UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

2023 Saskatchewan High School Physics Scholarship Competition

Friday May 5, 2023 Time allowed: 90 minutes

This competition is based on the Saskatchewan High School Physical Science 20 and Physics 30 curricula.

INSTRUCTIONS:

1. You should have a test paper and an OMR (Optical Machine Readable) or Opscan computer scan sheet. The test paper consists of 10 pages, including this cover page. There are 30 questions. **The student should check that the test paper is complete**.
2. Enter your **name** and **school** on the OMR sheet.
3. Enter your personal information on the table below.
4. At the end of the examination **only this cover page and the OMR sheet** must be submitted.
5. All questions are of equal value.
6. Marks are awarded for correct answers only. No marks will be deducted for wrong answers.
7. Calculators may **not** be used. (None of the questions require the use of a calculator.)

PLEASE **PRINT** THE FOLLOWING INFORMATION

Name: _____

School: _____

Physics Teacher: _____

Home Address: _____

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Postal Code: _____

Telephone: _____

Email address: _____

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FOR EACH OF THE FOLLOWING QUESTIONS ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

1. You want to know how much the temperature of a particular piece of material, with known mass, will rise when a known amount of heat is added to it. Which one of the following would it be necessary to know?

(A) The material's thermal conductivity.
(B) The material's density.
(C) The material's initial temperature.
(D) The material's coefficient of linear expansion.
(E) The material's specific heat capacity.

2. A beaker of water is placed under a boiler so that the heating coil is above the beaker. It is observed that only the surface layer boils. The water at the bottom of the beaker remains close to the initial temperature of the water. Which one of the following statements is the most reasonable conclusion to be drawn from these observations?

(A) The sample must contain impurities.
(B) Water is easily heated by radiation.
(C) Water is a poor conductor of heat.
(D) Water exhibits anomalous thermal behavior.
(E) The molecular motion is not random.

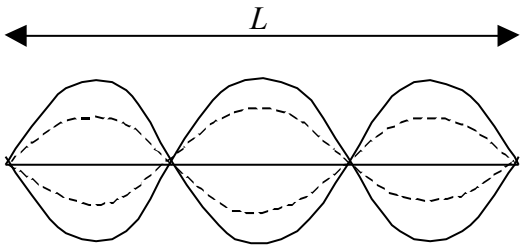
3. The length of an iron bar is measured when the bar is at a temperature of 20°C. If the temperature of the bar is increased to 40°C we find that the length of the bar has increased by 0.024%. If the temperature of the bar is increased to 60°C, what is the length of the bar now compared to when it was 20°C?

(A) It is 0.024% longer.
(B) It is 0.036% longer.
(C) It is 0.048% longer.
(D) It is 0.060% longer.
(E) It is 0.088% longer.

4. You hear that the horn on a car emits a sound with a certain frequency and wavelength when you are standing still and the car is stationary. Later, you are standing still and the car is moving toward you when the horn is sounded. What has happened to the sound reaching your ear, compared to when the car was stationary?

(A) The sound you hear has a higher frequency and a longer wavelength.
(B) The sound you hear has a higher frequency and a shorter wavelength.
(C) The sound you hear has a lower frequency and a longer wavelength.
(D) The sound you hear has the lower frequency and a shorter wavelength.
(E) The sound you hear has the same frequency and the same wavelength.

5. A guitar string has a length L and is fixed at both ends. It is made to vibrate with the standing wave pattern shown in the diagram. If the speed of the wave travelling along the string is v, the frequency of the vibration is



(A) $f = \frac{v}{2L}$

(B) $f = \frac{v}{3L}$

(C) $f = \frac{3v}{2L}$

(D) $f = \frac{3L}{2v}$

(E) $f = \frac{3L}{v}$

6. Photons of energy 5.0 eV strike a metal whose work function is 3.5 eV. Determine which one of the following best escribes the kinetic energy of the emitted electrons?

(A) 1.5 eV or less
(B) 1.5 eV or more
(C) 2.5 eV or more
(D) 3.5 eV or more
(E) 3.5 eV or less

7. Which one of the following statements concerning photons is **false**?

(A) Photons have zero mass.
(B) The rest energy of all photons is zero,
(C) Photons travel at the speed of light in a vacuum.
(D) Photons have been brought to rest by applying a strong magnetic field to them.
(E) The energy of a photon is proportional to its frequency.

8. Identify X in the following nuclear fission reaction: ${}^{235}_{92}\mathrm{U} + \gamma \longrightarrow {}^{142}_{56}\mathrm{Ba} + {}^{90}_{36}\mathrm{Kr} + \mathrm{X}$.

(A) one alpha particle
(B) two alpha particles
(C) three protons
(D) three neutrons
(E) six neutrons

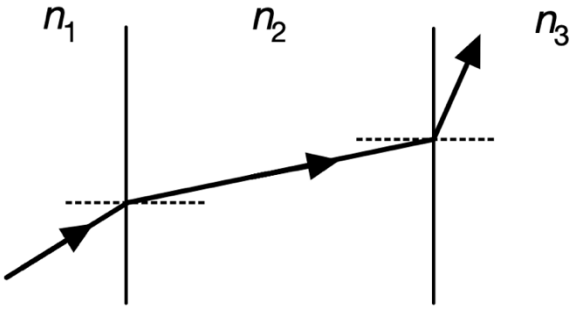
9. A radioactive nucleus has a half life of 10 days. A sample is prepared that has a certain number of these radioactive nuclei in it. After 30 days, what percentage of these nuclei has decayed?

(A) 10%
(B) 12.5%
(C) 70%
(D) 87.5%
(E) 90%

10. In a Young's double slit experiment, green light is incident on the two slits. The interference patten is observed on a screen. Which one of the following changes would cause the fringes to be more closely spaced?

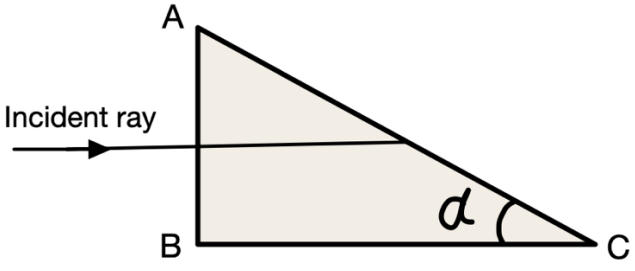
(A) Reduce the slit separation distance.
(B) Use the red light instead of green light.
(C) Use blue light instead of green light
(D) Move the screen farther away from the slits.
(E) Move the light source farther away from the slits.

11. The figure shows the path of a portion of a ray of light as it passes through three different materials. Note: The figure is drawn to scale. What can be concluded concerning the refractive indices of these materials?



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

12. A ray of light is normally incident on face AB of a plastic prism with an index of refraction $n = 1.20$ as shown. What is the largest value of the angle α so that the ray is totally reflected at the face AC if the prism is immersed in air.



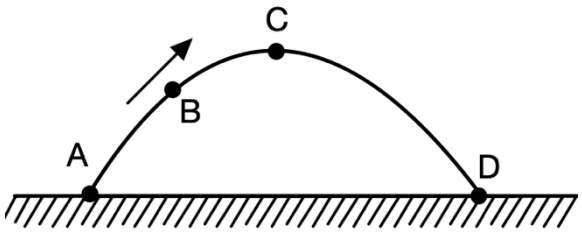
(A) 28°
(B) 34°
(C) 45°
(D) 56°
(E) Total internal reflection will not occur for any value of α.

13. A concave mirror is found to focus parallel rays at a distance of 9.0 cm. Where is the image formed when an object is placed 6.0 cm in front of the mirror?

(A) 3.6 cm in front of the mirror
(B) 5.6 cm behind the mirror
(C) 9.2 cm in front of the mirror
(D) 11 cm in front of the mirror
(E) 18 cm behind the mirror

14. A tennis ball is thrown upward at an angle from point A. It follows a parabolic trajectory and hits the ground at point D. At the instant shown, the ball is at point B. Point C represents the highest position of the ball above the ground. At which point is the velocity vector changing most rapidly with time?

(A) A
(B) B
(C) C
(D) D
(E) It is changing at the same rate at all four points.



15. A bullet is fired horizontally from a gun. At the same time and from the same height, a bullet is dropped. Ignoring air resistance, which one of the following statements is correct?

(A) The bullet that is fired will hit the ground first.
(B) The bullet that is dropped will hit the ground first.
(C) The bullet that is fired will have a higher kinetic energy just before it hits the ground.
(D) The bullet that is dropped will have a higher kinetic energy just before it hits the ground.
(E) Both bullets reach the ground simultaneously and with the same kinetic energy.

16. A projectile is launched at an angle of 30 º above the horizontal. Ignoring air resistance, what fraction of its initial kinetic energy does the projectile have at the top of its trajectory?

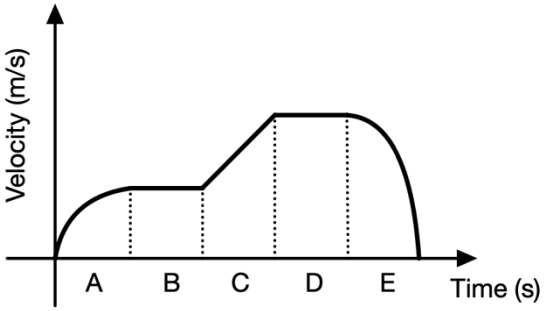
(A) 0
(B) ¼
(C) ½
(D) ¾
(E) 1

17. A horizontal force of 10 N is applied to a 2.5-kg box that is initially at rest on a horizontal surface. The coefficients of static and kinetic friction between the box and the surface are 0.50 and 0.20, respectively. Which one of the following options is correct?

(A) The box moves and its velocity increases.
(B) The box moves with a constant velocity.
(C) The box moves and its acceleration increases.
(D) The box does not move.
(E) The box starts moving and then slows down.

18. The graph shows how the velocity of an object varies with time. In which section of the graph is the magnitude of the net force decreasing?

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

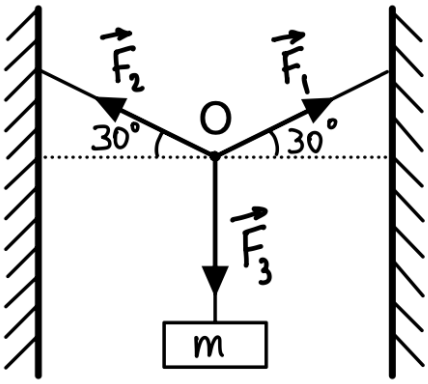


19. An astronaut orbits the earth in a space capsule whose height above the earth is equal to the earth's radius. How does the weight of the astronaut in the capsule compare to her weight on the earth?

(A) It is equal to her weight on earth.
(B) It is equal to one-half of her weight on earth.
(C) It is equal to one-third of her weight on earth.
(D) It is equal to one-fourth of her weight on earth.
(E) It is equal to one-sixth of her weight on earth.

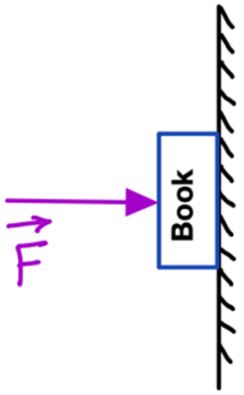
20. A block of mass *m* is hung by three ropes as shown. The system is in equilibrium. The point O represents the knot, the junction of three ropes. Which one of the following statements is true concerning the magnitudes of the tree forces in equilibrium?

(A) $F_1 = F_2 = F_3$
(B) $F_2 = 2F_3$
(C) $F_2 < F_3$
(D) $F_1 = F_2 = F_3/2$
(E) $F_1 > F_3$



21. A book of mass *m* is held against a vertical wall by applying a horizontal force $\vec{F}$ as shown. What is the magnitude of the normal force acting on the book?

(A) $n = mg$
(B) $n = F$
(C) $n = F + mg$
(D) $n = F - mg$
(E) $n = F - mg/2$

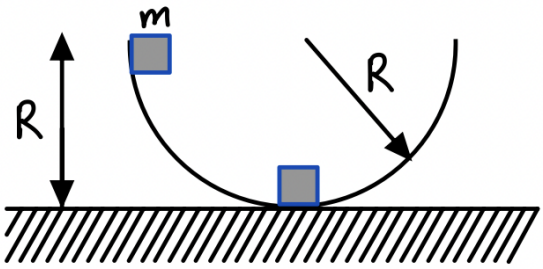


22. Two objects of different masses start from rest. The mass of object 2 is twice the mass of object 1. The same net force acts on each object as they move over equal distances. How do their final kinetic energies compare?

(A) The kinetic energy of object 2 is half the kinetic energy of object 1.
(B) The kinetic energy of object 2 is twice the kinetic energy of object 1.
(C) The kinetic energies are the same.
(D) The kinetic energy of object 2 is one-quarter the kinetic energy of object 1.
(E) The kinetic energy of object 2 is four times the kinetic energy of object 1.

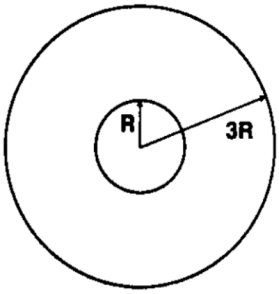
23. A block of mass m is released from rest at a height *R* above a horizontal surface. The block slides along the inside of a frictionless circular loop of radius *R*. Which one of the following expressions gives the speed of the mass at the bottom of the loop?

(A) $v = mgR$
(B) $v = \frac{mg}{2R}$
(C) $v^2 = \frac{g^2}{R}$
(D) $v^2 = 2gR$
(E) $v^2 = gR$



24. Two horses are running around two concentric circles with radii R and 3R. Both horses complete their own circles at the same time *T*. What is ratio of the speed of the outer horse to that of the inner one?

(A) 1/9
(B) 1/3
(C) 1
(D) 3
(E) 9

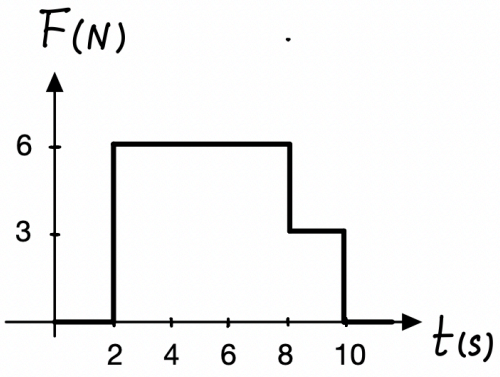


25. An object of mass 3*m*, initially at rest, explodes, breaking into two fragments of mass *m* and 2*m*. Which one of the following statements concerning the fragments after the explosion is true?

(A) They may fly off at right angles
(B) They may fly off in the same direction.
(C) The smaller fragment will have twice the speed of the larger fragment.
(D) The larger fragment will have twice the speed of the smaller fragment.
(E) The smaller fragment will have four times the speed of the larger fragment.

26. After two seconds, a 4.0-kg block slides along a horizontal frictionless surface with a constant speed of 5.0 m/s. The applied time-dependent force to the block is shown below. What is the magnitude of the change in the block's momentum?

(A) 20 kg.m/s
(B) 42 kg.m/s
(C) 48 kg.m/s
(D) 54 kg.m/s
(E) 60 kg.m/s



27. An object of mass 2*m* moving with speed υ in the +*x* direction strikes an object of mass *m* which had been at rest. Following the collision, the object of mass *m* moves with speed υ in the +*x* direction. The velocity of the object of mass 2*m* after the collision is

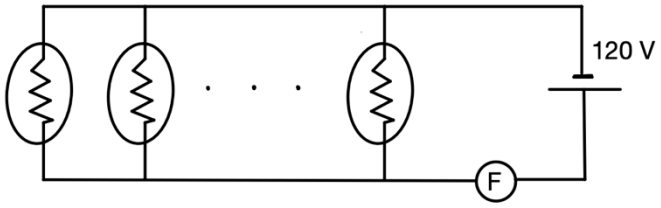
(A) zero.
(B) ½ υ in the +*x* direction.
(C) ½ υ in the –*x* direction.
(D) υ in the +*x* direction.
(E) υ in the –*x* direction.

28. Two positive point charges *Q* and 2*Q* are separated by a distance *R*. If the charge 2*Q* experiences a force of magnitude *F* when the separation is *R*, what is the magnitude of the force on the charge *Q* when the separation is increased to 2*R*?

(A) *F*/4
(B) *F*/2
(C) *F*
(D) 2*F*
(E) 4*F*

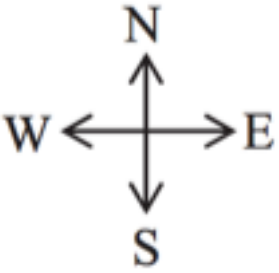
29. Some light bulbs are connected in parallel to a 120 V source as shown in the figure. Each bulb dissipates an average power of 60 W. The circuit has a fuse F that burns out when the current in the circuit exceeds 9 A. What is the largest number of bulbs which can be used in the circuit without burning out the fuse?

(A) 9
(B) 17
(C) 25
(D) 34
(E) 36



30. An electron traveling due east in a region that contains only a magnetic field experiences a vertically upward force away from the surface of the earth. What is the direction of the magnetic field?

(A) East
(B) West
(C) North
(D) South
(E) Down



END OF EXAMINATION