

The University of the State of New York  
REGENTS HIGH SCHOOL EXAMINATION

# PHYSICS

Tuesday, January 22, 2002 — 9:15 a.m. to 12:15 p.m., only

The answer paper is stapled in the center of this examination booklet. Open the examination booklet, carefully remove the answer paper, and close the examination booklet. Then fill in the heading on your answer paper.

All of your answers are to be recorded on the separate answer paper. For each question in Part I and Part II, decide which of the choices given is the best answer. Then on the answer paper, in the row of numbers for that question, circle with pencil the number of the choice that you have selected. The sample below is an example of the first step in recording your answers.

SAMPLE: (1) 2 3 4

If you wish to change an answer, erase your first penciled circle and then circle with pencil the number of the answer you want. After you have completed the examination and you have decided that all of the circled answers represent your best judgment, signal a proctor and turn in all examination material except your answer paper. Then and only then, place an X in ink in each penciled circle. Be sure to mark only one answer with an X in ink for each question. No credit will be given for any question with two or more X's marked. The sample below indicates how your final choice should be marked with an X in ink.

SAMPLE: (X) 2 3 4

For questions in Part III, record your answers in accordance with the directions given in the examination booklet.

The 2002 Edition of the *Reference Tables for Physical Setting/Physics*, which you may need to answer some questions in this examination, are supplied separately. Be certain you have a copy of these reference tables before you begin the examination. You must also have access to a centimeter ruler and protractor during this examination.

Additional reference information which you may need to answer some of the questions in this examination is provided as the last page of this examination booklet.

When you have completed the examination, you must sign the statement printed at the end of the answer paper, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer paper cannot be accepted if you fail to sign this declaration.

**DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

## Part I

Answer all 55 questions in this part. [65]

*Directions (1–55):* For each statement or question, select the word or expression that, of those given, best completes the statement or answers the question. Record your answer on the separate answer paper in accordance with the directions on the front page of this booklet.

1 What is the total displacement of a student who walks 3 blocks east, 2 blocks north, 1 block west, and then 2 blocks south?

- (1) 0  
(2) 2 blocks east  
(3) 2 blocks west  
(4) 8 blocks

2 Which measurement of an average classroom door is closest to 1 meter?

- (1) thickness  
(2) width  
(3) height  
(4) surface area

3 A group of bike riders took a 4.0-hour trip. During the first 3.0 hours, they traveled a total of 50. kilometers, but during the last hour they traveled only 10. kilometers. What was the group's average speed for the entire trip?

- (1) 15 km/hr  
(2) 30. km/hr  
(3) 40. km/hr  
(4) 60. km/hr

4 A skier starting from rest skis straight down a slope 50. meters long in 5.0 seconds. What is the magnitude of the acceleration of the skier?

- (1) 20. m/s<sup>2</sup>  
(2) 9.8 m/s<sup>2</sup>  
(3) 5.0 m/s<sup>2</sup>  
(4) 4.0 m/s<sup>2</sup>

5 An object falls freely from rest near the surface of Earth. What is the speed of the object after having fallen a distance of 4.90 meters?

- (1) 4.90 m/s  
(2) 9.80 m/s  
(3) 24.0 m/s  
(4) 96.1 m/s

6 Which two terms represent a vector quantity and the scalar quantity of the vector's magnitude, respectively?

- (1) acceleration and velocity  
(2) weight and force  
(3) speed and time  
(4) displacement and distance

7 A 4.0-kilogram rock and a 1.0-kilogram stone fall freely from rest from a height of 100 meters. After they fall for 2.0 seconds, the ratio of the rock's speed to the stone's speed is

- (1) 1:1  
(2) 1:2  
(3) 2:1  
(4) 4:1

8 Two concurrent forces have a maximum resultant of 45 newtons and a minimum resultant of 5 newtons. What is the magnitude of each of these forces?

- (1) 0 N and 45 N  
(2) 5 N and 9 N  
(3) 20. N and 25 N  
(4) 0 N and 50. N

9 In the diagram below, a box is on a frictionless horizontal surface with forces  $F_1$  and  $F_2$  acting as shown.



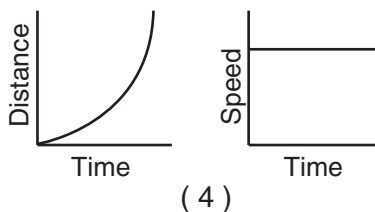
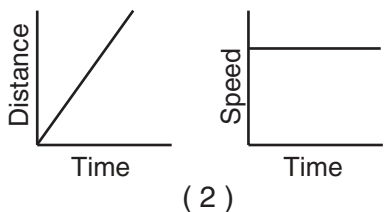
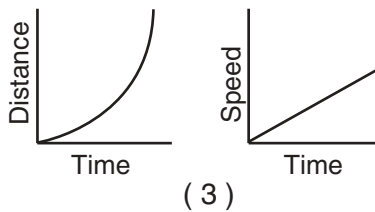
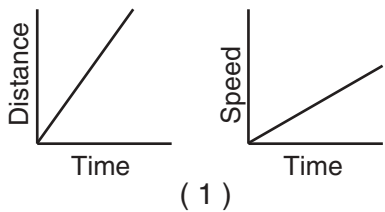
If the magnitude of  $F_1$  is greater than the magnitude of  $F_2$ , then the box is

- (1) moving at constant speed in the direction of  $F_1$   
(2) moving at constant speed in the direction of  $F_2$   
(3) accelerating in the direction of  $F_1$   
(4) accelerating in the direction of  $F_2$

10 When a satellite is a distance  $R$  from the center of Earth, the force due to gravity on the satellite is  $F$ . What is the force due to gravity on the satellite when its distance from the center of Earth is  $3R$ ?

- (1)  $\frac{F}{9}$   
(2)  $\frac{F}{3}$   
(3)  $F$   
(4)  $9F$

11 Which two graphs represent the motion of an object on which the net force is zero?



12 The table below lists the coefficients of kinetic friction for four materials sliding over steel.

Material	Coefficient of Kinetic Friction
aluminum	0.47
brass	0.44
copper	0.36
steel	0.57

A 10.-kilogram block of each of these materials is pulled horizontally across a steel floor at constant velocity. Which block requires the *smallest* applied force to keep it moving at constant velocity?

- (1) aluminum                      (3) copper  
 (2) brass                            (4) steel

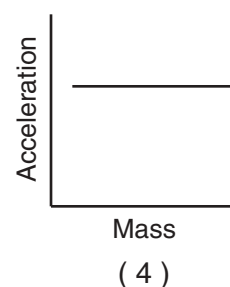
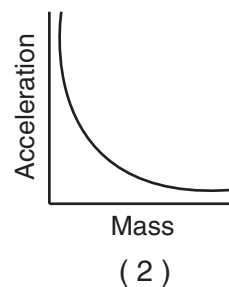
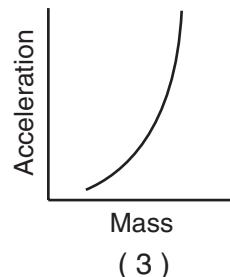
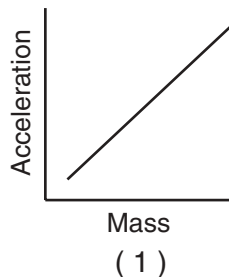
13 The magnitude of the force that a baseball bat exerts on a ball is 50. newtons. The magnitude of the force that the ball exerts on the bat is

- (1) 5.0 N                            (3) 50. N  
 (2) 10. N                            (4) 250 N

14 A bullet traveling at  $5.0 \times 10^2$  meters per second is brought to rest by an impulse of 50. newton•seconds. What is the mass of the bullet?

- (1)  $1.0 \times 10^{-2}$  kg                (3)  $1.0 \times 10^1$  kg  
 (2)  $1.0 \times 10^{-1}$  kg                (4)  $2.5 \times 10^4$  kg

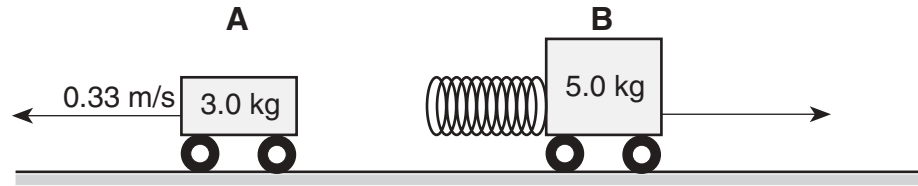
15 Which graph best represents the relationship between acceleration due to gravity and mass for objects near the surface of Earth? [Neglect air resistance.]



16 What is an essential characteristic of an object in equilibrium?

- (1) zero velocity  
 (2) zero acceleration  
 (3) zero potential energy  
 (4) zero kinetic energy

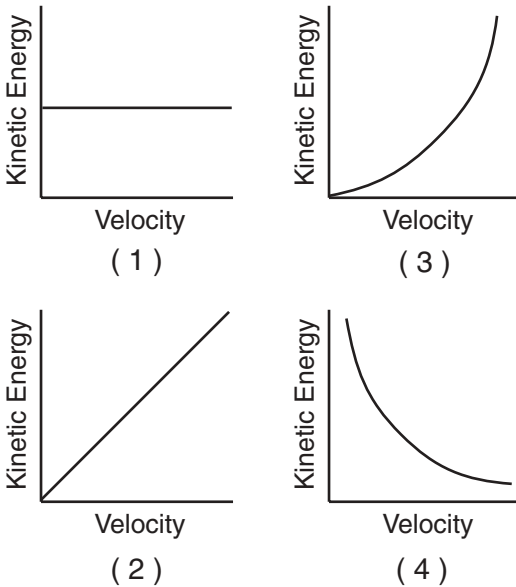
- 17 The diagram below shows two carts that were initially at rest on a horizontal, frictionless surface being pushed apart when a compressed spring attached to one of the carts is released. Cart A has a mass of 3.0 kilograms and cart B has a mass of 5.0 kilograms.



If the speed of cart A is 0.33 meter per second after the spring is released, what is the approximate speed of cart B after the spring is released?

- (1) 0.12 m/s  
 (2) 0.20 m/s  
 (3) 0.33 m/s  
 (4) 0.55 m/s

- 18 Which graph best represents the relationship between the kinetic energy of a moving object and its velocity?



- 19 How much work is done on a downhill skier by an average braking force of  $9.8 \times 10^2$  newtons to stop her in a distance of 10. meters?

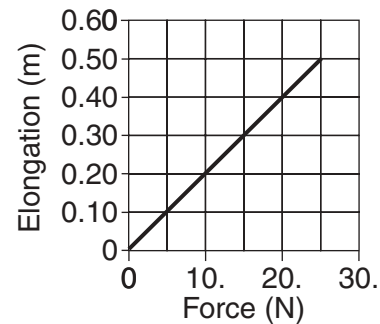
- (1)  $1.0 \times 10^1$  J  
 (2)  $9.8 \times 10^1$  J  
 (3)  $1.0 \times 10^3$  J  
 (4)  $9.8 \times 10^3$  J

- 20 A spring has a spring constant of 120 newtons per meter. How much potential energy is stored in the spring as it is stretched 0.20 meter?

- (1) 2.4 J  
 (2) 4.8 J  
 (3) 12 J  
 (4) 24 J

- 21 The graph below shows the relationship between the elongation of a spring and the force applied to the spring causing it to stretch.

**Elongation vs. Applied Force**



What is the spring constant for this spring?

- (1) 0.020 N/m  
 (2) 2.0 N/m  
 (3) 25 N/m  
 (4) 50. N/m

- 22 Which quantity and unit are correctly paired?

- (1) velocity —  $\text{m/s}^2$   
 (2) momentum —  $\frac{\text{kg} \cdot \text{m}}{\text{s}^2}$   
 (3) energy —  $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$   
 (4) work —  $\text{kg/m}$

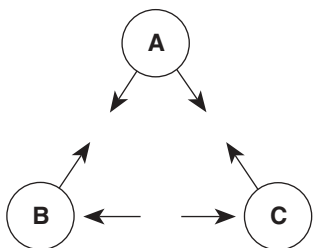
- 23 A 10.-newton force is required to move a 3.0-kilogram box at constant speed. How much power is required to move the box 8.0 meters in 2.0 seconds?

- (1) 40. W  
 (2) 20. W  
 (3) 15 W  
 (4) 12 W

24 A 0.10-kilogram ball dropped vertically from a height of 1.00 meter above the floor bounces back to a height of 0.80 meter. The mechanical energy lost by the ball as it bounces is

- (1) 0.080 J                      (3) 0.30 J  
 (2) 0.20 J                        (4) 0.78 J

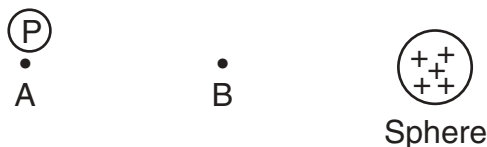
25 The diagram below shows the arrangement of three charged hollow metal spheres, A, B, and C. The arrows indicate the direction of the electric forces acting between the spheres. At least two of the spheres are positively charged.



Which sphere, if any, could be negatively charged?

- (1) sphere A                      (3) sphere C  
 (2) sphere B                      (4) no sphere

26 The diagram below shows proton *P* located at point A near a positively charged sphere.



If  $6.4 \times 10^{-19}$  joule of work is required to move the proton from point A to point B, the potential difference between A and B is

- (1)  $6.4 \times 10^{-19}$  V              (3) 6.4 V  
 (2)  $4.0 \times 10^{-19}$  V              (4) 4.0 V

27 An electrostatic force of magnitude *F* exists between two metal spheres having identical charge *q*. The distance between their centers is *r*. Which combination of changes would produce no change in the electrostatic force between the spheres?

- (1) doubling *q* on one sphere while doubling *r*  
 (2) doubling *q* on both spheres while doubling *r*  
 (3) doubling *q* on one sphere while halving *r*  
 (4) doubling *q* on both spheres while halving *r*

28 What is the magnitude of the electrostatic force acting on an electron located in an electric field having a strength of  $5.0 \times 10^3$  newtons per coulomb?

- (1)  $3.1 \times 10^{22}$  N                  (3)  $8.0 \times 10^{-16}$  N  
 (2)  $5.0 \times 10^3$  N                (4)  $3.2 \times 10^{-23}$  N

29 A charge of 5.0 coulombs moves through a circuit in 0.50 second. The current in the circuit is

- (1) 2.5 A                            (3) 7.0 A  
 (2) 5.0 A                            (4) 10. A

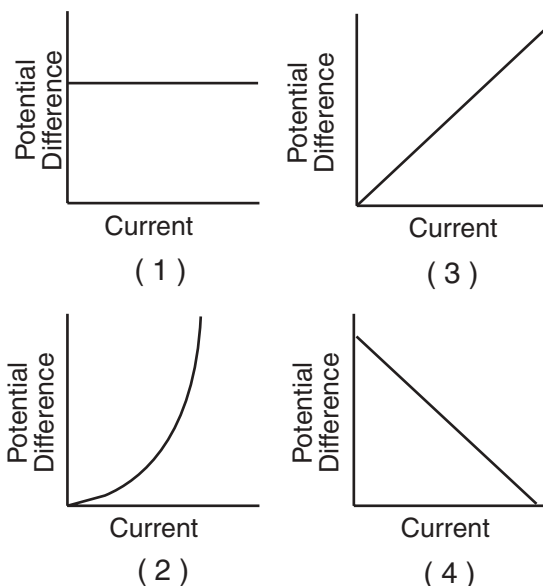
30 An operating electric iron draws a current of 5 amperes and has a resistance of 20 ohms. The amount of energy used by the iron in 40 seconds is

- (1)  $1 \times 10^2$  J                      (3)  $4 \times 10^3$  J  
 (2)  $5 \times 10^2$  J                      (4)  $2 \times 10^4$  J

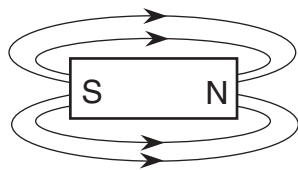
31 What is the net static electric charge on a metal sphere having an excess of +3 elementary charges?

- (1)  $1.60 \times 10^{-19}$  C              (3)  $3.00 \times 10^0$  C  
 (2)  $4.80 \times 10^{-19}$  C              (4)  $4.80 \times 10^{19}$  C

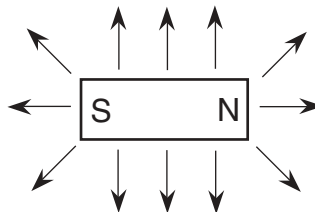
32 Which graph best represents the relationship between the potential difference across a conductor and the current through the conductor at constant temperature?



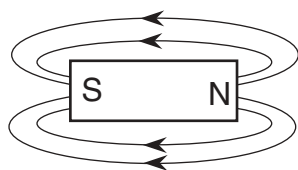
33 Which diagram below best represents the magnetic field near a bar magnet?



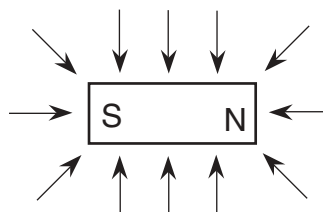
(1)



(3)

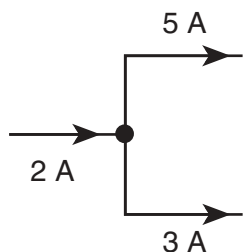


(2)

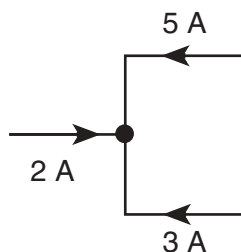


(4)

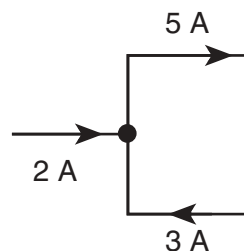
34 Which diagram shows correct current direction in a segment of an electric circuit?



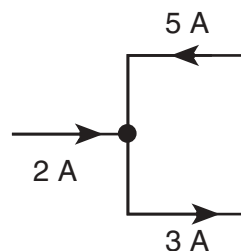
(1)



(3)



(2)

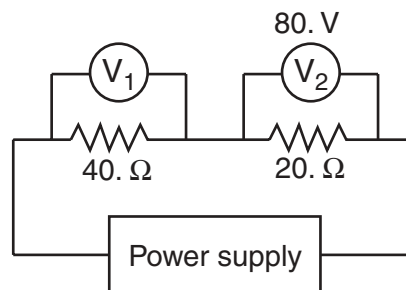


(4)

35 While operating at 120 volts, an electric toaster has a resistance of 15 ohms. The power used by the toaster is

- (1) 8.0 W                      (3) 960 W  
 (2) 120 W                     (4) 1,800 W

36 In the circuit shown below, voltmeter  $V_2$  reads 80. volts.



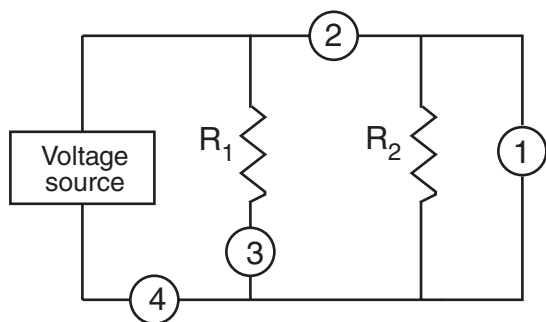
What is the reading of voltmeter  $V_1$ ?

- (1) 160 V                      (3) 40. V  
 (2) 80. V                      (4) 20. V

37 A physics student is given three 12-ohm resistors with instructions to create the circuit that would have the lowest possible resistance. The correct circuit would be a

- (1) series circuit with an equivalent resistance of  $36 \Omega$   
 (2) series circuit with an equivalent resistance of  $4.0 \Omega$   
 (3) parallel circuit with an equivalent resistance of  $36 \Omega$   
 (4) parallel circuit with an equivalent resistance of  $4.0 \Omega$

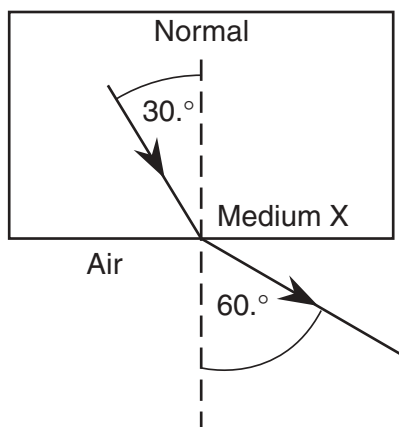
- 38 Two resistors are connected to a source of voltage as shown in the diagram below.



At which position should an ammeter be placed to measure the current passing only through resistor  $R_1$ ?

- (1) 1 (3) 3  
 (2) 2 (4) 4
- 39 Two points on a transverse wave that have the same magnitude of displacement from equilibrium are in phase if the points also have the
- (1) same direction of displacement and the same direction of motion  
 (2) same direction of displacement and the opposite direction of motion  
 (3) opposite direction of displacement and the same direction of motion  
 (4) opposite direction of displacement and the opposite direction of motion

- 40 The diagram below shows a ray of light passing from medium X into air.



What is the absolute index of refraction of medium X?

- (1) 0.500 (3) 1.73  
 (2) 2.00 (4) 0.577

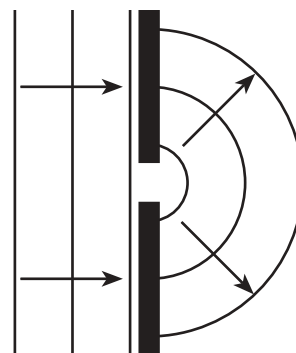
- 41 What is the frequency of a wave if its period is 0.25 second?

- (1) 1.0 Hz (3) 12 Hz  
 (2) 0.25 Hz (4) 4.0 Hz

- 42 What occurs when light passes from water into flint glass?

- (1) Its speed decreases, its wavelength becomes shorter, and its frequency remains the same.  
 (2) Its speed decreases, its wavelength becomes shorter, and its frequency increases.  
 (3) Its speed increases, its wavelength becomes longer, and its frequency remains the same.  
 (4) Its speed increases, its wavelength becomes longer, and its frequency decreases.

- 43 The diagram below shows straight wave fronts passing through an opening in a barrier.



This wave phenomenon is called

- (1) reflection (3) polarizaton  
 (2) refraction (4) diffraction

- 44 The speed of light in a material is  $2.50 \times 10^8$  meters per second. What is the absolute index of refraction of the material?

- (1) 1.20 (3) 7.50  
 (2) 2.50 (4) 0.833

- 45 An opera singer's voice is able to break a thin crystal glass when the singer's voice and the vibrating glass have the same

- (1) frequency (3) amplitude  
 (2) speed (4) wavelength





**Note that questions 53 through 55 have only three choices.**

53 If the diameter of a wire were decreased, its electrical resistance would

- (1) decrease
- (2) increase
- (3) remain the same

54 An astronomer on Earth studying light coming from a star notes that the observed light frequencies are lower than the actual emitted frequencies. The astronomer concludes that the distance between the star and Earth is

- (1) decreasing
- (2) increasing
- (3) unchanging

55 Compared to the wavelength of red light, the wavelength of yellow light is

- (1) shorter
- (2) longer
- (3) the same

## Part II

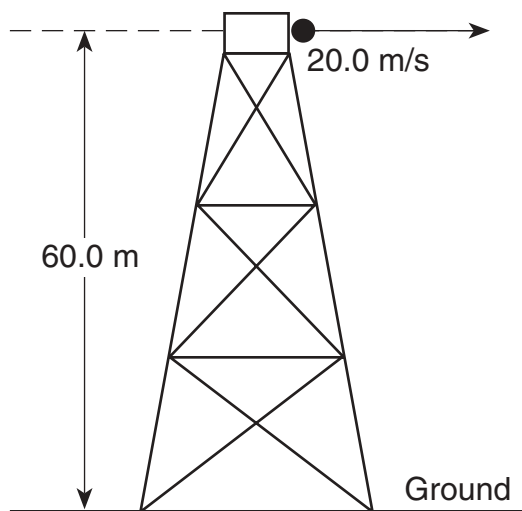
This part consists of six groups, each containing ten questions. Each group tests an optional area of the course. Choose two of these six groups. Be sure that you answer all ten questions in each group chosen. Record the answers to the questions in accordance with the directions on the front page of this booklet. [20]

### Group 1 — Motion in a Plane

If you choose this group, be sure to answer questions 56–65.

Base your answers to question 56 through 58 on the information and diagram below.

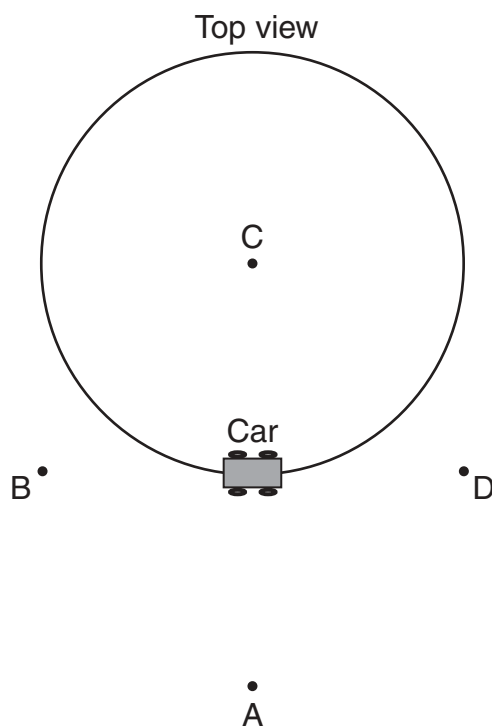
A ball is thrown horizontally with an initial velocity of 20.0 meters per second from the top of a tower 60.0 meters high.



- 56 What is the initial vertical velocity of the ball?
- (1) 0 m/s                      (3) 20.0 m/s  
(2) 9.81 m/s                 (4) 60.0 m/s
- 57 What is the approximate total time required for the ball to reach the ground? [Neglect air resistance.]
- (1) 12.2 s                      (3) 3.00 s  
(2) 2.04 s                      (4) 3.50 s
- 58 What is the horizontal velocity of the ball just before it reaches the ground? [Neglect air resistance.]
- (1) 9.81 m/s                    (3) 34.3 m/s  
(2) 20.0 m/s                   (4) 68.6 m/s

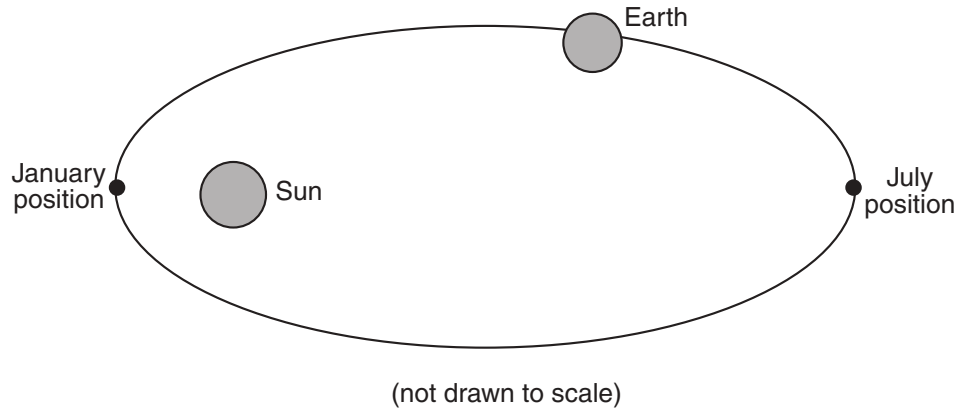
Base your answers to questions 59 and 60 on the information and diagram below.

A 60.-kilogram car travels clockwise in a horizontal circle of radius 10. meters at 5.0 meters per second.



- 59 The centripetal acceleration of the car at the position shown is directed toward point
- (1) A                              (3) C  
(2) B                              (4) D
- 60 The magnitude of the centripetal force acting on the car is
- (1) 590 N                        (3) 30. N  
(2) 150 N                        (4) 2.5 N

61 The diagram below represents the path of Earth around the Sun.

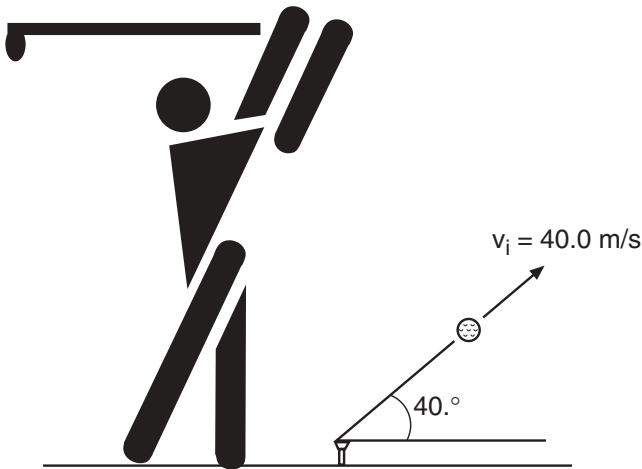


As Earth travels in its orbit from its January position to its July position, the potential energy of Earth

- (1) decreases and its kinetic energy decreases
- (2) decreases and its kinetic energy increases
- (3) increases and its kinetic energy decreases
- (4) increases and its kinetic energy increases

Base your answers to questions 62 and 63 on the information and diagram below

A golf ball leaves a golf club with an initial velocity of 40.0 meters per second at an angle of  $40.0^\circ$  with the horizontal.



62 What is the vertical component of the golf ball's initial velocity?

- (1) 25.7 m/s
- (2) 30.6 m/s
- (3) 40.0 m/s
- (4) 61.3 m/s

63 What is the total horizontal distance traveled by the golf ball during the first 2.50 seconds of its flight?

- (1) 100. m
- (2) 76.6 m
- (3) 64.3 m
- (4) 40.0 m

64 What is the period of orbit of a communications satellite in geosynchronous orbit about Earth?

- (1) 1 year
- (2) 24 hours
- (3) 12 hours
- (4) 60 minutes

65 The table below gives information about the Moon and a satellite orbiting Earth.

$R_m$ = mean radius of orbit of the Moon around Earth $R_s$ = mean radius of orbit of satellite around Earth $T_m$ = period of orbit of the Moon around Earth $T_s$ = period of orbit of satellite around Earth
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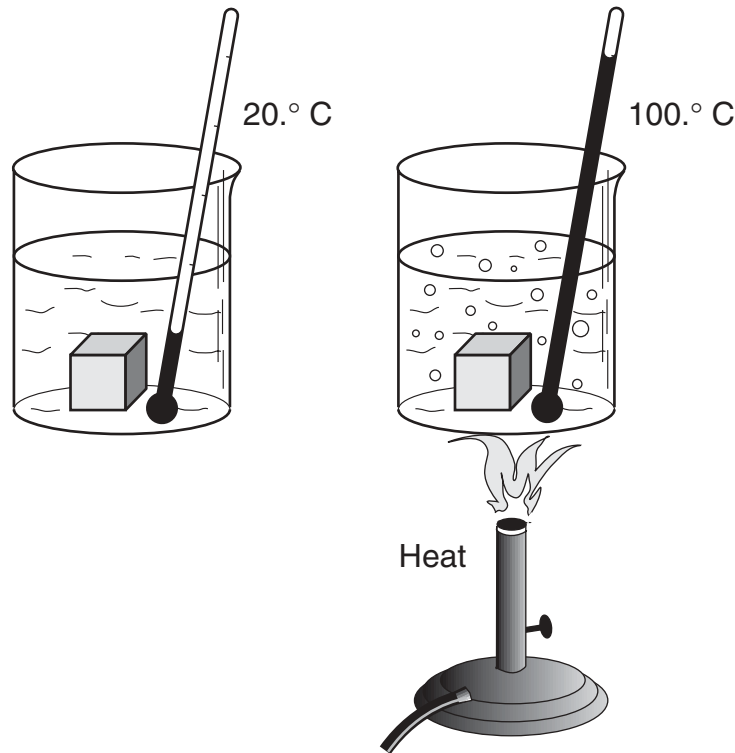
Which equation correctly relates these quantities?

- (1)  $R_m T_m = R_s T_s$
- (2)  $R_m T_s = R_s T_m$
- (3)  $\frac{R_m^2}{T_m} = \frac{R_s^2}{T_s}$
- (4)  $\frac{R_m^3}{T_m^2} = \frac{R_s^3}{T_s^2}$

## Group 2 — Internal Energy

If you choose this group, be sure to answer questions 66–75.

66 The diagram below represents an experiment in which a student placed a 0.030-kilogram lead cube in a beaker of water at  $20.^{\circ}\text{C}$  and then heated the beaker until the water began to boil.



The maximum amount of heat absorbed by the lead cube during the experiment was approximately

- (1) 0.31 kJ  
(2) 10. kJ  
(3) 60. kJ  
(4) 790 kJ

67 Absolute zero is best described as the temperature at which

- (1) water freezes at standard pressure  
(2) water is at its triple point  
(3) the molecules of a substance have maximum kinetic energy  
(4) the molecules of a substance have minimum kinetic energy

68 A temperature change of 20. Celsius degrees is equal to a temperature change of

- (1) 20. Kelvins  
(2) 120. Kelvins  
(3) 253 Kelvins  
(4) 293 Kelvins

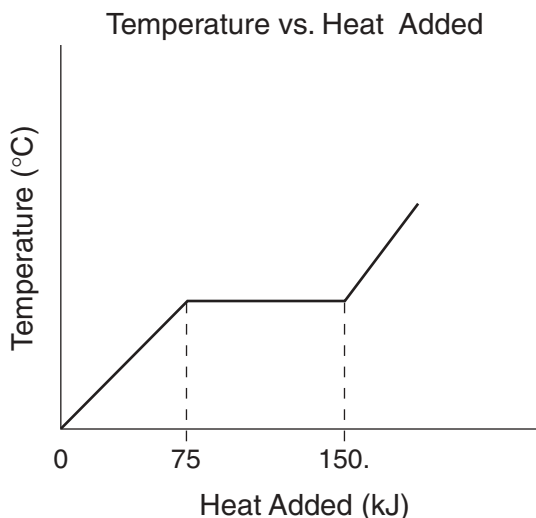
69 Heat will always flow from object *A* to object *B* if object *B* has a lower

- (1) mass  
(2) total energy  
(3) temperature  
(4) specific heat

70 Equal amounts of heat energy are given off by 1.0-kilogram samples of aluminum, iron, platinum, and zinc, all initially at  $100.^{\circ}\text{C}$ . Which sample has the greatest decrease in temperature?

- (1) aluminum  
(2) iron  
(3) platinum  
(4) zinc

- 71 The graph below shows the temperature of 3.0 kilograms of a pure substance initially in the solid phase as heat is added to it at a constant rate.

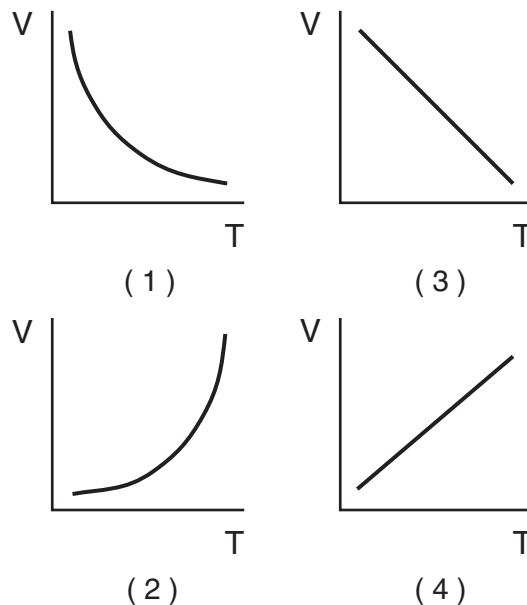


The substance is most likely

- |             |            |
|-------------|------------|
| (1) alcohol | (3) copper |
| (2) silver  | (4) lead   |
- 72 As a large quantity of salt is added to a container of boiling water, the water
- (1) stops boiling because the boiling point decreases
  - (2) stops boiling because the boiling point increases
  - (3) boils faster because the boiling point decreases
  - (4) boils faster because the boiling point increases

- 73 The total effect of all the processes that occur in the universe is an increase in
- |                 |            |
|-----------------|------------|
| (1) entropy     | (3) order  |
| (2) temperature | (4) energy |

- 74 Which graph best represents the relationship between volume  $V$  and absolute temperature  $T$  for a fixed mass of an ideal gas at constant pressure?



**Note that question 75 has only three choices.**

- 75 As the pressure of a fixed mass of gas is increased at constant temperature, the density of that gas
- (1) decreases
  - (2) increases
  - (3) remains the same

### Group 3 — Electromagnetic Applications

If you choose this group, be sure to answer questions 76–85.

- 76 If the current in an ammeter's coil is doubled, the resulting torque on the coil will be
- (1) unchanged                      (3) halved  
(2) doubled                        (4) quadrupled
- 77 An operating electric motor induces an EMF in the armature that opposes the applied potential difference. This phenomenon is an example of conservation of
- (1) inertia                          (3) momentum  
(2) electric charge                (4) energy
- 78 The rate of thermionic emission from a surface increases as the surface's
- (1) temperature decreases  
(2) thickness decreases  
(3) temperature increases  
(4) thickness increases
- 79 An electron moves at  $2.0 \times 10^6$  meters per second perpendicular to a magnetic field having a flux density of 2.0 teslas. What is the magnitude of the magnetic force on the electron?
- (1)  $1.0 \times 10^{-6}$  N                (3)  $3.6 \times 10^{-24}$  N  
(2)  $6.4 \times 10^{-13}$  N                (4)  $4.0 \times 10^6$  N
- 80 The Millikan oil drop experiment determined the smallest unit of
- (1) mass  
(2) weight  
(3) electric charge  
(4) electric field strength
- 81 Which device transforms mechanical energy into electrical energy?
- (1) generator  
(2) motor  
(3) transformer  
(4) mass spectrometer
- 82 Power would most effectively be supplied to the primary coil of a step-up transformer by
- (1) an ac generator                (3) a battery  
(2) a dc generator                (4) an ac motor
- 83 The 200.-turn primary coil of a transformer is connected to a 120-volt line. How many turns must the secondary coil of the transformer have if it is to provide 240 volts? [Assume 100% efficiency.]
- (1) 100                                (3) 1,200  
(2) 400                                (4) 2,400
- 84 Which device is used in the ignition system of a car to induce a time-varying potential difference from the car's battery?
- (1) electric motor                (3) transistor  
(2) electromagnet                (4) induction coil
- 85 A helium-neon laser emits energy in the visible red region in the form of
- (1) alpha particles                (3) electrons  
(2) gamma rays                    (4) photons
-

**Group 4 — Geometric Optics**

**If you choose this group, be sure to answer questions 86–95.**

86 The diagram below shows the letter *P* in front of a plane mirror.



Which diagram best represents the image of *P* produced by the plane mirror?



87 A student stands 2.0 meters in front of a vertical plane mirror. As the student walks toward the mirror, the image

- (1) decreases in size and remains virtual
- (2) decreases in size and remains real
- (3) remains the same size and remains virtual
- (4) remains the same size and remains real

88 An incident light ray travels parallel to the principal axis of a concave spherical mirror. After reflecting from the mirror, the light ray will travel

- (1) through the mirror's principal focus
- (2) through the mirror's center of curvature
- (3) parallel to the mirror's principal axis
- (4) normal to the mirror's principal axis

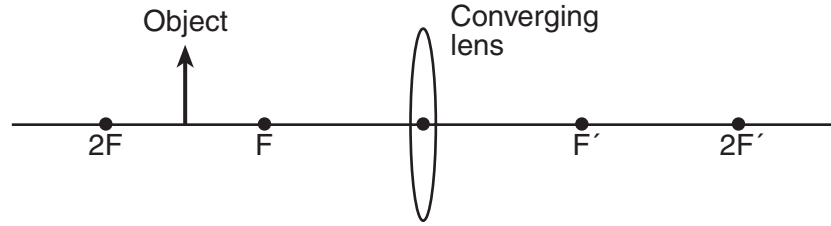
89 The focal length of a concave spherical mirror is 0.060 meter. What is the radius of curvature of the mirror?

- (1) 0.060 m
- (2) 0.12 m
- (3) 8.3 m
- (4) 17 m

90 An image that is  $1.0 \times 10^{-2}$  meter tall is formed on a screen behind a converging lens when an object 2.0 meters tall is placed 8.0 meters in front of the lens. What is the distance from the lens to the screen?

- (1)  $2.5 \times 10^{-3}$  m
- (2)  $4.0 \times 10^{-2}$  m
- (3)  $2.5 \times 10^{-1}$  m
- (4)  $4.0 \times 10^{-1}$  m

91 The diagram below shows an object placed between 1 and 2 focal lengths from a converging lens.



The image of the object produced by the lens is

- (1) real and inverted
  - (2) real and erect
  - (3) virtual and inverted
  - (4) virtual and erect
- 

92 The focal length of a lens is *not* dependent on the

- (1) material from which the lens is made
- (2) color of the light incident on the lens
- (3) distance of an object from the lens
- (4) shape or curvature of the lens

93 An object is placed 0.20 meter from a converging lens having a focal length of 0.040 meter. The distance of the image from the lens is

- (1) 0.033 m
- (2) 0.050 m
- (3) 0.16 m
- (4) 0.20 m

94 Images formed by diverging mirrors are always

- (1) real and inverted
- (2) real and erect
- (3) virtual and inverted
- (4) virtual and erect

95 Spherical aberration is a defect associated with

- (1) spherical mirrors, only
  - (2) plane mirrors, only
  - (3) both spherical mirrors and lenses
  - (4) both plane mirrors and lenses
-



## Group 5 — Solid State

**If you choose this group, be sure to answer questions 96–105.**

96 The conductivity of a material is equivalent to

- (1) its resistivity
- (2) the square of its resistivity
- (3) the reciprocal of its resistivity
- (4) the square of the reciprocal of its resistivity

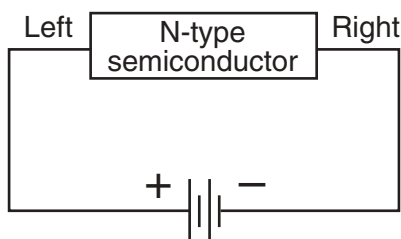
97 Which model most successfully explains conduction in solids?

- (1) electron-cloud model
- (2) electron-sea model
- (3) band model
- (4) doping model

98 As a donor material, arsenic provides a semiconducting material with extra

- (1) electrons
- (2) holes
- (3) protons
- (4) neutrons

99 The diagram below shows a circuit with a battery applying a potential difference across an *N*-type semiconductor.



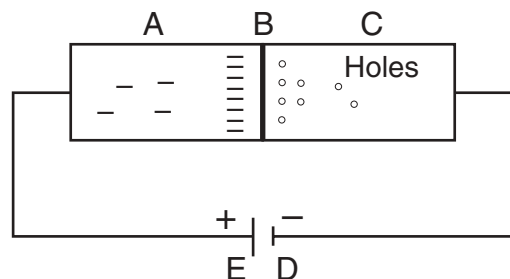
The majority charge carriers in the semiconductor are

- (1) negative electrons moving to the right
- (2) negative electrons moving to the left
- (3) positive holes moving to the right
- (4) positive holes moving to the left

100 Pulsating direct current results when a *P-N* junction is connected to

- (1) a battery
- (2) an oscilloscope
- (3) a source of direct current voltage
- (4) a source of alternating current

Base your answers to questions 101 and 102 on the diagram below, which represents a silicon semiconductor.



101 In the diagram, C represents the

- (1) *N*-type silicon
- (2) *P*-type silicon
- (3) anode
- (4) diode

102 The *P-N* junction in the diagram is biased

- (1) reverse
- (2) forward
- (3) A to E
- (4) C to D

103 The primary source of holes in a *P-N-P* transistor is the

- (1) *N*-type base
- (2) *P*-type base
- (3) *N*-type emitter
- (4) *P*-type emitter

104 In a working transistor circuit, as the emitter-base current is increased, the collector current

- (1) decreases a small amount
- (2) decreases a large amount
- (3) increases a small amount
- (4) increases a large amount

**Note that question 105 has only three choices.**

105 An *N*-type semiconductor and a *P*-type semiconductor are joined to form a diode. Compared to the total number of electrons in the semiconductors before joining, the number of electrons in the diode is

- (1) fewer
- (2) greater
- (3) the same

## Group 6 — Nuclear Energy

If you choose this group, be sure to answer questions 106–115.

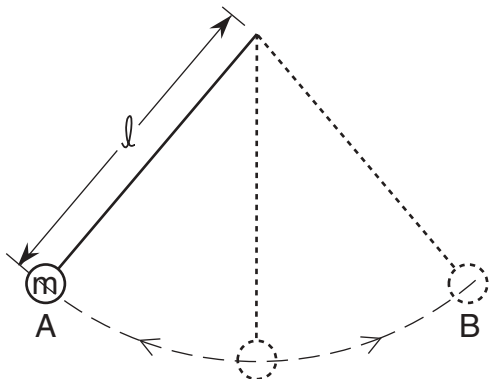
- 106 If nitrogen nuclei are bombarded with alpha particles they can be changed into oxygen nuclei. This phenomenon is known as
- (1) nuclear fission
  - (2) nuclear fusion
  - (3) artificial transmutation
  - (4) particle scattering
- 107 One atomic mass unit is defined as
- (1) the mass of an electron
  - (2) the mass of an alpha particle
  - (3) the mass of an atom of carbon-12
  - (4)  $\frac{1}{12}$  the mass of an atom of carbon-12
- 108 According to the Uranium Disintegration Series, which nuclide is an isotope of lead (Pb)?
- (1)  $^{206}_{82}\text{Pb}$
  - (2)  $^{214}_{83}\text{Pb}$
  - (3)  $^{214}_{84}\text{Pb}$
  - (4)  $^{222}_{86}\text{Pb}$
- 109 The nuclei of all the atoms in a single nuclide have
- (1) the same number of neutrons and the same number of protons
  - (2) the same number of neutrons, but different numbers of protons
  - (3) different numbers of neutrons, but the same number of protons
  - (4) different numbers of neutrons and different numbers of protons
- 110 What occurs when an atom emits gamma radiation?
- (1) The excited nucleus changes to a more stable state by absorbing a photon.
  - (2) The excited nucleus changes to a more stable state by emitting a photon.
  - (3) The stable nucleus changes to an excited state by emitting a photon.
  - (4) The stable nucleus changes to an excited state by absorbing a photon.
- 111 What particle is represented by  $X$  in the nuclear reaction  $^9_4\text{Be} + ^4_2\text{He} \rightarrow ^{12}_6\text{C} + X$ ?
- (1)  $^0_{-1}\text{e}$
  - (2)  $^1_1\text{H}$
  - (3)  $^1_0\text{n}$
  - (4)  $^2_1\text{H}$
- 112 The half-life of a particular radioactive material is 6.0 hours. What fraction of a sample of the material would remain after 1 day?
- (1)  $\frac{1}{4}$
  - (2)  $\frac{2}{3}$
  - (3)  $\frac{3}{8}$
  - (4)  $\frac{1}{16}$
- 113 Which device can be used to detect subatomic particles that exit nuclei?
- (1) Van de Graaff generator
  - (2) Geiger counter
  - (3) linear accelerator
  - (4) cyclotron
- 114 In a nuclear reactor, which substance can be used as both the moderator and the coolant?
- (1) cadmium
  - (2) boron
  - (3) water
  - (4) uranium
- 115 If the nucleus of an atom emits a positron, the atomic number of the atom will
- (1) decrease by one
  - (2) increase by one
  - (3) remain unchanged
  - (4) decrease by two

### Part III

You must answer *all* questions in this part. Record your answers in the spaces provided on the separate answer paper. Pen or pencil may be used. [15]

Base your answers to questions 116 through 119 on the information, diagram, and data table below.

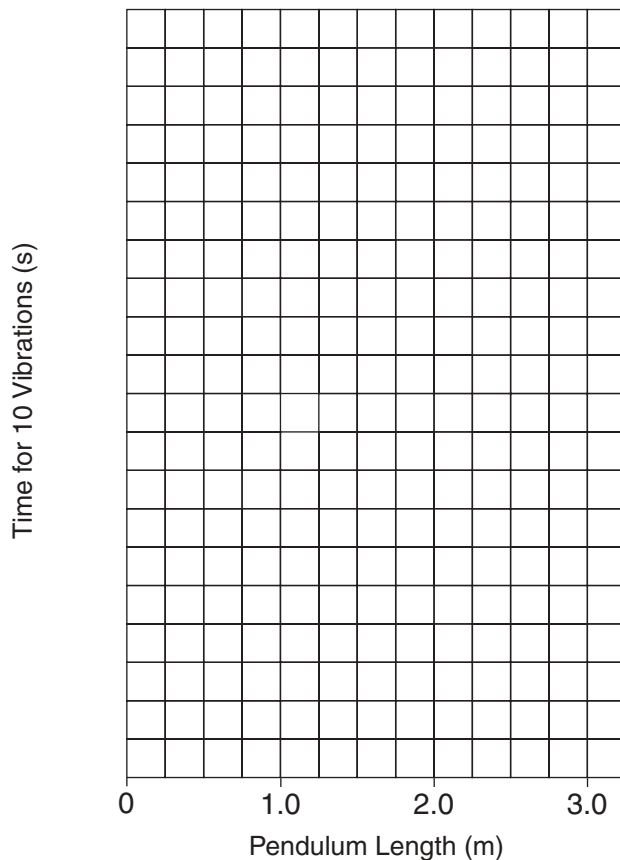
The diagram shows a light string attached to mass  $m$  forming a pendulum of length  $\ell$ . One complete vibration of the pendulum consists of mass  $m$  moving from position  $A$  to position  $B$  and back to position  $A$ . The data table shows the results of an experiment measuring the time for 10 complete vibrations of the pendulum for various pendulum lengths.



Pendulum Length (meters)	Time for 10 Vibrations (seconds)
0	0
0.2	9
0.5	14
1.0	20.
1.5	25
2.0	28
2.5	32

Using the information in the data table, construct a graph on the grid provided *on your answer paper*, following the directions below. The grid below is provided for practice purposes only. Be sure your final answer appears *on your answer paper*.

**Time for 10 Vibrations  
vs. Length**



116 Mark an appropriate scale on the axis labeled “Time for 10 Vibrations.” [1]

117 Plot the data points for time for 10 vibrations versus length. [1]

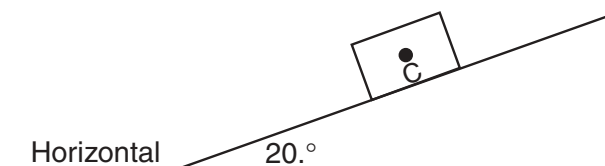
118 Draw the best-fit curve. [1]

119 Determine the period of the 1.0-meter pendulum. [1]

---

Base your answers to questions 120 through 122 on the information and diagram below. The diagram below is provided for practice purposes only. Be sure your final answer appears *on your answer paper*.

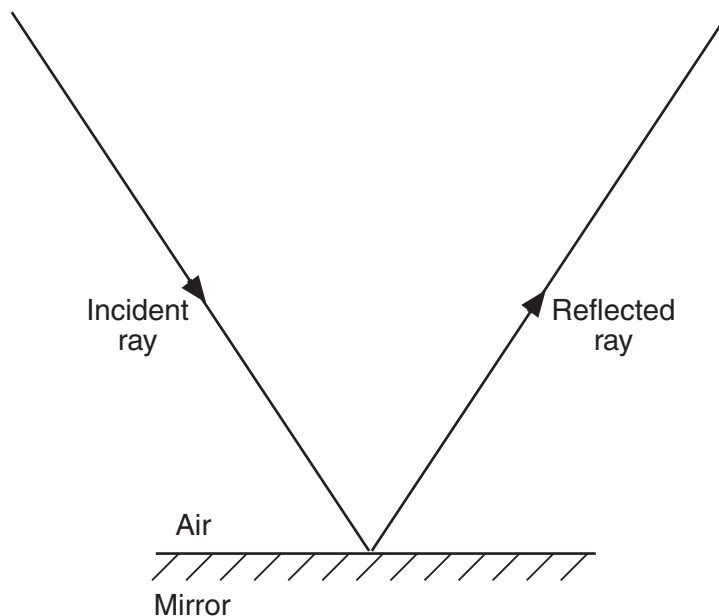
A 10.0-kilogram block slides at constant speed down a plane inclined at  $20.^\circ$  to the horizontal, as shown.



- 120 On the diagram *on your answer paper*, draw an arrow to represent and identify the direction of each of the *three* forces (weight, friction, normal force) acting on the block. Begin *each* arrow at point C and label *each* arrow with the force that it represents. [3]
- 121 Determine the weight of the block. [Show all calculations, including the equation and substitution with units.] [2]
- 122 In one or more complete sentences, describe the change in the motion of the block as the angle of inclination is increased to  $30.^\circ$ . [1]
-

Base your answers to questions 123 through 126 on the information and diagram below. The diagram below is provided for practice purposes only. Be sure your final answer appears *on your answer paper*.

A ray of monochromatic light of frequency  $5.00 \times 10^{14}$  hertz is incident on a mirror and reflected, as shown.



- 123 Using a protractor and ruler, construct and label the normal to the mirror at the point of incidence on the diagram *on your answer paper*. [1]
- 124 Using a protractor, measure the angle of incidence to the nearest degree and record the value *on your answer paper*. [1]
- 125 Determine the wavelength of the ray of light. [Show all calculations, including the equation and substitution with units.] [2]
- 126 What is the color of the ray of light? [1]
-



**PHYSICS**

Tuesday, January 22, 2002 — 9:15 a.m. to 12:15 p.m., only

**ANSWER PAPER**

Student ..... Sex:  Female  
 Male  
 Teacher .....  
 School .....

Record all of your answers on this answer paper in accordance with the instructions on the front page of the test booklet.

**Part I (65 credits)**

1	1	2	3	4	21	1	2	3	4	41	1	2	3	4
2	1	2	3	4	22	1	2	3	4	42	1	2	3	4
3	1	2	3	4	23	1	2	3	4	43	1	2	3	4
4	1	2	3	4	24	1	2	3	4	44	1	2	3	4
5	1	2	3	4	25	1	2	3	4	45	1	2	3	4
6	1	2	3	4	26	1	2	3	4	46	1	2	3	4
7	1	2	3	4	27	1	2	3	4	47	1	2	3	4
8	1	2	3	4	28	1	2	3	4	48	1	2	3	4
9	1	2	3	4	29	1	2	3	4	49	1	2	3	4
10	1	2	3	4	30	1	2	3	4	50	1	2	3	4
11	1	2	3	4	31	1	2	3	4	51	1	2	3	4
12	1	2	3	4	32	1	2	3	4	52	1	2	3	4
13	1	2	3	4	33	1	2	3	4	53	1	2	3	
14	1	2	3	4	34	1	2	3	4	54	1	2	3	
15	1	2	3	4	35	1	2	3	4	55	1	2	3	
16	1	2	3	4	36	1	2	3	4					
17	1	2	3	4	37	1	2	3	4					
18	1	2	3	4	38	1	2	3	4					
19	1	2	3	4	39	1	2	3	4					
20	1	2	3	4	40	1	2	3	4					

**FOR TEACHER USE ONLY**

Part I Score .....  
 (Use table below)  
 Part II Score .....  
 Part III Score .....  
 Total Score .....

Rater's Initials: .....

**PART I CREDITS**

**Directions to Teacher:**

In the table below, draw a circle around the number of right answers and the adjacent number of credits. Then write the number of credits (not the number right) in the space provided above.

No. Right	Credits	No. Right	Credits
55	65	27	42
54	64	26	41
53	63	25	40
52	63	24	40
51	62	23	39
50	61	22	38
49	60	21	37
48	59	20	36
47	58	19	35
46	58	18	35
45	57	17	34
44	56	16	33
43	55	15	32
42	54	14	31
41	54	13	31
40	53	12	29
39	52	11	26
38	51	10	24
37	50	9	21
36	49	8	19
35	49	7	17
34	48	6	14
33	47	5	12
32	46	4	10
31	45	3	7
30	44	2	5
29	44	1	2
28	43	0	0

No. right .....



Part II (20 credits)

Answer the questions in only two of the six groups in this part. Be sure to mark the answers to the groups of questions you choose in accordance with the instructions on the front page of the test booklet. Leave blank the four groups of questions you do not choose to answer.

**Group 1**  
**Motion in a Plane**

- 56 1 2 3 4  
57 1 2 3 4  
58 1 2 3 4  
59 1 2 3 4  
60 1 2 3 4  
61 1 2 3 4  
62 1 2 3 4  
63 1 2 3 4  
64 1 2 3 4  
65 1 2 3 4

**Group 3**  
**Electromagnetic Applications**

- 76 1 2 3 4  
77 1 2 3 4  
78 1 2 3 4  
79 1 2 3 4  
80 1 2 3 4  
81 1 2 3 4  
82 1 2 3 4  
83 1 2 3 4  
84 1 2 3 4  
85 1 2 3 4

**Group 5**  
**Solid State**

- 96 1 2 3 4  
97 1 2 3 4  
98 1 2 3 4  
99 1 2 3 4  
100 1 2 3 4  
101 1 2 3 4  
102 1 2 3 4  
103 1 2 3 4  
104 1 2 3 4  
105 1 2 3

**Group 2**  
**Internal Energy**

- 66 1 2 3 4  
67 1 2 3 4  
68 1 2 3 4  
69 1 2 3 4  
70 1 2 3 4  
71 1 2 3 4  
72 1 2 3 4  
73 1 2 3 4  
74 1 2 3 4  
75 1 2 3

**Group 4**  
**Geometric Optics**

- 86 1 2 3 4  
87 1 2 3 4  
88 1 2 3 4  
89 1 2 3 4  
90 1 2 3 4  
91 1 2 3 4  
92 1 2 3 4  
93 1 2 3 4  
94 1 2 3 4  
95 1 2 3 4

**Group 6**  
**Nuclear Energy**

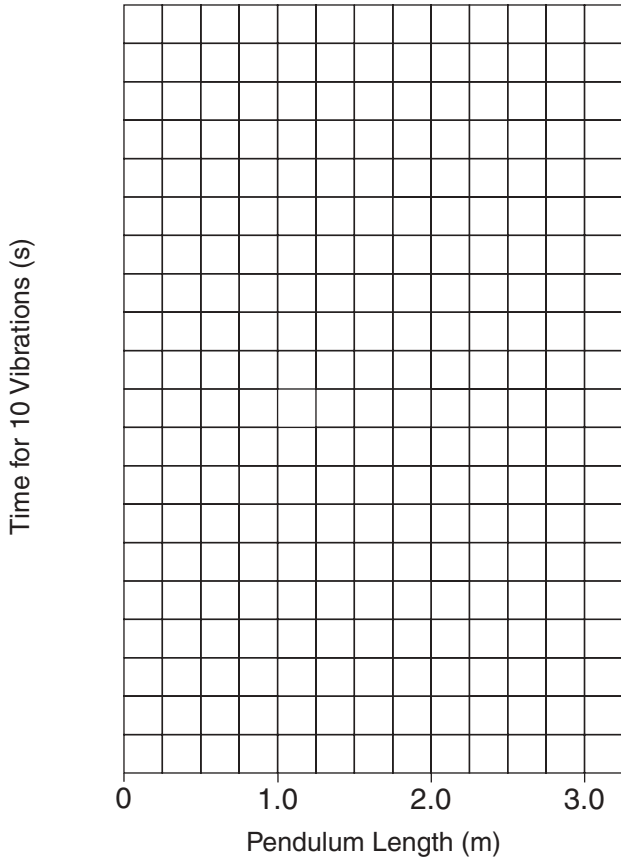
- 106 1 2 3 4  
107 1 2 3 4  
108 1 2 3 4  
109 1 2 3 4  
110 1 2 3 4  
111 1 2 3 4  
112 1 2 3 4  
113 1 2 3 4  
114 1 2 3 4  
115 1 2 3 4

Part III (15 credits)

Answer all questions in this part.

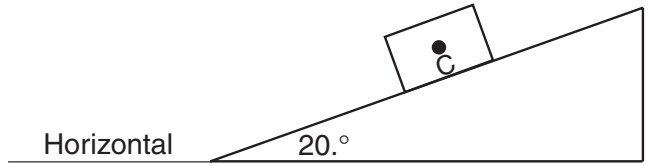
116–118

Time for 10 Vibrations  
vs. Length



119 \_\_\_\_\_

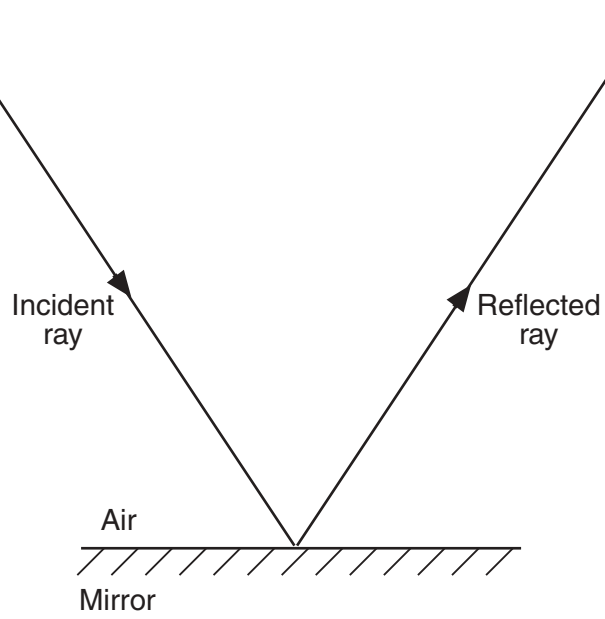
120



121

122 \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

123



124 \_\_\_\_\_

125

126 \_\_\_\_\_

I do hereby affirm, at the close of this examination, that I had no unlawful knowledge of the questions or answers prior to the examination and that I have neither given nor received assistance in answering any of the questions during the examination.

\_\_\_\_\_  
Signature



## Additional Reference Information

### VALUES OF TRIGONOMETRIC FUNCTIONS

Angle	Sine	Cosine	Angle	Sine	Cosine
5°	.0872	.9962	50°	.7660	.6428
10°	.1736	.9848	55°	.8192	.5736
15°	.2588	.9659	60°	.8660	.5000
20°	.3420	.9397	65°	.9063	.4226
25°	.4226	.9063	70°	.9397	.3420
30°	.5000	.8660	75°	.9659	.2588
35°	.5736	.8192	80°	.9848	.1736
40°	.6428	.7660	85°	.9962	.0872
45°	.7071	.7071	90°	1.0000	.0000

### MOTION IN A PLANE

$$v_{iy} = v_i \sin \theta$$

$a_c$  = centripetal acceleration

$$v_{ix} = v_i \cos \theta$$

$F_c$  = centripetal force

$m$  = mass

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

$r$  = radius

$v$  = velocity

$$F_c = \frac{mv^2}{r}$$

$\theta$  = angle

### INTERNAL ENERGY

$$Q = mc\Delta T_C$$

$c$  = specific heat

$$Q_f = mH_f$$

$H_f$  = heat of fusion

$H_v$  = heat of vaporization

$$Q_v = mH_v$$

$m$  = mass

$Q$  = amount of heat

$T_C$  = Celsius temperature

### HEAT CONSTANTS

	Specific Heat (average) (kJ/kg·C°)	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion (kJ/kg)	Heat of Vaporization (kJ/kg)
Alcohol (ethyl)	2.43 (liq.)	-117	79	109	855
Aluminum	0.90 (sol.)	660	2467	396	10500
Ammonia	4.71 (liq.)	-78	-33	332	1370
Copper	0.39 (sol.)	1083	2567	205	4790
Iron	0.45 (sol.)	1535	2750	267	6290
Lead	0.13 (sol.)	328	1740	25	866
Mercury	0.14 (liq.)	-39	357	11	295
Platinum	0.13 (sol.)	1772	3827	101	229
Silver	0.24 (sol.)	962	2212	105	2370
Tungsten	0.13 (sol.)	3410	5660	192	4350
Water	ice	0	—	334	—
	water	—	100	—	2260
	steam	—	—	—	—
Zinc	0.39 (sol.)	420	907	113	1770

Tear Here

Tear Here

### ELECTROMAGNETIC APPLICATIONS

$$F = qvB$$

$B$  = flux density

$F$  = force

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$I_p$  = current in primary coil

$I_s$  = current in secondary coil

$$V_p I_p = V_s I_s$$

(ideal)

$N_p$  = number of turns of primary coil

$N_s$  = number of turns of secondary coil

$q$  = charge

$v$  = velocity

$V_p$  = voltage of primary coil

$V_s$  = voltage of secondary coil

### GEOMETRIC OPTICS

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

$d_i$  = image distance

$d_o$  = object distance

$$\frac{S_o}{S_i} = \frac{d_o}{d_i}$$

$f$  = focal length

$S_i$  = image size

$S_o$  = object size

### NUCLEAR ENERGY

$$E = mc^2$$

$c$  = speed of light in a vacuum

$$m_f = \frac{m_i}{2^n}$$

$E$  = energy

$m$  = mass

$n$  = number of half-lives

### URANIUM DISINTEGRATION SERIES

Atomic Number and Chemical Symbol

