speed, v_{air}. Which one of the following relationships correctly compares the frequencies, wavelengths, and wave speeds of the waves in the air and water?

a.	$f_{water}=f_{air}$	$\lambda_{water} = \lambda_{air}$	$v_{water} = v_{air}$
b.	$f_{water}=f_{air}$	$\lambda_{water} > \lambda_{air}$	$v_{water} > v_{air}$
c.	$f_{water}< f_{air}$	$\lambda_{water} > \lambda_{air}$	$v_{water} = v_{air}$
d.	$f_{water}< f_{air}$	$\lambda_{water} = \lambda_{air}$	$v_{water} < v_{air}$
e.	$f_{water}=f_{air}$	$\lambda_{water} < \lambda_{air}$	$v_{water} > v_{air}$