Physics Olympiad

Entia non multiplicanda sunt praeter necessitatem

1997 MULTIPLE CHOICE SCREENING TEST

30 QUESTIONS—40 MINUTES

INSTRUCTIONS

DO NOT OPEN THIS TEST UNTIL YOU ARE TOLD TO BEGIN

This test contains 30 multiple choice questions. Your answer to each question must be marked on the optical mark answer sheet that accompanies the test. Only the boxes preceded by numbers 1 through 30 are to be used on the answer sheet.

Select the single answer that provides the best response to each question. Please be sure to use a No. 2 pencil and completely fill the box corresponding to your choice. If you change an answer, the previous mark must be completely erased.

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

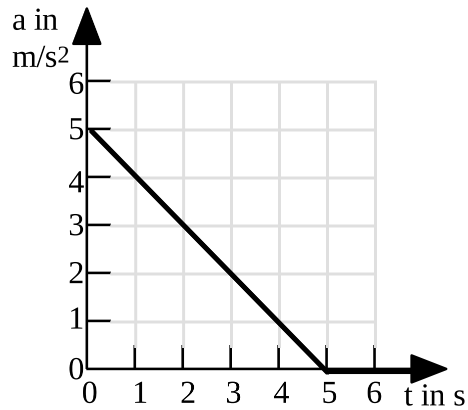
Your grade on this multiple choice test will be your number of correct answers. There is no penalty for guessing. It is to your advantage to answer every question.

The values of some possibly useful constants are given below:

mass of electron	m_e	$= 9.1 \times 10^{-31}$ kg
mass of proton	m_p	$= 1.7 \times 10^{-27}$ kg
electronic charge	e	$= 1.6 \times 10^{-19}$ C
speed of light	c	$= 3.0 \times 10^{8}$ m/s
Coulomb's constant	k	$= 9.0 \times 10^{9}$ N·m²/C²
permittivity constant	ε_0	= 8.9 x 10 C / 2
	μ	= π -7 T·m/A
	G	-11 N·m /kg
mass of Earth	$_E$	$= 6.0 \times 10^{24}$ kg
radius of Earth	R_E	$= 6.4 \times 10^{6}$ m
gravitational field at Earth's surface	g	$= 9.8$ m/s²
speed of sound (20 °C)	v_s	= 340 m/s

DO NOT OPEN THIS TEST UNTIL YOU ARE INSTRUCTED TO BEGIN

1. Starting from rest at time t = 0, a car moves in a straight line with an acceleration given by the accompanying graph. What is the speed of the car at t = 3 s?



A. 1.0 m/s
B. 2.0 m/s
C. 6.0 m/s
D. 10.5 m/s
E. 12.5 m/s

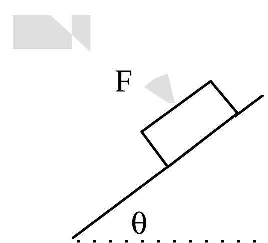
2. A flare is dropped from a plane flying over level ground at a velocity of 70 m/s in the horizontal direction. At the instant the flare is released, the plane begins to accelerate horizontally at 0.75 m/s^2. The flare takes 4.0 s to reach the ground. Assume air resistance is negligible. Relative to a spot directly under the flare at release, the flare lands

A. directly on the spot.
B. 6.0 m in front of the spot.
C. 274 m in front of the spot.
D. 280 m in front of the spot.
E. 286 m in front of the spot.

3. As seen by the pilot of the plane (in question #2) and measured relative to a spot directly under the plane when the flare lands, the flare lands

A. 286 m behind the plane.
B. 6.0 m behind the plane.
C. directly under the plane.
D. 12 m in front of the plane.
E. 274 m in front of the plane

4. A force F is used to hold a block of mass m on an incline as shown in the diagram. The plane makes an angle of θ with the horizontal and F is perpendicular to the plane. The coefficient of friction between the plane and the block is μ. What is the minimum force, F, necessary to keep the block at rest?



A. μ mg
B. mg cosθ
C. mg sinθ
D. (mg/μ) sinθ
E. (mg/μ) (sinθ - μ cosθ)

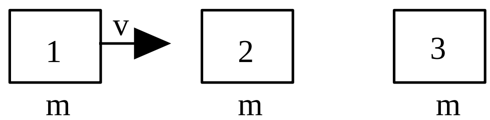
5. You hold a rubber ball in your hand. The Newton's third law companion force to the force of gravity on the ball is the force exerted by the

A. ball on the Earth.
B. ball on the hand.
C. hand on the ball.
D. Earth on the ball.
E. Earth on your hand.

6. A ball of mass *m* is fastened to a string. The ball swings in a vertical circle of radius *R* with the other end of the string held fixed. Neglecting air resistance, the difference between the string's tension at the bottom of the circle and at the top of the circle is

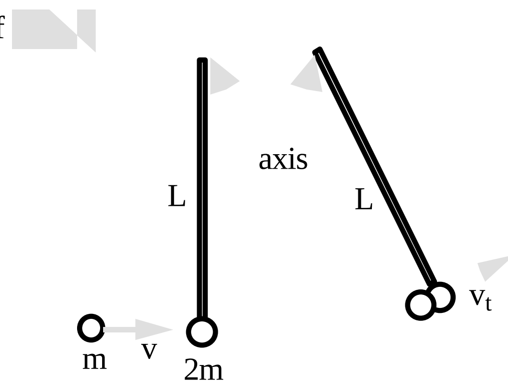
A. mg B. 2 mg C. 4 mg D. 6 mg E. 8 mg

7. Three air track cars, shown in the accompanying figure, all have the same mass *m*. Cars *2* and *3* are initially at rest. Car *1* is moving to the right with speed *v*. Car *1* collides with car *2* and sticks to it. The *1-2* combination collides elastically with car *3*. Which of the following is most nearly the final speed of car *3*?



A. 0.17 v B. 0.50 v C. 0.67 v D. 0.80 v E. 1.0 v

8. A point object of mass *2m* is attached to one end of a rigid rod of negligible mass and length *L*. The rod is initially at rest but free to rotate about a fixed axis perpendicular to the rod and passing through its other end (see diagram to the right). A second point object with mass *m* and initial speed *v* collides and sticks to the *2m* object. What is the tangential speed v_t of the object immediately after the collision?



A. $v/3$
B. $v/2$
C. $v/\sqrt{3}$
D. $v/\sqrt{2}$
E. $2v/\sqrt{3}$

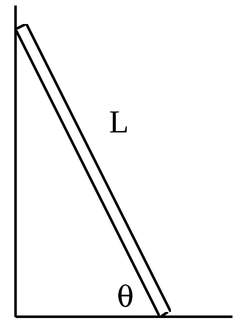
9. Two artificial satellites I and II have circular orbits of radii *R* and 2*R*, respectively, about the same planet. The orbital velocity of satellite I is *v*. What is the orbital velocity of satellite II?

A. $\frac{v}{2}$ B. $\frac{v}{\sqrt{2}}$ C. v D. $v\sqrt{2}$ E. 2v

10. The gravitational acceleration on the surface of the moon is 1.6 m/s^2. The radius of the moon is 1.7 x 10^6 m. The period of a satellite placed in a low circular orbit about the moon is most nearly

A. 1.0 x 10^3 s B. 6.5 x 10^3 s C. 1.1 x 10^6 s D. 5.0 x 10^6 s E. 7.1 x 10^{12} s

11. A uniform ladder of length L rests against a smooth frictionless wall. The floor is rough and the coefficient of static friction between the floor and ladder is μ. When the ladder is positioned at angle θ, as shown in the accompanying diagram, it is just about to slip. What is θ?



A. $\theta = \frac{\mu}{L}$ B. $\tan\theta = 2\mu$ C. $\tan\theta = \frac{1}{2\mu}$ D. $\sin\theta = \frac{1}{\mu}$ E. $\cos\theta = \mu$

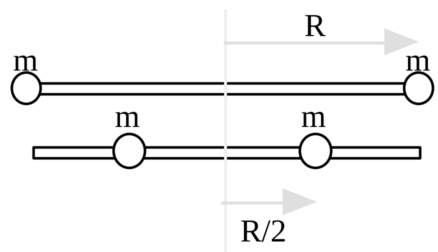
12. Three objects, all of mass M, are released simultaneously from the top of an inclined plane of height H. The objects are described as follows

I. a cube of side R.
II. a solid cylinder of radius R
III. a hollow cylinder of radius R

Assume the cylinders roll down the plane without slipping and the cube slides down the plane without friction. Which object(s) reach(es) the bottom of the plane first?

A. I B. II C. III D. I & II E. II & III

13. A massless rod of length $2R$ can rotate about a vertical axis through its center as shown in the diagram. The system rotates at an angular velocity ω when the two masses m are a distance R from the axis. The masses are simultaneously pulled to a distance of $R/2$ from the axis by a force directed along the rod. What is the new angular velocity of the system?



A. $\omega/4$ B. $\omega/2$ C. ω D. 2ω E. 4ω

14. A meter stick moves with a velocity of 0.60 c relative to an observer. The observer measures the length of the meter stick to be L. Which of the following statements is always true?

A. L = 0.60 m B. L = 0.80 m C. 0.80 m ² L ² 1.00 m D. L = 1.00 m E. L ³ 1.00m

15. A glowing ember (hot piece of charcoal) radiates power P in watts at an absolute temperature T. When the temperature of the ember has decreased to $T/2$, the power it radiates is most nearly

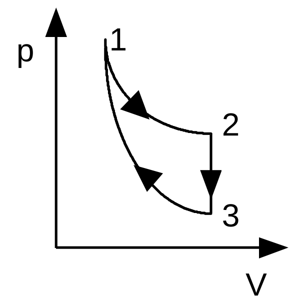
A. P B. $P/2$ C. $P/4$ D. $P/8$ E. $P/16$

16. Three processes compose a thermodynamic cycle shown in the accompanying pV diagram of an ideal gas.

Process 1→2 takes place at constant temperature (300 K). During this process 60 J of heat enters the system.

Process 2→3 takes place at constant volume. During this process 40 J of heat leaves the system.

Process 3→1 is adiabatic. T_3 is 275 K.



What is the change in internal energy of the system during process 3→1?

A. -40 J B. -20 J C. 0 D. +20 J E. +40 J

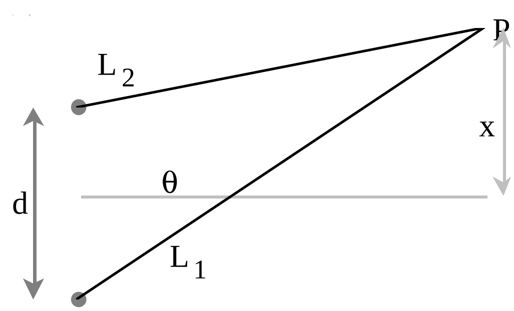
17. What is the change in entropy of the system described in Question # 16 during the process 3→1?

A. +5.0 K/J B. +0.20 J/K C. 0 D. -1.6 J/K E. -6.9 K/J

18. A wave is described by the equation: $y(x,t) = 0.030 \cdot \sin(5\pi x + 4\pi t)$ where x and y are in meters and t is in seconds. The +x direction is to the right. What is the velocity of the wave?

A. 0.80 m/s to the left
B. 1.25 m/s to the left
C. 0.12 π m/s to the right
D. 0.80 m/s to the right
E. 1.25 m/s to the right

19. Two sources, in phase and a distance *d* apart, each emit a wave of wavelength l . See accompanying figure. Which of the choices for the path difference $\Delta L = L_1 - L_2$ will *always* produce destructive interference at point P?

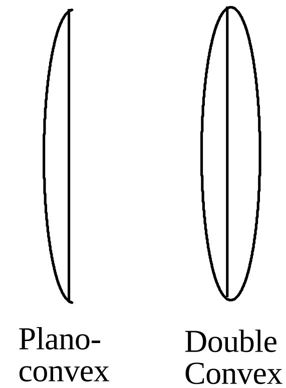


A. d sinθ
B. x/L_1
C. $(x/L_2)d$
D. λ/2
E. 2 λ

20. You are given two lenses, a converging lens with focal length + 10 cm and a diverging lens with focal length - 20 cm. Which of the following would produce a virtual image that is larger than the object?

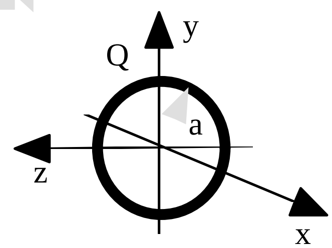
A. Placing the object 5 cm from the converging lens.
B. Placing the object 15 cm from the converging lens.
C. Placing the object 25 cm from the converging lens.
D. Placing the object 15 cm from the diverging lens.
E. Placing the object 25 cm from the diverging lens.

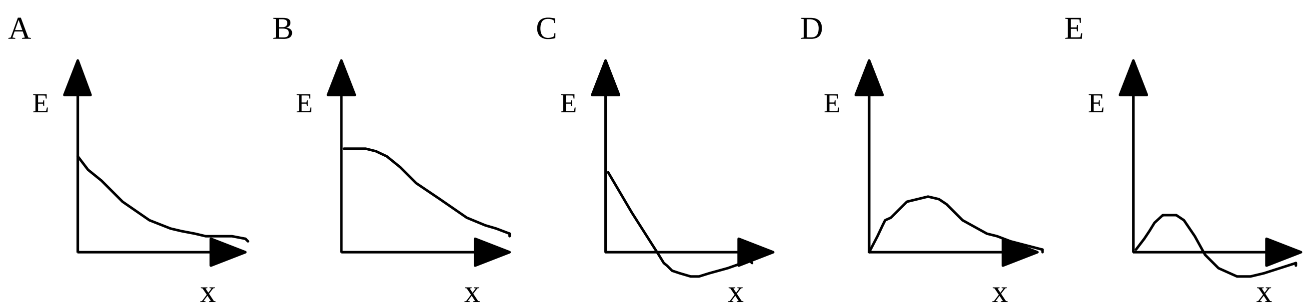
21. You are given two identical plano-convex lenses, one of which is shown to the right. When you place an object 20 cm to the left of a single plano-convex lens, the image appears 40 cm to the right of the lens. You then arrange the two plano-convex lenses back to back to form a double convex lens. If the object is 20 cm to the left of this new lens, what is the approximate location of the image?



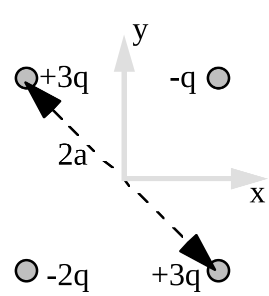
A. 6.7 cm to the right of the lens.
B. 10 cm to the right of the lens.
C. 20 cm to the right of the lens.
D. 80 cm to the right of the lens.
E. 80 cm to the left of the lens.

22. Positive charge *Q* is uniformly distributed over a ring of radius *a* that lies in the y-z plane as shown in the diagram. The ring is centered at the origin. Which of the following graphs best represents the value of the electric field *E* as a function of *x*, the distance along the positive x axis?



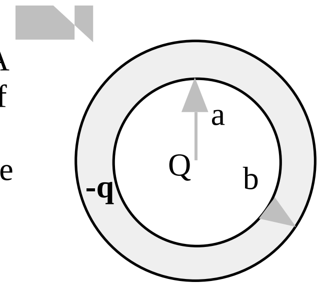


23. Four point charges are placed at the corners of a square with diagonal *2a* as shown in the diagram. What is the total electric field at the center of the square?



A. kq/a^2 at an angle 45° above the +x axis.
B. kq/a^2 at an angle 45° below the -x axis.
C. $3\ kq/a^2$ at an angle 45° above the -x axis.
D. $3\ kq/a^2$ at an angle 45° below the +x axis.
E. $9\ kq/a^2$ at an angle 45° above the +x axis.

Both questions 24 and 25 refer to the system shown in the diagram. A spherical shell with an inner surface of radius *a* and an outer surface of radius *b* is made of conducting material. A point charge +*Q* is placed at the center of the spherical shell and a total charge -*q* is placed on the shell.



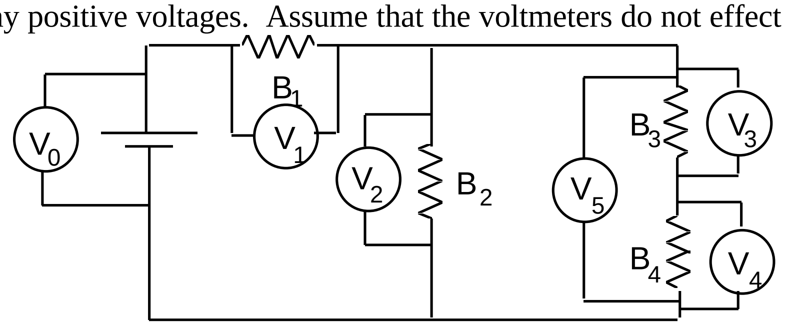
24. How is the charge -*q* distributed after it has reached equilibrium?

A. Zero charge on the inner surface, -q on the outer surface.
B. -Q on the inner surface, -q on the outer surface.
C. -Q on the inner surface, -q+Q on the outer surface.
D. +Q on the inner surface, -q-Q on the outer surface.
E. The charge -*q* is spread uniformly between the inner and outer surface.

25. Assume that the electrostatic potential is zero at an infinite distance from the spherical shell. What is the electrostatic potential at a distance *R* from the center of the shell, where *b* ³ *R* ³ *a*?

A. 0 B. $k\frac{Q}{a}$ C. $k\frac{Q}{R}$ D. $k\frac{Q-q}{R}$ E. $k\frac{Q-q}{b}$

Use the circuit below to answer questions 26 and 27. B_1, B_2, B_3, and B_4 are **identical** light bulbs. There are six voltmeters connected to the circuit as shown. All voltmeters are connected so that they display positive voltages. Assume that the voltmeters do not effect the circuit.



26. If B_2 were to burn out, opening the circuit, which voltmeter(s) would read zero volts?

A. none would read zero.
B. only V_2
C. only V_3 and V_4
D. only V_3, V_4, and V_5
E. they would all read zero

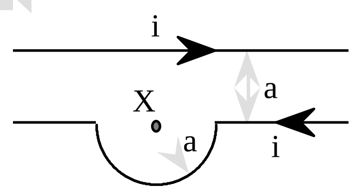
27. If B_2 were to burn out, opening the circuit, what would happen to the reading of V_1? Let V be its original reading when all bulbs are functioning and let V' be its reading when B_2 is burnt out.

A. V' ³ 2V B. 2V > V' > V C. V' = V D. V > V' > V/2 E. V/2 ³ V'

28. A particle with positive charge q and mass m travels along a path perpendicular to a magnetic field. The particle moves in a circle of radius R with frequency f. What is the magnitude of the magnetic field?

A. $\frac{mf}{q}$ B. $\frac{2\pi fm}{q}$ C. $\frac{m}{2\pi fq}$ D. $\frac{mc}{qR}$ E. $\frac{\mu qf}{2\pi R}$

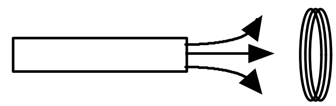
29. Two wires, each carrying a current i, are shown in the diagram to the right. Both wires extend in a straight line for a very long distance on both the right and the left. One wire contains a semi-circular loop of radius a centered on point X. What is the correct expression for the magnetic field at point X? HINT: The magnitude of the magnetic field at the center of a circular current loop of radius R is $\mu_0 i/(2R)$.



A. $\mu_0 i/(4a) + \mu_0 i/(2\pi a)$ out of the page
B. $\mu_0 i/(2a) - \mu_0 i/(2\pi a) + \mu_0 i/(2\pi a)$ out of the page
C. $\mu_0 i/(4a) + \mu_0 i/(2\pi a)$ into the page
D. $\mu_0 i/(4a) + \mu_0 i/(2\pi a) + \mu_0 i/(2\pi a)$ into the page
E. $\mu_0 i/(2a) - \mu_0 i/(2\pi a)$ into the page

30. You are given a bar magnet and a looped coil of wire. Which of the following would induce an emf in the coil?

I. Moving the magnet toward the coil.
II. Moving the coil away from the magnet.
III. Turning the coil about a vertical axis.



A. I only B. II only C. I & II D. I & III E. I, II, III

1997 MULTIPLE CHOICE SCREENING TEST

ANSWER KEY

1.	D	11.	C	21.	B
2.	D	12.	A	22.	D
3.	B	13.	E	23.	B
4.	E	14.	C	24.	C
5.	A	15.	E	25.	E
6.	D	16.	E	26.	A
7.	C	17.	C	27.	D
8.	A	18.	A	28.	B
9.	B	19.	D	29.	C
10.	B	20.	A	30.	E