PHYSICSBOWL 2012

MARCH 28 – APRIL 11, 2012

40 QUESTIONS – 45 MINUTES

The sponsors of the 2012 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 fifteen regions, each with two divisions.
  - *Division 01* is for students *taking physics for the first time* (even if that first course is AP Physics).
  - *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 this information is not properly bubbled, ***you will be disqualified*** 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 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 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 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!

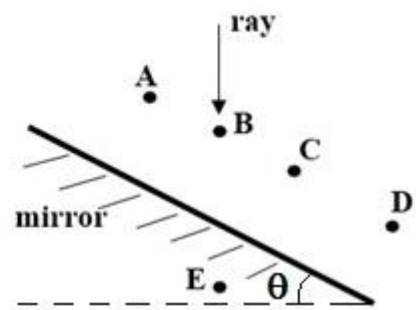
ATTENTION: **All Division 01 students, START HERE.**
All Division 02 students – skip the first 10 questions and begin on #11.

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

1. Which one of the following lengths is the largest?

(A) one centimeter **(B)** one kilometer **(C)** one millimeter **(D)** one meter **(E)** one nanometer

2. A ray of light passes straight downward through the point labeled B in the diagram shown. The ray reaches a flat mirror placed at an angle θ to the horizontal as shown. Which one of the locations labeled in the figure best represents the point through which the ray reflected from the mirror will pass?



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

3. Which one of the following choices best represents the value of the speed of light using units of $\frac{miles}{week}$?

(A) 5.90×10^{12} **(B)** 1.13×10^{11} **(C)** 1.61×10^{10} **(D)** 6.75×10^{8} **(E)** 1.13×10^{8}

4. The wave speed is $20.0\, {}^{m}/_{s}$ for waves traveling on a string tied at both ends. If sinusoidal waves with a frequency of $2.00\ Hz$ are traveling on this string, which one of the following choices best represents the period of these waves?

(A) $40.0\ s$ **(B)** $10.0\ s$ **(C)** $3.16\ s$ **(D)** $0.50\ s$ **(E)** $0.10\ s$

5. A solid rectangular box is measured to have length $L = 13.34\ cm$, width $W = 8.45\ cm$, and height $H = 3.36\ cm$. Which one of the following choices best represents the volume of the box using proper significant digits?

(A) $4 \times 10^2\ cm^3$
(B) $3.8 \times 10^2 cm^3$
(C) $3.79 \times 10^2\ cm^3$
(D) $3.787 \times 10^2 cm^3$
(E) $3.7875 \times 10^2\ cm^3$

6. Electromagnetic radiation travels through vacuum with a wavelength of $400\ nm$. Which one of the following choices best describes this type of radiation?

(A) X-rays **(B)** Radio Waves **(C)** Microwaves **(D)** Red Light **(E)** Violet Light

Questions 7 and 8 deal with the following information:

An object of mass $5.00\ kg$ moves only to the right along the $+x$-axis. During some time interval, the object's speed is increased from $4.00\ ^{m}/_{s}$ to $8.00\ ^{m}/_{s}$ with a constant acceleration of $2.00\ ^{m}/_{s^2}$.

7. What is the net force acting on the object during the time interval of the acceleration?

(A) $10.0\ N$
(B) $20.0\ N$
(C) $30.0\ N$
(D) $40.0\ N$
(E) The answer cannot be determined without more information about the forces involved.

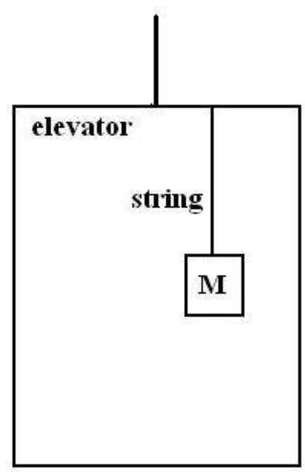
8. Through what distance does the object move during the time interval of the acceleration?

(A) $2.00\ m$ **(B)** $4.00\ m$ **(C)** $8.00\ m$ **(D)** $12.0\ m$ **(E)** $24.0\ m$

9. A constant current of $4.00\ A$ through a light bulb results in a power of $24.0\ W$ associated with the bulb. Which one of the following choices best represents the resistance of the light bulb?

(A) $96.0\ \Omega$ **(B)** $6.00\ \Omega$ **(C)** $2.45\ \Omega$ **(D)** $1.50\ \Omega$ **(E)** $0.67\ \Omega$

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 acceleration of magnitude $6.0\ ^{m}/_{s^2}$.
Let T represent the magnitude of the force by the string (tension) acting on the mass M, let G represent the magnitude of the gravitational force by the Earth acting on the mass M, and let 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) $T = G = F$
(B) $F < G < T$
(C) $T = F < G$
(D) $F < T = G$
(E) $T < F < G$

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. A girl twirls a small mass connected to the end of a string counterclockwise in a horizontal circle above her head. The figure shows an outline of the mass's path viewed from above the twirling mass. If the girl needs the mass to pass through the point labeled P in the figure, at which lettered point on the path should she let go of the string?

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

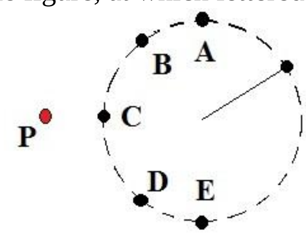


Figure for #11: overhead view of the mass's circular path.

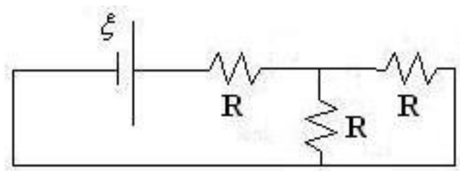
12. Which one of the following quantities is a scalar quantity?

(A) Impulse **(B)** Linear Momentum **(C)** Acceleration **(D)** Speed **(E)** Displacement

13. Approximately how many electrons must be removed from an electrically neutral object to give it a net charge of $Q = +1.00\ C$?

(A) 1.60×10^{-19} **(B)** 1 **(C)** 6.25×10^{18} **(D)** 6.02×10^{23} **(E)** 1.10×10^{30}

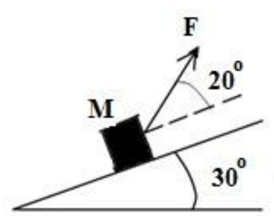
14. For the circuit shown to the right, what is the equivalent resistance? Assume that all wires are ideal, the battery has no internal resistance, and all three resistors have identical resistance R.



(A) $3R$ **(B)** $\frac{3}{2}R$ **(C)** $\frac{2}{3}R$ **(D)** $\frac{1}{3}R$ **(E)** R

15. Which one of the following phases of the lunar cycle immediately follows "First Quarter"?

(A) Waxing Gibbous
(B) Waning Gibbous
(C) Waxing Crescent
(D) Waning Crescent
(E) New Moon

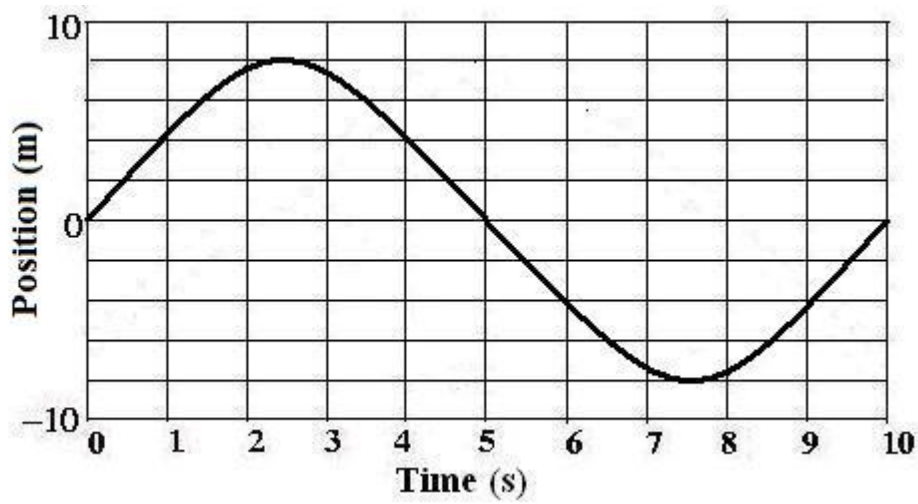


16. A constant force $F = 50\ N$ (as shown in the figure) is applied for the 6.0 meter motion of the box upward along the incline. The mass of the block is $M = 15\ kg$. Which one of the following choices best represents the work done by the force F on the box for the motion?

(A) $300\ J$ **(B)** $282\ J$ **(C)** $260\ J$ **(D)** $193\ J$ **(E)** $150\ J$

Question 17 deals with the following information:

A mass moves according to the graph of position as a function of time shown below.



17. Which one of the following choices correctly represents the time instants or time interval for which the instantaneous velocity of the mass is considered always to be negative? Let t represent time.

(A) $t = 0.0\ s,\ t = 5.0\ s\ \ and\ \ t = 10.0\ s$
(B) $0.0\ s < t < 2.5\ s$
(C) $2.5\ s < t < 7.5\ s$
(D) $5.0\ s < t < 10.0\ s$
(E) $2.5\ s < t < 10.0\ s$

18. A $1.00\ kg$ object is released from rest near the surface of the Earth. The gravitational force acting on the $1.00\ kg$ object by the Earth does $10.0\ J$ of work on the object as it falls $1.00\ m$ to the ground. Which one of the following choices best represents the amount of work done by the gravitational force acting on the Earth by the $1.00\ kg$ object during the fall?

(A) $0.0\ J$ **(B)** $-10.0\ J$ **(C)** $10.0\ J$ **(D)** $-5.86 \times 10^{25}\ J$ **(E)** $5.86 \times 10^{25}\ J$

19. The magnitude of the linear momentum of a $4.00\ kg$ point mass is changed from $6.00\ kg \cdot \frac{m}{s}$ to $14.0\ kg \cdot \frac{m}{s}$ in a time interval of $6.00\ s$. What is the change in the kinetic energy of the mass during this time interval?

(A) $8.0\ J$ **(B)** $10.0\ J$ **(C)** $16.0\ J$ **(D)** $20.0\ J$ **(E)** $32.0\ J$

20. "Both the position and momentum of an electron cannot be known exactly at the same instant of time." To whom is this concept attributed?

(A) Pauli **(B)** de Broglie **(C)** Einstein **(D)** Dirac **(E)** Heisenberg

21. A child's balloon is filled with pure Xenon gas. This balloon then is released from rest two meters above the ground on Earth. Which one of the following choices best describes the response of the balloon?

(A) The balloon immediately falls toward the ground.
(B) The balloon floats gently in the air, finally reaching the ground after several minutes.
(C) The balloon floats gently in the air, essentially hovering at the same height for at least a day.
(D) The balloon very, very slowly and gently rises upward.
(E) The balloon rapidly rises into the sky.

22. A girl swings a 4.0 kg mass with a constant speed of 3.24 $\frac{m}{s}$ in a vertically-oriented circle of radius $0.75\ m$. What is the net force acting on the mass when it is at the lowest point of the circle?

(A) $96\ N$ **(B)** $56\ N$ **(C)** $40\ N$ **(D)** $16\ N$ **(E)** $0\ N$

Questions 23 and 24 deal with the following information:

A collision of two blocks takes place along a horizontal surface without friction.
A block with mass $M_1 = 3.00\ kg$ initially moves to the left with speed $V_1 = 5.00\ {}^{m}/_{s}$ when it hits a block with mass $M_2 = 5.00\ kg$ initially moving to the right with speed $V_2 = 2.00\ {}^{m}/_{s}$.
After colliding, the block with mass M_1 is moving to the right with speed $1.00\ {}^{m}/_{s}$.

23. Which of the blocks underwent a larger magnitude of acceleration during the collision?

(A) The block with mass M_1.
(B) The block with mass M_2.
(C) The magnitude of the acceleration was the same for both blocks.
(D) The answer depends on how much kinetic energy was transferred out of the two-block system.
(E) More information about the time of the collision is required to answer the question.

24. What is the speed of the block with mass M_2 after the collision?

(A) $0.40\ {}^{m}/_{s}$ **(B)** $1.00\ {}^{m}/_{s}$ **(C)** $1.60\ {}^{m}/_{s}$ **(D)** $4.29\ {}^{m}/_{s}$ **(E)** $4.40\ {}^{m}/_{s}$

25. Which one of the following choices best represents the average angular speed of the hour hand on a standard clock (in units of $\frac{rad}{s}$)?

(A) 5.24×10^{-1} **(B)** 2.62×10^{-1} **(C)** 1.75×10^{-3} **(D)** 1.45×10^{-4} **(E)** 7.27×10^{-5}

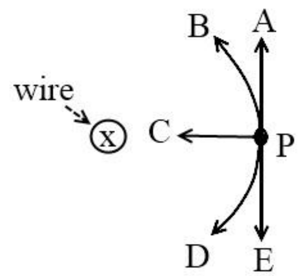
26. An object is thrown horizontally with speed $10.0\ {}^{m}/_{s}$ from a height H above the ground. The object reaches the ground with a speed of $20.0\ {}^{m}/_{s}$. Which one of the following choices best represents the time of the object's flight to the ground? Ignore air resistance.

(A) $1.00\ s$ **(B)** $1.22\ s$ **(C)** $1.41\ s$ **(D)** $1.50\ s$ **(E)** $1.73\ s$

27. The pressure inside a container with two moles of an ideal gas is $0.75\ atm$. The temperature of the gas is $100\ °C$. The container maintains constant volume as the pressure is tripled. Which one of the following choices best represents the temperature of the gas after the pressure is tripled?

(A) $33\ °C$ **(B)** $300\ °C$ **(C)** $573\ °C$ **(D)** $846\ °C$ **(E)** $1119\ °C$

28. A long straight wire has a conventional current directed into the plane of the page as shown in the figure. Which one of the arrows shown best indicates the direction of the magnetic field associated with this wire at the location labeled P?



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

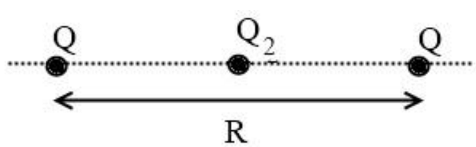
29. A vehicle completes one lap around a circular track at an average speed of $50\ {}^{m}/_{s}$ and then completes a second lap at an average speed of V. The average speed of the vehicle for the completion of both laps was $80\ {}^{m}/_{s}$. What was the average speed V of the second lap?

(A) $100\ {}^{m}/_{s}$ **(B)** $110\ {}^{m}/_{s}$ **(C)** $125\ {}^{m}/_{s}$ **(D)** $150\ {}^{m}/_{s}$ **(E)** $200\ {}^{m}/_{s}$

30. Coherent light of wavelength $550\ nm$ shines on a double slit apparatus that has point slits spaced by a distance of $42.4\ \mu m$. In theory, what is the maximum order bright fringe that can be viewed?

(A) 1297 **(B)** 77 **(C)** 12 **(D)** 8 **(E)** 1

31. Three particles with charges $Q, Q,$ and Q_2 are initially at rest very (infinitely) far apart from one another. The particles are moved to the locations shown in the figure where they are fixed in place. The particles on the left and right have charge Q and are separated by a distance R. The particle with charge Q_2 is located at the midpoint directly between the other charged particles. The total work required to configure this three-particle arrangement is $0\ Joules$. Ignore any self-energies for the particles. What is the value of the charge Q_2?

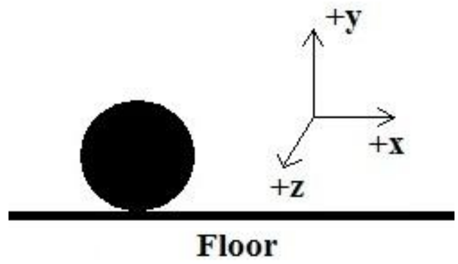


(A) $-{}^{1}/_{4}\,Q$
(B) $-{}^{\sqrt{2}}/_{4}\,Q$
(C) $-{}^{1}/_{2}\,Q$
(D) $-{}^{1}/_{8}\,Q$
(E) It is not possible to accomplish what is required.

32. To whom was the first Nobel Prize in physics awarded?

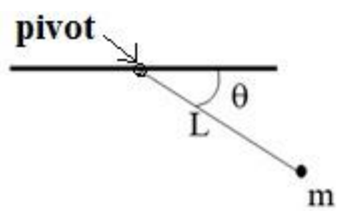
(A) Isaac Newton for his contributions to physics and calculus.
(B) James Chadwick for the discovery of the neutron.
(C) Wilhelm Röntgen for the discovery of X-rays.
(D) Marie Curie for her work in radioactivity.
(E) Albert Einstein for his explanation of the photoelectric effect and for the theories of relativity.

33. A solid, uniform sphere rolls without slipping on a floor along the $+x$-axis (to the right). The rotational kinetic energy associated with the sphere about an axis of rotation through its center of mass along the $+z$-axis (out of the plane of the page) is $20\, Joules$. What is the translational kinetic energy associated with the sphere?



(A) $8\,J$ **(B)** $10\,J$ **(C)** $20\,J$ **(D)** $40\,J$ **(E)** $50\,J$

34. A mass m attached to a light string of length L is located at an angle θ below the horizontal as shown in the figure to the right. The mass then is released from rest. Calculated from an axis perpendicular to the plane of the page through the pivot, which one of the following choices represents the magnitude of the torque produced by the gravitational force acting on the mass at this instant?



(A) mgL
(B) $mgL\sin\theta$
(C) $mgL\cos\theta$
(D) $mgL(1-\sin\theta)$
(E) $mgL(1-\cos\theta)$

35. A student wants to set up an experiment with a thin convex lens of focal length f such that a thin real object produces a focused real image on a movable screen. At how many locations along the optical axis (principal axis) can the object be placed so that the distance between the object and the focused image on the screen is equal to $3f$?

(A) There is no location.
(B) There is exactly one location.
(C) There are exactly two locations.
(D) There are exactly four locations.
(E) There are an infinite number of locations.

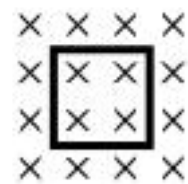
36. A positive charge moves with constant velocity through a region of space containing both an electric field and a magnetic field. The electric field is directed out of the plane of the page. Ignoring any gravitational field, which one of the following choices represents possible directions of both the particle's velocity and the total magnetic field in the region of space?

	Velocity of particle	**Magnetic Field**
(A)	Toward the bottom of the page	Into the plane of the page
(B)	Into the plane of the page	Out of the plane of the page
(C)	To the left	Toward the bottom of the page
(D)	Toward the top of the page	To the right
(E)	Out of the plane of the page	Toward the top of the page

37. The cylindrical head of an aluminum nail has a diameter of 1.00 cm. For the top layer of atoms in the nail's head, which one of the following choices best represents the number of aluminum atoms in that layer?

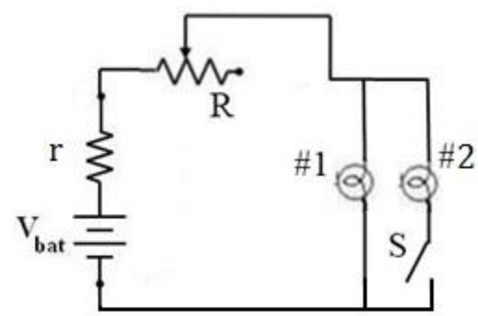
(A) 10^{10} **(B)** 10^{15} **(C)** 10^{20} **(D)** 10^{25} **(E)** 10^{30}

38. A square, conducting wire loop sits in a plane perpendicular to a spatially uniform magnetic field pointing into the plane of the page as shown. The magnetic field strength steadily increases with time. Which one of the following effects best describes the result of this field increase?



(A) The entire loop moves up the plane of the page.
(B) The loop rotates with the top edge of the loop initially moving out of the plane of the page and the bottom edge moving into the plane of the page.
(C) The loop rotates with the top edge of the loop initially moving into the plane of the page and the bottom edge moving out of the plane of the page.
(D) The legs of the loop attempt to increase the area enclosed by the loop.
(E) The legs of the loop attempt to decrease the area enclosed by the loop.

39. For the circuit shown, all wires have no resistance, the battery has a constant internal resistance of $r = 8.0\ \Omega$ and the two light bulbs (#1 and #2) are identical, each with resistance R_{bulb}. The variable resistor is initially set to $R = 26.0\ \Omega$. The switch S in the circuit now is closed. To what resistance must the variable resistor be set if bulb #1 is to have the same brightness after the switch is closed as it did with the switch open?



(A) 9.0 Ω
(B) 13.0 Ω
(C) 16.0 Ω
(D) 22.0 Ω
(E) The answer can be computed only if the bulbs' resistance R_{bulb} is known.

40. Using the kinetic theory of gases, which one of the following choices best represents the rms (root mean square) speed of 58 grams of a monatomic ideal gas at a pressure of 3.0 atm in an enclosed container of volume 6.0 L?

(A) 0.557 $^{m}/_{s}$ **(B)** 9.71 $^{m}/_{s}$ **(C)** 177 $^{m}/_{s}$ **(D)** 307 $^{m}/_{s}$ **(E)** 3150 $^{m}/_{s}$

IMPORTANT: All Division 01 students STOP HERE. 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, STOP HERE.
All Division 02 students, continue to question #50.

Questions 41 and 42 deal with the following information:

A hypothetical radioactive substance Aaptinium decays via alpha-emission into Physicsbowlium. The decay constant for this alpha-emission is $20\ s^{-1}$.

41. Which one of the following statements correctly compares Physicsbowlium to Aaptinium?

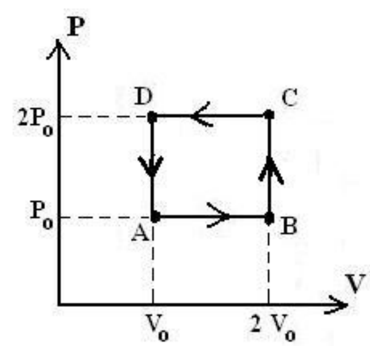
(A) Physicsbowlium has 4 fewer protons and 2 fewer neutrons than Aaptinium.
(B) Physicsbowlium has 4 fewer neutrons and 2 fewer protons than Aaptinium.
(C) Physicsbowlium has 2 fewer protons and 2 fewer neutrons than Aaptinium.
(D) Physicsbowlium has 4 fewer protons than, and the same number of neutrons as, Aaptinium.
(E) Physicsbowlium has 2 fewer protons than, and the same number of neutrons as, Aaptinium.

42. What is the half-life of Aaptinium?

(A) $0.035\ s$ **(B)** $0.050\ s$ **(C)** $0.100\ s$ **(D)** $0.297\ s$ **(E)** $0.693\ s$

43. Several forces act on a rigid body. If the resultant (net) force on the body is zero, which one of the following statements must be true?

(A) The object is in translational equilibrium and rotational equilibrium.
(B) The object is in translational, but not necessarily rotational, equilibrium.
(C) The object is in rotational, but not necessarily translational, equilibrium.
(D) The object is in static equilibrium.
(E) The object is in neither translational nor rotational equilibrium.



44. A monatomic ideal gas is the working substance for a refrigerator that undergoes the cyclic process (ABCDA) shown in the PV diagram. The processes are all isochoric or isobaric with pressures between P_0 and $2P_0$ and volumes between V_0 and $2V_0$. What is the coefficient of performance for this refrigerator?

(A) $^1/_4$ **(B)** $^1/_3$ **(C)** $^4/_3$ **(D)** $^{11}/_2$ **(E)** $^{13}/_2$

45. A stationary atom of mass $4.00 \times 10^{-26}\ kg$ spontaneously emits a photon of energy $10.0\ eV$. Which one of the following choices best represents the speed, in units of $^m/_s$, of the atom after emitting the photon?

(A) 4.00×10^{7} **(B)** 8.94×10^{3} **(C)** 1.33×10^{-1} **(D)** 1.58×10^{-4} **(E)** 2.50×10^{-8}

46. There is a quantity called the Planck time, t_{Planck}, which is computed in terms of constants as $t_{Planck}^2 = \frac{\hbar G}{c^n}$ where ħ is Planck's constant divided by 2π, G is the Universal Gravitational Constant, and c is the speed of light. In order for this expression for time to be consistent, what is the numerical value of n, the power to which the speed of light is raised?

(A) 2 **(B)** 3 **(C)** 4 **(D)** 5 **(E)** 6

47. Water flows ideally through a cylindrically-shaped pipe. At the lower end, the pipe's cross-sectional area is $30.0\ cm^2$ whereas in the upper portion, the pipe's cross-sectional area is $10.0\ cm^2$ and fluid is moving at $9.0\ {}^{m}/_{s}$. Which one of the following choices best represents the difference in pressure between the lower section of the pipe and the upper section if the vertical distance between the centers of the pipe sections is $2.0\ m$?

(A) $5.6\ Pa$ **(B)** $6.05\ Pa$ **(C)** $56\ kPa$ **(D)** $60.5\ kPa$ **(E)** $65\ kPa$

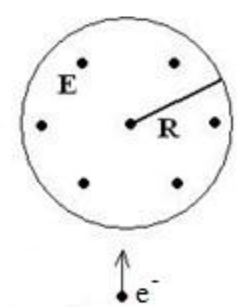
48. An object of mass M is dropped from a height H above the ground. The object bounces off of a horizontal surface in a collision lasting time T. The object then rises upward to a maximum height ${}^{H}/_{2}$. What was the magnitude of the average net force acting on the mass during the collision with the surface?

(A) $\left(2-\sqrt{2}\right)\frac{M\sqrt{gH}}{T}$ **(B)** $\left(\frac{1}{\sqrt{2}}+1\right)\frac{M\sqrt{gH}}{T}$ **(C)** $\left(\sqrt{3}\right)\frac{M\sqrt{gH}}{T}$ **(D)** $\left(2\sqrt{2}-1\right)\frac{M\sqrt{gH}}{T}$ **(E)** $\left(\sqrt{2}+1\right)\frac{M\sqrt{gH}}{T}$

49. A beam of unpolarized light traveling in air strikes a piece of optically flat glass at an angle of incidence of 58°. Some of the light is reflected while the remainder is transmitted into the glass. The reflected beam is 100% polarized parallel to the surface of the glass. What is the index of refraction for the glass?

(A) 1.60 **(B)** 1.53 **(C)** 1.47 **(D)** 1.38 **(E)** 1.18

50. A spatially uniform electric field is constrained within the circular region of radius R as shown. The field is directed out of the plane of the page and its strength is decreasing uniformly with time. Which one of the following choices best represents the direction of the Lorentz force on the electron at the instant shown in the figure when the electron is moving up the plane of the page? Ignore gravity.



(A) No Force
(B) Into the plane of the page
(C) Out of the plane of the page
(D) To the right
(E) To the left

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