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

1. Approximately how many seconds is it until the PhysicsBowl takes place in the year *2109* ?

(A) 10^2 **(B)** 10^7 **(C)** 10^8 **(D)** 10^9 **(E)** 10^{12}

2. A room has a floor area of $25\,m^2$. What is this area written in cm^2?

(A) 25000000 **(B)** 250000 **(C)** 2500 **(D)** 0.25 **(E)** 0.0025

3. Which one of the following quantities can have its unit expressed as $\frac{kg \cdot m}{s^2}$?

(A) Force **(B)** Power **(C)** Energy **(D)** Pressure **(E)** Linear Momentum

4. The length measurement $L = 0.01230\ cm$ has how many significant digits?

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

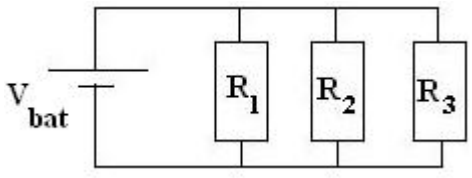
5. At an instant of time, a block of mass $0.50\,kg$ has a position of $3.0\,m$, a speed of $4.0\ {}^{m}\!/_{s}$, and an acceleration of $1.0\ {}^{m}\!/_{s^2}$. What is the block's kinetic energy (in Joules) at this instant?

(A) 1.0 **(B)** 1.5 **(C)** 2.0 **(D)** 4.0 **(E)** 8.0

6. For a standing wave mode on a string fixed at both ends, adjacent antinodes are separated by a distance of $20\,cm$. Waves travel on this string at a speed of $1200\ {}^{cm}\!/_{s}$. At what frequency is the string vibrated to produce this standing wave?

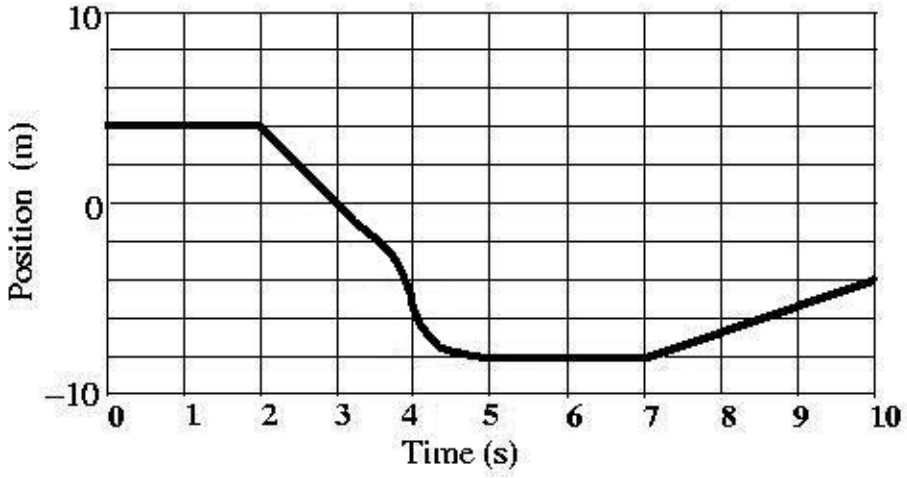
(A) 120 *Hz* **(B)** 60 *Hz* **(C)** 40 *Hz* **(D)** 30 *Hz* **(E)** 20 *Hz*

7. The equivalent resistance of the circuit shown to the right with resistances $R_1 = 4.00\,\Omega$, $R_2 = 3.00\,\Omega$, and $R_3 = 2.00\,\Omega$ is



(A) 0.111 Ω **(B)** 0.923 Ω **(C)** 1.08 Ω **(D)** 3.00 Ω **(E)** 9.00 Ω

8. Consider the motion of an object given by the position vs. time graph shown. For what time(s) is the speed of the object greatest?



(A) At all times from $t = 0.0\,s \rightarrow t = 2.0\,s$

(B) At time $t = 3.0\,s$

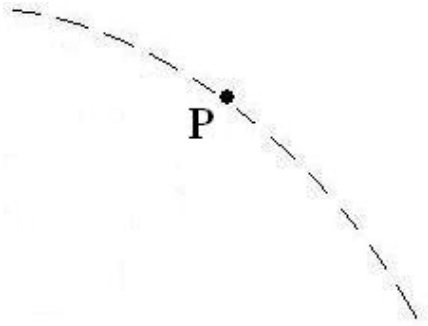
(C) At time $t = 4.0\,s$

(D) At all times from $t = 5.0\,s \rightarrow t = 7.0\,s$

(E) At time $t = 8.5\,s$

9. The free fall trajectory of an object thrown horizontally from the top of a building is shown as the dashed line in the figure. Which sets of arrows best correspond to the directions of the velocity and of the acceleration for the object at the point labeled P on the trajectory?

	velocity	acceleration
(A)	↘	↓
(B)	→	↓
(C)	→	↖
(D)	↘	↙
(E)	↘	↘



10. A car with mass M initially travels to the East with speed $4V$. A truck initially travels to the West with speed $3V$. After the vehicles collide, they move together to the West with common speed $2V$. What is the mass of the truck?

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

ATTENTION: All Division 01 students, continue through question 40.

ATTENTION: All Division 02 students, START HERE. Numbers 1-10 on your answer sheet should be blank. Your first answer should be for #11.

11. What is the orientation of the Earth, Sun, and Moon during a total lunar eclipse?

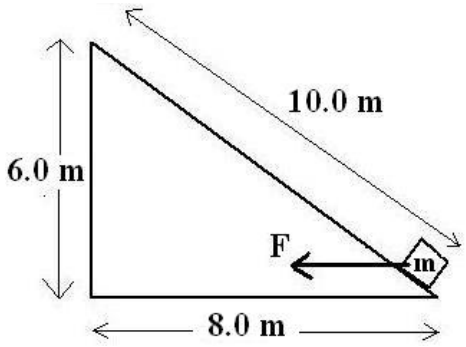
(A) The Sun is between the Earth and Moon.
(B) The Earth is between the Sun and Moon.
(C) The Moon is between the Sun and Earth.
(D) The Earth, Moon, and Sun make a right triangle.
(E) The Earth is above the Sun and Moon.

12. A $5.0\,kg$ solid sphere is in free fall near the surface of the Earth. What is the magnitude of the gravitational force acting *on the Earth by the solid sphere*? The Earth's mass is $5.98\times10^{24}\ kg$.

(A) $0\,N$
(B) $5\,N$
(C) It is immeasurably small, but not zero.
(D) $50\,N$
(E) $5.98\times10^{25}\ N$

Questions 13 – 14 deal with the following information:

In the figure to the right, a box moves with speed $5.00\,m/s$ at the bottom of a rough, fixed inclined plane. The box slides with constant acceleration to the top of the incline as it is being pushed directly to the left with a constant force of $F = 240\,N$. The box, of mass $m = 20.0\,kg$, has a speed of $2.50\,m/s$ when it reaches the top of the incline.



13. What is the magnitude of the acceleration of the box as it slides up the incline?

(A) $12.0\,m/s^2$ **(B)** $10.0\,m/s^2$ **(C)** $5.88\,m/s^2$ **(D)** $1.88\,m/s^2$ **(E)** $0.938\,m/s^2$

14. How much work is done by the applied force, F, to the box?

(A) $2400\,J$ **(B)** $1920\ J$ **(C)** $1200\ J$ **(D)** $988.5\ J$ **(E)** $-187.5\ J$

15. An ideal gas in a closed container of volume $6.0\,L$ is at a temperature of $100\ ^{\circ}C$. If the pressure of the gas is $2.5\,atm$, how many moles of gas are in the container?

(A) 0.0048 **(B)** 0.018 **(C)** 0.49 **(D)** 1.83 **(E)** 490

16. What condition *must* be met in order to use the rotational kinematics equation $\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$?

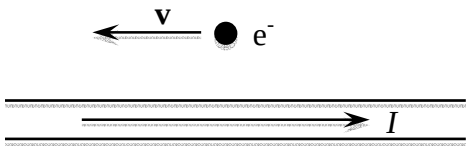
(A) The angular acceleration is constant.
(B) The angular velocity is constant.
(C) The linear acceleration is zero.
(D) The angular acceleration is zero.
(E) There is no restriction on the use of this equation.

17. A toy car moves $3.0\,m$ to the North in one second. The car then moves at $9.0\,m/s$ due South for two seconds. What is the average speed of the car for this three second trip?

(A) $4.0\,m/s$ **(B)** $5.0\,m/s$ **(C)** $6.0\,m/s$ **(D)** $7.0\,m/s$ **(E)** $12.0\,m/s$

18. A wire has a conventional current *I* directed to the right. At the instant shown in the figure, an electron has a velocity directed to the left. The magnetic force on the electron at this instant is

(A) zero.
(B) directed out of the plane of the page.
(C) directed into the plane of the page.
(D) directed toward the top of the page.
(E) directed toward the bottom of the page.



19. A scientist claims to be investigating "The transfer of energy that results from the bulk motion of a fluid." Which of the following terms best describes the energy transfer method that this scientist is studying?

(A) radiation **(B)** convection **(C)** conduction **(D)** latent heat **(E)** specific heat

20. A projectile launched from the ground landed a horizontal distance of $120.0\,m$ from its launch point. The projectile was in the air for a time of 4.00 seconds. If the projectile landed at the same vertical position from which it was launched, what was the launch speed of the projectile? Ignore air resistance.

(A) $22.4\,m/s$ **(B)** $30.0\,m/s$ **(C)** $36.1\,m/s$ **(D)** $42.4\,m/s$ **(E)** $50.0\,m/s$

21. A $20.0\,kg$ box remains at rest on a horizontal surface while a person pushes directly to the right on the box with a force of $60\,N$. The coefficient of kinetic friction between the box and the surface is $\mu_k = 0.20$. The coefficient of static friction between the box and the surface is $\mu_s = 0.60$. What is the magnitude of the force of friction acting on the box during the push?

(A) $200\,N$ **(B)** $120\,N$ **(C)** $60\,N$ **(D)** $40\,N$ **(E)** $0\,N$

22. A point object is connected to the end of a long string of negligible mass and the system swings as a simple pendulum with period T. What is the period of the pendulum if the string is made to have one-quarter of its original length?

(A) $4T$ **(B)** $2T$ **(C)** T **(D)** $T/2$ **(E)** $T/4$

23. A person rubs a neutral comb through their hair and the comb becomes negatively charged. Which of the following is the best explanation for this phenomenon?

(A) The hair gains protons from the comb.
(B) The hair gains protons from the comb while giving electrons to the comb.
(C) The hair loses electrons to the comb.
(D) The comb loses protons to the person's hand holding the comb.
(E) The comb loses protons to the person's hand while also gaining electrons from the hair.

24. A point mass moves along a horizontal circular path of radius $8.0\,m$ with a constant kinetic energy of $128\,J$. What is the magnitude of the net force acting on the mass as it moves?

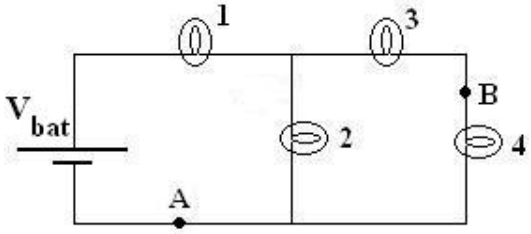
(A) $64\,N$ **(B)** $32\,N$ **(C)** $16\,N$ **(D)** $8\,N$ **(E)** $0\,N$

25. Which of the following types of electromagnetic radiation has the largest magnitude of momentum per photon?

(A) FM radio **(B)** Microwaves **(C)** Violet light **(D)** Infrared light **(E)** Gamma rays

26. For the circuit shown, when a shorting wire (no resistance) connects the points labeled A and B, which of the numbered light bulbs become brighter? Assume that all four bulbs are identical and have resistance R.

(A) Bulb 1 only
(B) Bulb 2 only
(C) Bulb 3 only
(D) Bulbs 1 and 3 only
(E) Bulbs 1, 2, and 3



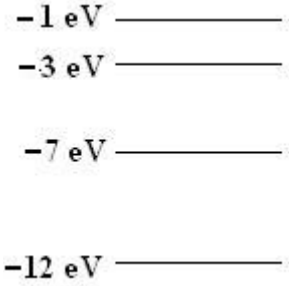
27. A proton moves straight up the plane of this page into a region that has a magnetic field directed to the right. If the particle is undeflected as it passes through this region, in what direction must there be a component of electric field? Ignore gravity.

(A) To the left **(B)** Into the page **(C)** Out of the page **(D)** Down the page **(E)** To the right

28. White light shines through ideal filters to produce cyan light. If an ideal pigment appears yellow in white light, what color does the pigment appear in the cyan light?

(A) magenta **(B)** yellow **(C)** blue **(D)** red **(E)** green

29. The diagram to the right shows the lowest four energy levels for an electron in a hypothetical atom. The electron is excited to the $-1\ eV$ level of the atom and transitions to the lowest energy state by emitting only two photons. Which of the following energies could not belong to either of the photons?



(A) $2\ eV$ **(B)** $4\ eV$ **(C)** $5\ eV$ **(D)** $6\ eV$ **(E)** $9\ eV$

30. In terms of the seven fundamental SI units in the MKS system, the Ohm is written as

(A) $\frac{kg \cdot m^2}{A^2 \cdot s^3}$ **(B)** $\frac{kg \cdot m^2 \cdot s}{C^2}$ **(C)** $\frac{kg \cdot m}{C \cdot s}$ **(D)** $\frac{kg \cdot m^2}{A \cdot s^2}$ **(E)** $\frac{kg \cdot s^2}{A^2 \cdot m^2}$

31. A car moves to the right along a one-dimensional track for total time T in two parts.

- Part One: The car maintains constant non-zero speed V for the first ¾ of the total time.
- Part Two: The car accelerates uniformly to rest during the last ¼ of the total time.

What is the ratio of the distance traveled during Part One of the trip to the distance traveled during Part Two of the trip?

(A) $6:1$
(B) $3:2$
(C) The values of V and T are required to answer the question.
(D) $4:3$
(E) $8:3$

32. A cube of unknown material and uniform density floats in a container of water with 60% of its volume submerged. If this same cube were placed in a container of oil with density $\rho_{oil} = 800\ {}^{kg}\!/_{m^3}$, what portion of the cube's volume would be submerged while floating?

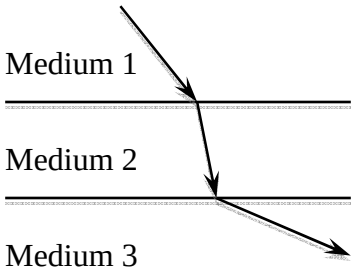
(A) 33% **(B)** 50% **(C)** 58% **(D)** 67% **(E)** 75%

33. An ideal gas undergoes an isobaric expansion followed by an isochoric cooling. Which of the following statements *must* be true after the completion of these processes?

(A) The final pressure is less than the original pressure.
(B) The final volume is less than the original volume.
(C) The final temperature is less than the original temperature.
(D) The total quantity of heat, Q, associated with these processes is positive.
(E) The internal energy of the gas is unchanged.

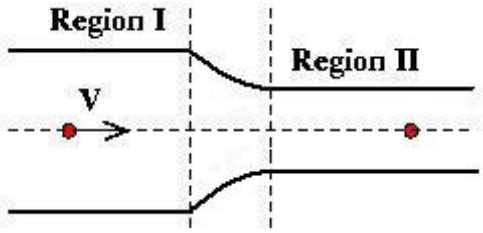
34. The diagram below shows the path taken by a monochromatic light ray traveling through three media. The symbols v_1, λ_1, and f_1 represent the speed, wavelength, and frequency of the light in Medium 1, respectively. Which of the following relationships for the light in the three media is true?

(A) $\lambda_1 < \lambda_3 < \lambda_2$
(B) $v_2 < v_3 < v_1$
(C) $f_2 < f_1 < f_3$
(D) $v_3 < v_1 < v_2$
(E) $\lambda_2 < \lambda_1 < \lambda_3$



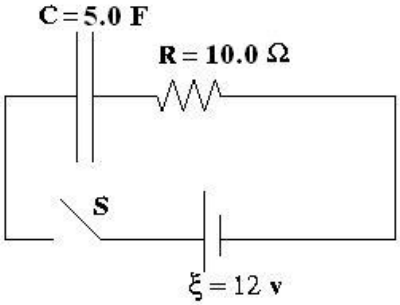
35. A piece of an ideal fluid is marked as it moves along a horizontal streamline through a pipe, as shown in the figure. In Region I, the speed of the fluid on the streamline is V. The cylindrical, horizontal pipe narrows so that the radius of the pipe in Region II is half of what it was in Region I. What is the speed of the marked fluid when it is in Region II?

(A) $4V$
(B) $2V$
(C) V
(D) $V/2$
(E) $V/4$



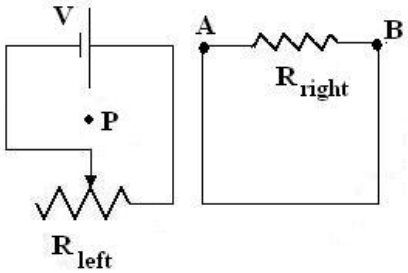
36. For the RC circuit shown, the resistance is $R = 10.0\,\Omega$, the capacitance is $C = 5.0\,F$ and the battery has voltage $\xi = 12$ *volts*. The capacitor is initially uncharged when the switch S is closed at time $t = 0$. At some time later, the current in the circuit is $0.50\,A$. What is the magnitude of the voltage across the capacitor at that moment?

(A) 0 *volts*
(B) 5 *volts*
(C) 6 *volts*
(D) 7 *volts*
(E) 12 *volts*

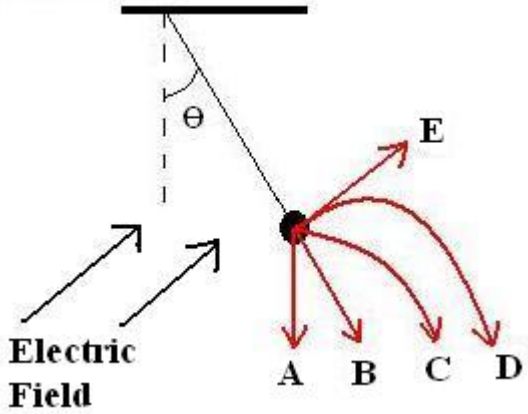


37. For the figure shown, the variable resistance in the circuit on the left is increased at a constant rate. What is the direction of the magnetic field at the point P at the center of the left-hand circuit and in what direction is the conventional current through the resistor in the right-hand circuit?

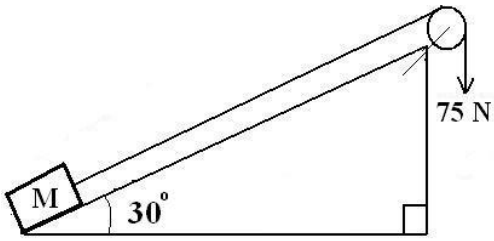
	Magnetic Field at P	*Current through resistor*
(A)	Into the page	From B to A
(B)	Into the page	From A to B
(C)	Out of the page	From B to A
(D)	Out of the page	From A to B
(E)	There is no field.	There is no current.



38. A small object of mass M and charge Q is connected to an insulating massless string in a vacuum on Earth. A uniform electric field exists throughout the region of the vacuum as indicated. The mass remains in static equilibrium at an angle of θ with the vertical as shown in the figure. When the string is cut, which of the illustrated paths best indicates the trajectory of the mass?

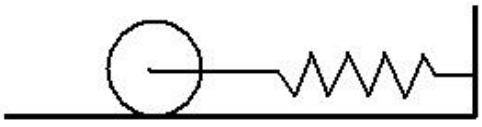


39. For the compound machine comprised of the inclined plane and pulley shown, a $75.0\,N$ force is required to slide a box with mass $M = 10.0\,kg$ up the incline at a constant speed. What is the efficiency of this compound machine?



(A) $\frac{1}{3}$ **(B)** $\frac{3}{8}$ **(C)** $\frac{1}{2}$ **(D)** $\frac{2}{3}$ **(E)** $\frac{3}{4}$

40. A uniform solid cylinder of mass $M = 2.00\,kg$ and radius $R = 10.0\,cm$ is connected about an axis through the center of the cylinder to a horizontal spring with spring constant $4.00\,{}^{N}/_{m}$. The cylinder is pulled back, stretching the spring $1.00\,m$ from equilibrium. When released, the cylinder rolls without slipping. What is the speed of the center of the cylinder when it returns to equilibrium?



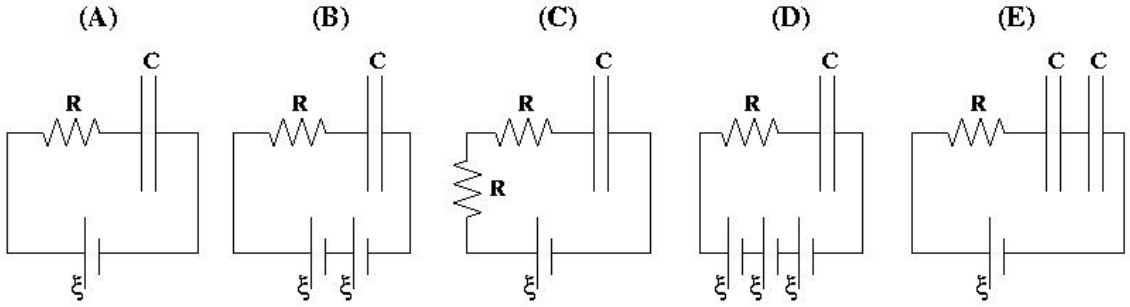
(A) $0.577\,{}^{m}/_{s}$ **(B)** $1.00\,{}^{m}/_{s}$ **(C)** $1.15\,{}^{m}/_{s}$ **(D)** $1.22\,{}^{m}/_{s}$ **(E)** $1.41\,{}^{m}/_{s}$

IMPORTANT: All Division 01 students <u>STOP HERE</u>. Your last answer should be number 40. Numbers 41-50 should remain blank for Division 01 students.

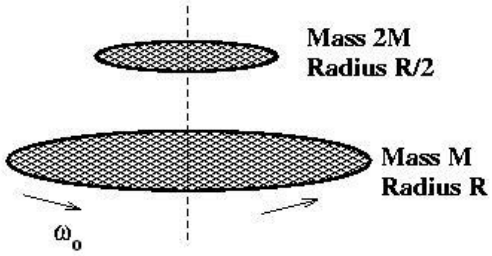
All Division 02 students continue to Questions 41 – 50.

ATTENTION: **All Division 01 students, <u>STOP HERE</u>.**
All Division 02 students, continue to question 50.

41. For the circuits shown below, which will take the least time to charge the capacitor(s) to 90% of the full charge? All batteries are ideal and identical with emf ξ, all resistors are identical with resistance R, and all capacitors are identical with capacitance C and are initially uncharged.



42. A uniform, solid disk with mass M and radius R is rotating on a fixed, frictionless platform with constant angular speed ω_0 about a fixed axis through its center. A second uniform solid disk of mass $2M$ and radius $R/2$ is placed from rest directly on top of the first disk so that the centers of the disks line up. When equilibrium is established, the disks are spinning at the same rate. What is the angular speed of the disks at equilibrium?



(A) $\left(1/4\right)\omega_0$ **(B)** $\left(1/3\right)\omega_0$ **(C)** $\left(1/2\right)\omega_0$ **(D)** $\left(2/3\right)\omega_0$ **(E)** $\left(\sqrt{2/3}\right)\omega_0$

43. A real object is located in front of a convex lens at a distance greater than the focal length of the lens. What type of image is formed and what is true of the image's size compared to that of the object?

	Type of Image	**Size of Image**
(A)	Real	Larger than object
(B)	Real	More information is needed
(C)	Virtual	Smaller than object
(D)	Virtual	Larger than object
(E)	More information is needed	More information is needed

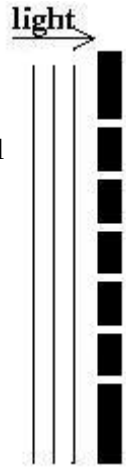
44. In an ideal LC circuit, what is the time difference between all of the energy in the circuit being stored in the inductor and all of the energy being stored in the capacitor?

(A) No time difference
(B) One-eighth of a period of oscillation
(C) One-quarter of a period of oscillation
(D) One-half of a period of oscillation
(E) After one full period of oscillation has passed

45. In neutron decay, the process is written as $n \rightarrow p + e^- + \bar{\nu}$, where $\bar{\nu}$ is an antineutrino necessary to have conservation of momentum and energy. Who postulated the existence of neutrinos?

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

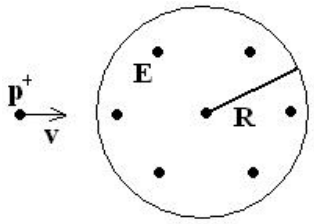
46. Monochromatic light is incident on a slide containing six infinitely thin, equally spaced slits as shown in the figure. The resulting interference pattern on a distant screen reveals a place of total destructive interference. Of the following, what must be the phase difference (in radians) between the electric fields from each of the adjacent slits for this location on the screen?



(A) 0 **(B)** $\pi/12$ **(C)** $\pi/6$ **(D)** $\pi/3$ **(E)** $\pi/2$

47. 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 increasing uniformly in time. What is the direction of the force on the proton in the figure if the proton is moving to the right at the instant shown? Ignore gravity.

(A) No Force
(B) Up
(C) Down
(D) Out of the page
(E) Into the page



Questions 48 – 49 deal with the following information:

An electromagnetic wave has an electric field given by the expression (in Cartesian coordinates):

$$\vec{E}(x,t) = 6.0\cos\left(1.14\times10^{7}\,x - 3.43\times10^{15}\,t\right)\hat{z}$$

48. What is the direction of the energy flow for the wave?

(A) $-x$ **(B)** $+x$ **(C)** $-y$ **(D)** $+y$ **(E)** $+z$

49. What is the direction of the magnetic field at time $t = 0$ and position $x = 0$?

(A) $-x$ **(B)** $+x$ **(C)** $-y$ **(D)** $+y$ **(E)** $+z$

50. What is the magnitude of the linear momentum (in units of $kg \cdot m/s$) of an electron moving in a straight line if it has $3.2\times10^{-13}\ J$ of kinetic energy?

(A) 0 **(B)** 2.6×10^{-22} **(C)** 7.6×10^{-22} **(D)** 1.3×10^{-21} **(E)** 1.9×10^{-12}