April 2000
Dear Physics Teacher:

This package contains examinations and answer sheets for ***the 2000 AAPT/Metrologic PHYSICS BOWL High School Physics Contest.*** A competitive examination of this type contains some fairly easy questions at the beginning, but the level of difficulty increases. Students should be informed of the nature of the exam. For example, a mean score at the 50 percent level is anticipated; it is not likely that any student will answer every question correctly.

In order for your school's entries to be eligible for this competition, it is essential that each of the following procedures be followed exactly:

(1) Many teachers have expressed concerns about the security of the exam. To help ensure a fair contest, please take these steps:
   (a) Remove this letter, the extra instruction and formula sheet from the package.
   (b) Place the rest of the package (exams & answer sheets) under lock-and-key, preferably in the school safe, until a few minutes before the contest.
   (c) Do not open any test booklets; each student is to open his/her own booklet as the contest begins.
   (d) Unless the student is physically challenged, each student must fill out his/her own answer sheet and these must be the ones submitted.

(2) You must use the instructions on the **back side** of this page to form the school's identification number and determine the school's special codes. The school's I.D. number will be the 9 digit zip code if you have a U.S. postal address. Special codes "A" will identify division and special codes "F" and "G" will identify region. Any school may enter Region 20. ALL student papers must have properly filled in Student Name, School I.D. Number, division and region to be assured eligibility for team or national recognition.

(3) The 45-minute examination is to be administered on Wednesday, April 19. Be sure that the answer sheets are marked with a #2 pencil.

(4) All students take the same examination. However, the competition is organized in two separate divisions: Division I (first-year physics students) and Division 2 (second-year).

(5) After you have distributed the answer sheets to your students, but before they open their test booklets to begin the examination, go over the instructions on the first page of the exam booklet. Please insure that the identification number and special codes are entered correctly on the answer sheet.

(6) **RETURN RESULTS MUST BE POSTMARKED BY SATURDAY, APRIL 22** to be eligible for the competition. Answer sheets that are folded or mutilated are not reliably read, please use a large flat envelope for returning results. **RETURN ALL ANSWER SHEETS, ALONG WITH THIS LETTER** indicating your name and school address so that your school can be identified to: **AAPT - *PHYSICS BOWL, Attn: Courtney Willis, Physics Department, University of Northern Colorado, Greeley, CO 80639 -0116*.** Contest results, the answer key, and your school grades will be mailed out about May 12, 2000.

Certificates are enclosed for all competing students in your school and for the teachers. Metrologic Instruments, Inc. will provide the prizes. If you have any questions or comments about the prizes, please contact Metrologic directly.

Good luck!

Courtney Willis
AAPT Examinations Director

Dear Physics Teacher,

The Physicsbowl 2000 results will be machine processed therefore it is very important that the students correctly fill out **ALL** of the requested information correctly on the provided answer forms. If the information is not properly filled out and bubbled-in, a student's results will not be counted towards the schools team score and they may become ineligible for individual recognition. Xeroxed forms can not be machine read.

The following information will have to be correctly coded on each student's answer form.

1. NAME (Last, First, M.I.),
2. SEX (M or F)
3. GRADE (9-12 US, 9-13 Canada)
4. SCHOOL IDENTIFICATION NUMBER (see procedures below for determining school ID)
5. SPECIAL CODES (see procedures below for determining both special codes)

Students must write in the values in the proper place as well as correctly BUBBLE-IN the information. Students do not need to fill in birthdate information.

SCHOOL IDENTIFICATION NUMBER

All addresses served by the U.S. Postal Service have a 9 digit postal ZIP code. This number should be entered in the area marked IDENTIFICATION NUMBER. You should start with your regular 5 digit ZIP code and follow it with your additional "plus 4" digits. If you are unsure of your entire 9 digit code please check with your local post office, call 1-800-275-8777, or the internet. If you are not served by the U.S. Postal Service and your school's address has a six character postal code (such as N6B 2P8) enter "000000" (6 0's) followed by the *numbers* in your school's postal code (for example given 000000628). If your school's address has neither, enter "0000000" (7 0's) and an arbitrary 2 digit number. (**Teachers: Please fill in your schools ID number below**)

_____ _____ _____ - _____ _____ - _____ _____ _____ _____

SPECIAL CODES

The special codes area on the answer form will determine each students Division and Region. These are very important. Special code "A" will identify the level of physics the student is presently taking while the two special codes "F" and "G" will be used to identify the students region. Teachers may want to check these areas before sending in the results to make sure they have been properly filled out

Division: Enter a "1" for division I (first-year physics students) or a "2" for division II (second-year physics students) in special code column "A".

A					F	G
_____	__x__	__x__	__x__	__x__	_____	_____

Region: If you attend a specialized science and math school, enter "20" in the special code columns "F" and "G" . Any school may enter Region 20. If not, find your state, province, or other geographic region in the following list and enter its two-digit code in the special code columns "F" and "G".

02 Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
03 New York, Maritime Provinces, Ontario, Quebec
04 New Jersey, Pennsylvania
05 Delaware, District of Columbia, Maryland, North Carolina, Virginia
06 Florida, Georgia, South Carolina, Puerto Rico, Virgin Islands
07 Kentucky, Ohio, West Virginia
08 Indiana, Michigan
09 Illinois, Iowa
10 Minnesota, North Dakota, South Dakota, Wisconsin
11 Alabama, Arkansas, Louisiana, Mississippi, Tennessee
12 Colorado, Kansas, Missouri, Nebraska, Oklahoma, Wyoming
13 Arizona, New Mexico, Texas, Utah
14 California, Hawaii, Nevada, American Samoa, Guam

15 Alaska, Idaho, Montana, Oregon, Washington, Alberta, British Columbia, Manitoba, Saskatchewan, and others
20 Specialized Science and Math Schools

PHYSICS BOWL - APRIL 19, 2000

40 QUESTIONS–45 MINUTES

This contest is sponsored by the **American Association of Physics Teachers** (AAPT) and **Metrologic Instruments** to generate interest in physics and to recognize outstanding high school physics students and their teachers.

This competition is held in 15 regions, each with two divisions. Division I is for students in a first-year physics course; Division II is for students in a second-year physics course. A school's score in each division is the sum of the four highest student scores in that division. To compete in a division, a school must have at least four students participating. A school may compete in either or both divisions, provided that it has at least four eligible students participating in each division.

The ten highest scoring students nation wide will receive $1000 scholarships. The highest scoring student in each region will receive $300 scholarships while the second highest scoring student in each region will receive a $100 scholarships for a total of 70 scholarships in all. All participating students will be recognized with a certificate from AAPT and Metrologic Instruments.

NOTE: one award per student

If your exam is a photocopy or previously opened, your school is in violation of US copyright law and the contest rules.

INSTRUCTIONS

Answer sheet: Write and bubble-in the appropriate information on your answer sheet. You should fill in your name, sex, grade, and ID Number and 2 special codes. In the block labeled "IDENTIFICATION NUMBER," write in and encode the ten-digit school identification number your teacher gives you. You will also need to fill in two special codes to identify the region you are from and which level of physics you are taking. Failure to properly fill in all the above information on your answer sheet will mean your score will not be counted towards the school's team overall score and you may become ineligible for individual recognition. 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. You will use only the first 40 answer blocks on the sheet.

Calculator: A hand-held calculator may be used. However, any memory must be cleared of data and programs. Calculators may not be shared.

Formulas and constants: The formulas and constants provided with these instructions 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!

Do Not Open This Booklet Until You Are Told to Begin.

acceleration due to gravity	g	$= 10\ \text{m/s}^2$
gravitational constant	G	$= 6.7 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2$
specific heat of water	c_w	$= 1.0\ \text{kcal/kg·K} = 4.2 \times 10^3\ \text{J/kg·K}$
atomic mass unit	1 u	$= 1.7 \times 10^{-27}\ \text{kg} = 9.3 \times 10^2\ \text{MeV/c}^2$
electron volt	1 eV	$= 1.6 \times 10^{-19}\ \text{J}$
rest mass of electron	m_e	$= 9.1 \times 10^{-31}\ \text{kg}$
rest mass of proton	m_p	$= 1.7 \times 10^{-27}\ \text{kg}$
electronic charge	e	$= 1.6 \times 10^{-19}\ \text{C}$
Coulomb's constant	k	$= 9.0 \times 10^9\ \text{N·m}^2/\text{C}^2$
permittivity constant	ε_0	$= 8.9 \times 10^{-12}\ \text{C}^2/\text{N·m}^2$
permeability constant	μ_0	$= 4\pi \times 10^{-7}\ \text{T·m/A}$
speed of sound in air (20˚C)	v_s	$= 340\ \text{m/s}$
speed of light in vacuum	c	$= 3.0 \times 10^8\ \text{m/s}$
Planck's Constant	h	$= 6.6 \times 10^{-34}\ \text{J·s} = 4.14 \times 10^{-15}\ \text{eV·s}$

$x = v_0 t + \frac{1}{2}at^2$

$v_f = v_0 + at$

$\bar{v} = \frac{\Delta x}{\Delta t}$

$v_f^2 = v_0^2 + 2a\Delta x$

$v_{0x} = v_0 \cos\theta$

$v_{0y} = v_0 \sin\theta$

$a_c = \frac{v^2}{r}$

$\sum \mathbf{F} = m\mathbf{a}$

$F_g = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$\mathbf{p} = m\mathbf{v}$

$W = Fs\cos\theta = F_{\|}s = Fs_{\|}$

$E_k = \frac{1}{2}mv^2$

$E_p = mgh$

$E_p = \frac{1}{2}kx^2$

$P = \frac{W}{\Delta t} = Fv\cos\theta = F_{\|}v$

$\tau = RF\sin\theta = RF_{\perp} = R_{\perp}F$

$\sum \boldsymbol{\tau} = I\boldsymbol{\alpha}$

$n = \frac{c}{v}$

$v = f\lambda$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n\lambda = d\frac{x_n}{L} = d\sin\theta_n$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$m = -\frac{d_i}{d_o}$

$Q = mc\Delta T$

$Q = mL$

$\Delta U = Q - W$

$pV = nRT$

$W = p\Delta V$

$F_e = k\frac{q_1 q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$V = \frac{W}{q}$

$V = k\frac{q}{r}$

$V = Ed$

$Q = CV$

$V = RI$

$P = VI$

$F = qvB\sin\theta = qvB_{\perp}$

$F = ILB\sin\theta = ILB_{\perp}$

$B = \frac{\mu_0 I}{2\pi r}$

$B = \mu_0 nI$

$emf = BLv$

$E = mc^2$

$E = hf$

$p = \frac{h}{\lambda}$

Nuclear notation: $^{A}_{Z}X$ where A is the atomic mass number and Z is the nuclear charge.

Quantities in bold type are vectors. Quantities in regular type are scalars or the magnitude of vectors.

1. As a wave moves from one medium to a second medium with a different index of refraction which of the following wave properties would NEVER change?

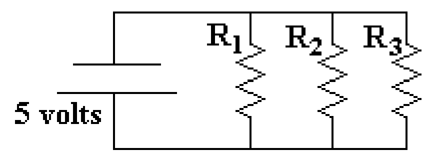
A) frequency B) wavelength C) speed D) angle E) all will change

2. The following equation is an example of what kind of nuclear reaction?

$$^{12}_{6}C + ^{4}_{2}He \rightarrow ^{16}_{8}O + \text{Energy}$$

A) fission
B) fusion
C) alpha decay
D) beta decay
C) positron decay

3. Which of the following statements is NOT true concerning the simple circuit shown where resistors R_1, R_2 and R_3 are have equal resistances?



A) the largest current will pass through R_1
B) the voltage across R_2 is 5 volts
C) the power dissipated in R_3 could be 10 watts
D) if R_2 were to burn out, current would still flow through both R_1 and R_3
E) the net resistance of the circuit is less than R_1

4. Specular reflection occurs whenever light is incident on

A) a smooth surface
B) a rough surface
C) a boundary between high index of refraction and low index of refraction materials
D) a boundary between low index of refraction and high index of refraction materials
E) a boundary between any two transparent substances, regardless of index of refraction

5. A cart with mass $2m$ has a velocity v before it strikes another cart of mass $3m$ at rest. The two carts couple and move off together with a velocity

A) $v/5$ B) $2v/5$ C) $3v/5$ D) $2v/3$ E) $(2/5)^{1/2}v$

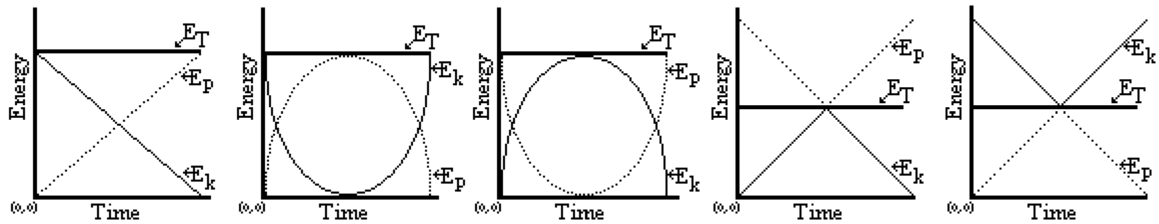
6. How much work would be required to move a 4 coulomb charge 6 meters parallel to a 24 N/C electric field?

A) 0 J B) 24 J C) 96 J D) 144 J E) 576 J

7. The length of the most effective transmitting antenna is equal to one-fourth the wavelength of the broadcast wave. If a radio station has an antenna 4.5 meters long then what is the broadcast frequency of the radio station?

A) 1.5×10^{-8} Hz. B) 6.0×10^{-8} Hz C) 1.7×10^{7} Hz D) 6.7×10^{7} Hz E) 3.0×10^{8} Hz

8. A pendulum is pulled to one side and released. It swings freely to the opposite side and stops. Which of the following might best represent graphs of kinetic energy (E_k), potential energy (E_p) and total energy (E_T)?



A) B) C) D) E)

9. Is it possible for an object's velocity to increase while its acceleration decreases?

A) No, this is impossible because of the way in which acceleration is defined.
B) No, because if acceleration is decreasing the object will be slowing down.
C) No, because velocity and acceleration must always be in the same direction.
D) Yes, an example would be a falling object near the surface of the moon.
E) Yes, an example would be a falling object in the presence of air resistance.

10. When a wire moving through a magnetic field has a voltage induced between the wire's ends, that voltage is

I. directly proportional to the strength of the magnetic field
II. directly proportional to the velocity of the wire
III. directly proportional to the diameter of the wire

A) I only B) II only C) III only D) I and II only E) II and III only

11. A certain particle undergoes erratic motion. At every point in its motion, the direction of the particle's momentum is ALWAYS

A) the same as the direction of its velocity
B) the same as the direction of its acceleration
C) the same as the direction of its net force
D) the same as the direction of its kinetic energy vector
E) none of the above

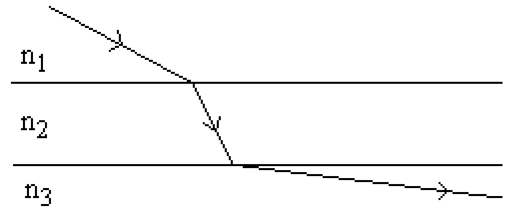
12. Astronauts in an orbiting space shuttle are "weightless" because
A) of their extreme distance from the earth
B) the net gravitational force on them is zero
C) there is no atmosphere in space
D) the space shuttle does not rotate
E) they are in a state of free fall

13. An object near the surface of the earth with a weight of 100 newtons is accelerated at 4 m/s^2. What is the net force on the object?

A) 25 N B) 40 N C) 250 N D) 400 N E) 2500 N

14. A beam of light passes from medium 1 to medium 2 to medium 3 as shown in the diagram. What may be concluded about the three indexes of refraction, n_1, n_2 and n_3?

A) $n_3 > n_1 > n_2$
B) $n_1 > n_2 > n_3$
C) $n_1 > n_3 > n_2$
D) $n_2 > n_3 > n_1$
E) $n_2 > n_1 > n_3$



15. A student initially at rest on a frictionless frozen pond throws a 1 kg hammer in one direction. After the throw, the hammer moves off in one direction while the student moves off in the other direction. Which of the following correctly describes the above situation?

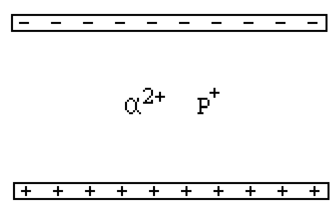
A) The hammer will have the momentum with the greater magnitude.
B) The student will have the momentum with the greater magnitude.
C) The hammer will have the greater kinetic energy.
D) The student will have the greater kinetic energy.
E) The student and the hammer will have equal but opposite amounts of kinetic energy.

16. Consider an illuminated object, a pinhole, and a screen arranged to form a pinhole image on the screen. Which of the following will occur if the screen is moved away from the pinhole?

I. the image will go out of focus
II. the image will become larger
III. the image will become brighter

A) I only B) II only C) III only D) I and III only E) II and III only

17. An alpha particle and a proton are placed equal distance between two large charged metal plates as shown. Which of the following would best describe the motion of the two particles if they were free to move?



A) The alpha particle will travel upwards with twice the velocity of the proton.
B) Both particles will travel upwards with the same velocity.
C) The alpha particle will accelerate upwards with twice the acceleration of the proton.
D) Both particles will accelerate upwards with the same acceleration.
E) The alpha particle will accelerate upwards with half the acceleration of the proton.

18. Two parallel metal plates carry opposite electrical charges each with a magnitude of *Q*. The plates are separated by a distance *d* and each plate has an area *A*. Consider the following:

I. increasing *Q* II. increasing *d* III. increasing *A*

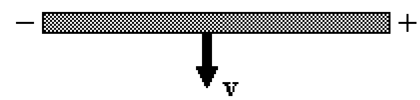
Which of the following would have the effect of reducing the potential difference between the plates?

A) I only B) II only C) III only D) I and III E) II and III

19. An astronaut in an orbiting space craft attaches a mass *m* to a string and whirls it around in uniform circular motion. The radius of the circle is *r*, the speed of the mass is *v*, and the tension in the string is *F*. If the mass, radius, and speed were all to double the tension required to maintain uniform circular motion would be

A) $F/2$ B) F C) $2F$ D) $4F$ E) $8F$

20. A wire moves with a velocity *v* through a magnetic field and experiences an induced charge separation as shown. What is the direction of the magnetic field?



A) Into the page
B) Towards the bottom of the page
C) Towards the right
D) Out of the page
E) Towards the top of the page

The next TWO questions will refer to the following information. A car of mass *m* slides across a patch of ice at a speed *v* with its brakes locked. It then hits dry pavement and skids to a stop in a distance *d*. The coefficient of kinetic friction between the tires and the dry road is μ.

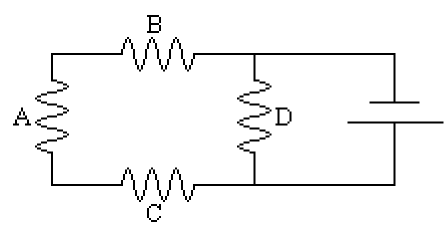
21. If the car had a mass of 2*m*, it would have skidded a distance of

A) 0.5 *d* B) *d* C) 1.41 *d* D) 2 *d* E) 4 *d*

22. If the car had a speed of 2*v*, it would have skidded a distance of

A) 0.5 *d* B) *d* C) 1.41 *d* D) 2 *d* E) 4 *d*

23. If all of the resistors in the following simple circuit have the same resistance, which would dissipate the greatest power?



A) resistor A
B) resistor B
C) resistor C
D) resistor D

24. Consider an object that has a mass, *m*, and a weight, *W*, at the surface of the moon. If we assume the moon has a nearly uniform density, which of the following would be closest to the object's mass and weight at a distance halfway between Moon's center and its surface?

A) ½ *m* & ½ *W* B) ¼ *m* & ¼ *W* C) 1 *m* & 1 *W* D) 1 *m* & ½ *W* E) 1 *m* & ¼ *W*

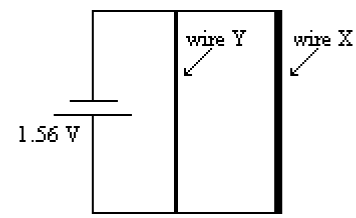
25. The net force on a rocket with a weight of 1.5×10^4 newtons is 2.4×10^4 newtons. About how much time is needed to increase the rocket's speed from 12 m/s to 36 m/s near the surface of the Earth at takeoff?

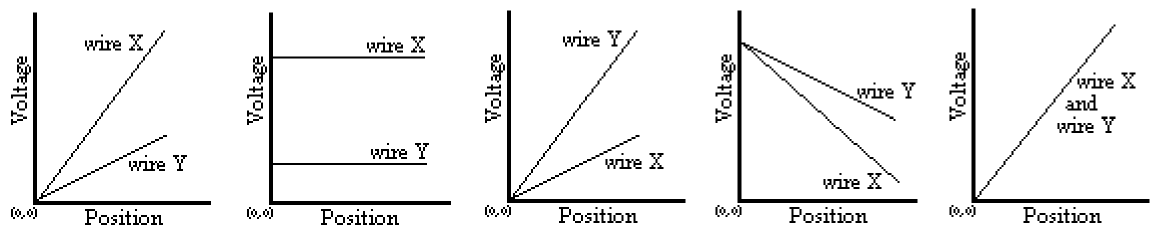
A) .62 seconds B) .78 seconds C) 1.5 seconds D) 3.8 seconds E) 15 seconds

26. A 500-gram ball moving at 15 m/s slows down uniformly until it stops. If the ball travels 15 meters, what was the average net force applied while it was coming to a stop?

A) 0.37 newtons B) 3.75 newtons C) 37.5 newtons D) 375 newtons E) 3750 newtons

27. The following diagram represents an electrical circuit containing two uniform resistance wires connected to a single flashlight cell. Both wires have the same length, but the thickness of wire X is twice that of wire Y. Which of the following would best represent the dependence of electric potential on position along the length of the two wires?

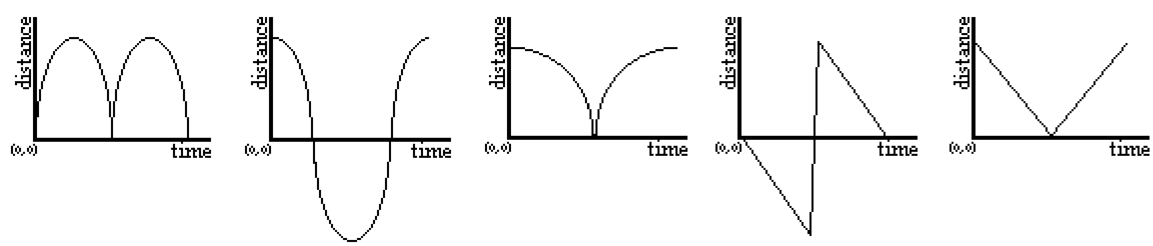




A) B) C) D) E)

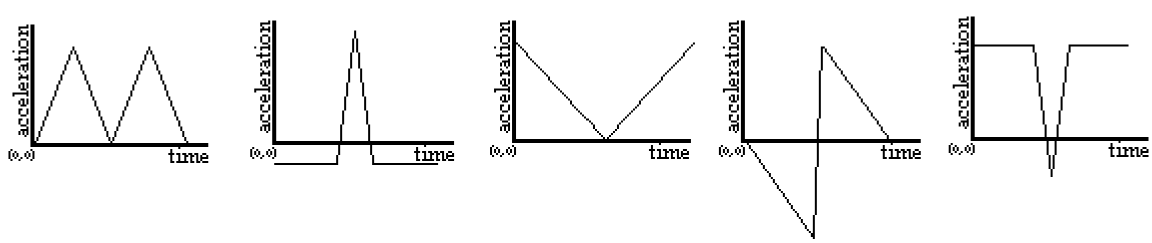
The following TWO questions refer to the following information. An ideal elastic rubber ball is dropped from a height of about 2 meters, hits the floor and rebounds to its original height.

28. Which of the following graphs would best represent the distance above the floor versus time for the above bouncing ball?



A) B) C) D) E)

29. Which of the following graphs would best represent acceleration versus time for the bouncing ball?



A) B) C) D) E)

30. Monochromatic light falls on a single slit 0.01 cm wide and develops a first-order minimum (dark band) 0.59 cm from the center of the central bright band on a screen that is one meter away. Determine the wavelength of the light.

A) 1.18×10^{-2} cm
B) 5.90×10^{-3} cm
C) 1.18×10^{-4} cm
D) 5.90×10^{-5} cm
E) 1.18×10^{-6} cm

31. The average signal to noise ratio for a particular tape recorder is 50 decibels. This means that the loudness of an average reproduced signal is about how many times louder than the loudness of the tape noise?

A) 7.07 times B) 50 times C) 625 times D) 2500 times E) 100,000 times

32. A block rests on a flat plane inclined at an angle of 30^{o} with respect to the horizontal. What is the minimum coefficient of friction necessary to keep the block from sliding?

A) $\frac{1}{2}$ B) $\frac{1}{\sqrt{2}}$ C) $\frac{1}{\sqrt{3}}$ D) $\frac{1}{4}$ E) $\frac{2}{\sqrt{3}}$

The next TWO questions refer to the following information. A natural horn (trumpet with no valves) is similar to an pipe open at both ends. A musician plans to create a fundamental frequency of 256 Hz (middle C) using the horn.

33. If sound travels at 350 m/s, what must be the length of this horn?

A) 0.34 meters B) 0.68 meters C) 0.73 meters D) 1.36 meters E) 1.46 meters

34. A talented musician can produce a number of overtones on this natural horn, What would be the frequency of the fourth overtone produced when the musician is playing a middle C fundamental?

A) 512 Hz B) 768 Hz C) 1024 Hz D) 1280 Hz E) 1536 Hz

35. A 100 g block of aluminum at 90 ^{o}C is brought into contact with a 100 g block of lead at 10 ^{o}C inside a thermally isolated container. The final temperature of the system at equilibrium would be closest to

A) 10 ^{o}C B) 20 ^{o}C C) 50 ^{o}C D) 80 ^{o}C E) 90 ^{o}C

36. A ball is thrown vertically upward with an initial velocity v and an initial kinetic energy E_k. When the ball is half way to the top of its flight, it has a velocity of _?_ and a kinetic energy of _?_.

A) $\frac{v}{2}; \frac{E_k}{2}$ B) $\frac{v}{\sqrt{2}}; \frac{E_k}{2}$ C) $\frac{v}{4}; \frac{E_k}{2}$ D) $\frac{v}{2}; \frac{E_k}{\sqrt{2}}$ E) $\frac{v}{\sqrt{2}}; \frac{E_k}{\sqrt{2}}$

The next TWO questions will refer to the following information. During a recent winter storm, bales of hay had to be dropped from an airplane to a herd of cattle below. Assume the airplane flew horizontally at an altitude of 180 m with a constant velocity of 50 m/s and dropped one bail of hay every two seconds. It is reasonable to assume that air resistance will be negligible for this situation.

37. As the bales are falling through the air, what will happen to their distance of separation?

A) the distance of separation will increase
B) the distance of separation will decrease
C) the distance of separation will remain constant
D) the distance of separation will depend on the mass of the bales
E) none of the above are always true

38. About how far apart from each other will the bales land on the ground?

A) 9000 m B) 300 m C) 180 m D) 100 m E) 50 m

39. If a boat can travel with a speed of v in still water, which of the following trips will take the least amount of time.

A) traveling a distance of 2d in still water
B) traveling a distance of 2d across (perpendicular to) the current in a stream
C) traveling a distance d downstream and returning a distance d upstream
D) traveling a distance d upstream and returning a distance d downstream
E) all of the above will take equal times

40. Suppose two cars are racing on a circular track one kilometer in circumference. The first car can circle the track in 15 seconds at top speed while the second car can circle the track in 12 seconds at top speed. How much lead does the first car need starting the last lap of the race not to lose?

A) at least 250 m
B) at least 200 m
C) at least 104 m
D) at least 83 m
E) at least 67 m

Answers to PhysicsBowl 2000

1. A	21. B
2. B	22. E
3. A	23. D
4. A	24. D
5. B	25. C
6. E	26. B
7. C	27. E
8. C	28. C
9. E	29. B
10. D	30. D
11. A	31. E
12. E	32. C
13. B	33. B
14. E	34. D
15. C	35. D
16. B	36. B
17. E	37. A
18. C	38. D
19. D	39. A
20. A	40. A

A - 8
B - 9
C - 7
D - 8
E – 7

MECHANICS	- 21
WAVES	- 9
HEAT	- 1
E & M	- 8
MODERN	- 1