UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

2017 Saskatchewan High School Physics Scholarship Competition

Wednesday May 10, 2017 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 Computer scan sheet. The test paper consists of 8 pages, including this cover page. **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: _____

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

Note: In all the questions the symbol g denotes the magnitude of the acceleration due to gravity on the Earth's surface.

1. The width of a rectangular field is measured to be 27.0 m and its length is measured to be 135.2 m. We calculate the area of the field by multiplying its width by its length and find that our calculator display reads "3,650.40". The correct way to express the area to the appropriate number of significant figures is

(A) $3650\ m^2$
(B) $3.650 \times 10^3\ m^2$
(C) $3650.4\ m^2$
(D) $3.65 \times 10^3\ m^2$
(E) $3.7 \times 10^3\ m^2$

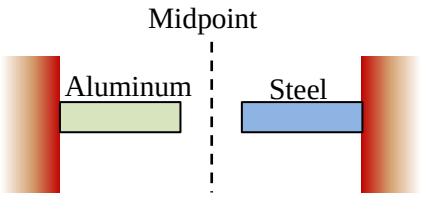
2. Which statement is correct regarding heat transfer by convection?

(A) It requires no significant displacement of molecules.
(B) It cannot be an effective heat transfer mechanism in a solid.
(C) It is the only possible heat transfer mechanism in a vacuum.
(D) It does not occur in liquids.

3. The specific heat capacity of substance A is greater than that of substance B. Both A and B are at the same initial temperature. Equal amounts of energy are added to each substance. Assuming that no melting or vaporization occurs, which of the following can be concluded about the final temperature of substance A, T_A, and the final temperature of substance B, T_B?

(A) $T_A > T_B$.
(B) $T_A = T_B$.
(C) $T_A < T_B$.
(D) We need more information to make a conclusion.

4. The diagram shows two rods, one made of aluminum and the other made of steel. The coefficient of linear expansion for aluminum is about two times that of steel. The two rods are of equal length when they are at the same initial temperature. Each rod is attached at one end to an immovable wall, as shown. The dashed line shows the midpoint between the ends of the rods when they are at the same initial temperature. The temperatures of the two rods is increased, both by the same amount, until the gap between the rods is closed. Where do the rods meet when the gap is closed?



(A) The rods meet exactly at the midpoint.
(B) The rods meet to the right of the midpoint.
(C) The rods meet to the left of the midpoint.
(D) We need to know the actual lengths of the rods to decide.

5. The frequency of a periodic wave travelling on the surface of water is 0.2 Hz. What is the time between wave crests passing a certain point?

(A) 2 seconds.
(B) 4 seconds.
(C) 5 seconds.
(D) 0.2 seconds.
(E) 0.5 seconds.
(F) Cannot be determined without knowing the speed of the wave.

6. A string (e.g. a guitar string) is stretched between two fixed points. When the string is made to vibrate, the lowest (fundamental) frequency of vibration is 100 Hz. When it is made to vibrate so that there are two nodes between the ends, as shown in the diagram, the frequency of vibration is

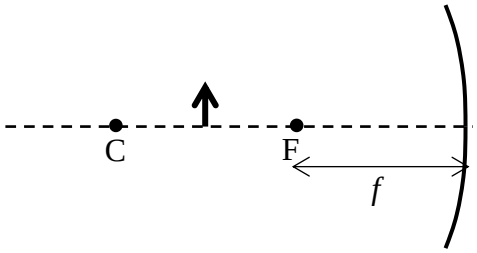
(A) 300 Hz (B) 200 Hz (C) 150 Hz (D) 50 Hz (E) 33 Hz

7. Which one of the following is an example of a longitudinal wave?

(A) Waves on the surface of water.
(B) Waves travelling up and down a guitar string.
(C) Light waves.
(D) Sound waves.
(E) X-rays.

8. An object, represented by the arrow in the diagram, is placed half way between the focal point (labeled F) of a spherical concave mirror and the center of curvature (labeled C) of the mirror. The image of the arrow will be

(A) Virtual and upright.
(B) Virtual and upside down.
(C) Real and upright.
(D) Real and upside down.
(E) No image will be formed.



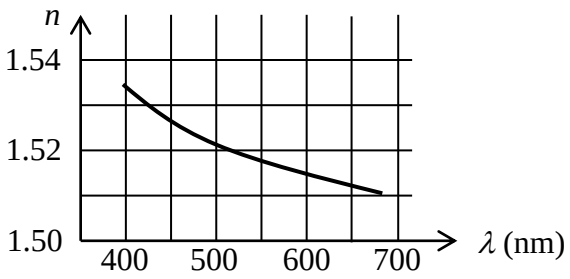
9. For the situation described in question 8, the concave mirror has a focal length *f*. What is the magnitude of the distance between the image and the mirror?

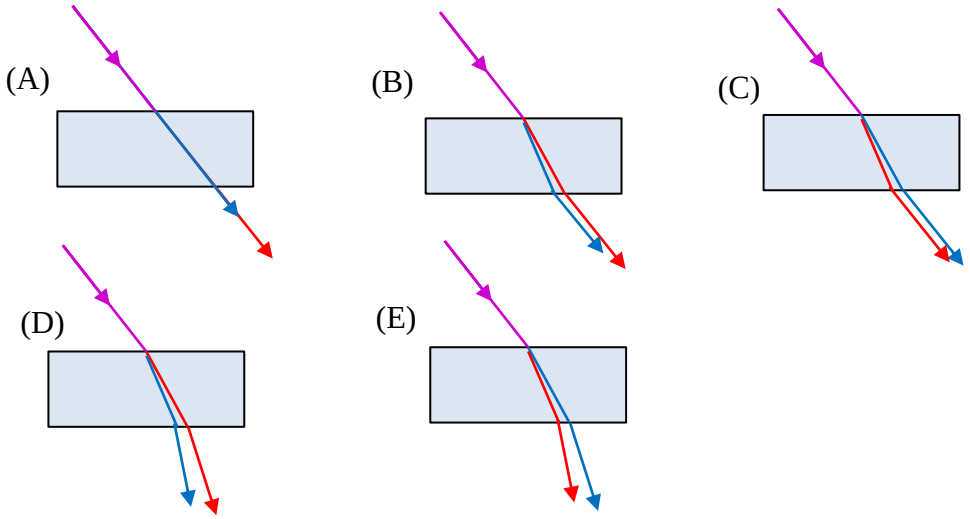
(A) $\frac{1}{2}f$ (B) $\frac{3}{2}f$ (C) $\frac{5}{2}f$ (D) $2f$ (E) $3f$
(F) The image will be an infinite distance away.

10. A sound wave is produced under water. The sound travels to the surface of the water and some of the sound is transmitted into the air. The speed of sound in water is 1450 m/s and speed of sound in air is 330 m/s. As the sound passes from water into air, the effect on the frequency of the sound, f, and on the wavelength of the sound, λ, is

(A) f and λ remain unchanged.
(B) f remains unchanged, but λ decreases.
(C) f remains unchanged, but λ increases.
(D) f increases, but λ decreases.
(E) f decreases, but λ increases.

11. The graph shows how the index of refraction of glass depends on wavelength. A ray of light containing both red and blue wavelengths is incident on a parallel-sided glass block. Which of the diagrams below show the most likely paths of the colours through the block?





12. An object is placed 40 cm from a diverging lens which has focal points that are 10 cm from the lens. The image formed by the lens is

(A) real, inverted and smaller than the object.
(B) real, inverted and larger than the object.
(C) real, upright and smaller than the object.
(D) virtual, inverted and smaller than the object.
(E) virtual, upright and larger than the object.
(F) virtual, upright and smaller than the object.

13. A small bomb contains an internal clock so that it is set to explode 5 s after the rocket in which it is located is launched. Very quickly after launch from Earth, the rocket reaches a speed of 0.99*c*. *c* is the speed of light (3×10^8 m/s). According to an observer on Earth, approximately how far away from Earth will the rocket explode?

(A) It will explode at a distance of about 15×10^8 m from Earth.
(B) It will explode at a distance much less than 15×10^8 m from Earth.
(C) It will explode at a distance much greater than 15×10^8 m from Earth.
(D) There is not enough information given to decide.

14. A metal surface is illuminated with blue light and electrons are ejected from the surface at a certain rate, and with each electron having a certain amount of energy. If the intensity of the blue light is increased, what happens to the ejected electrons?

(A) Electrons are ejected at the same rate, but with more energy per electron.
(B) Electrons are ejected at the same rate, but with less energy per electron.
(C) Electrons are ejected at an increased rate, and with more energy per electron.
(D) Electrons are ejected at an increased rate, with no change in the energy per electron.
(E) Electrons are ejected at an increased rate, with less energy per electron.

15. In the radioactive decay of an unstable nucleus a β^- particle is emitted from the nucleus. In this process what changes take place in the nucleus?

(A) The number of protons decrease by one, and the number of neutrons increase by one.
(B) The number of protons increase by one, and the number of neutrons decrease by one.
(C) The number of protons decrease by one, and the number of neutrons do not change.
(D) The number of neutrons decrease by one, and the number of protons do not change
(E) The number of protons decrease by two, and the number of neutrons decrease by two.

16. In a nuclear reactor, one of the reactions that take place is ${}^{235}_{92}\mathrm{U} + n \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + neutrons$. The number of neutrons produced by this reaction is

(A) one. (B) two. (C) three. (D) four. (E) five.

17. A stone, with mass *m*, is thrown straight up with initial speed v_o and it reaches a height *h*. A second stone, with mass 2*m*, is thrown straight up with initial speed $2v_o$. We may ignore air resistance. What is the height reached by the second stone?

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

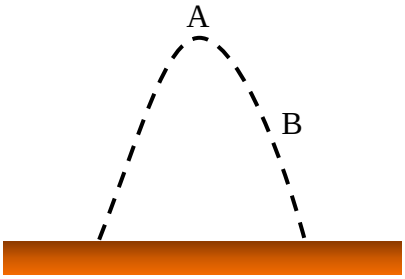
18. Two cars, A and B, start from rest and each car maintains a constant acceleration. Car A has acceleration a_A and car B has acceleration a_B. In the same elapsed time car A travels 2 times further than car B. Which of the following is true concerning the accelerations of the two cars?

(A) $a_A = \sqrt{2}a_B$ (B) $a_A = 2a_B$ (C) $a_A = 4a_B$ (D) $a_A = 2\sqrt{2}a_B$ (E) $a_A = a_B$

19. An object of mass *m* is suspended from the ceiling by means of a string. The force of gravity pulls downward on the object. Consider this to be the "action" force in Newton's third law. The "reaction" force is

(A) the string pulling upward on the object, with magnitude *mg*.
(B) the ceiling pulling upward on the string, with magnitude *mg*.
(C) the string pulling downward on the ceiling, with magnitude *mg*.
(D) the object pulling downward on the string, with magnitude *mg*.
(E) the object pulling upward on the Earth, with magnitude *mg*.

20. The figure shows the trajectory of a ball. Air resistance is ignored. Point A is where the ball is at its highest above the ground. Point B is where the ball is descending to the ground. Which statement is correct?



(A) At point A the ball's velocity is zero, but its acceleration is not zero.
(B) At point A the ball's velocity is not zero, but its acceleration is zero.
(C) At point A the ball's speed is less than at B, but its acceleration is greater than at B.
(D) At point A the ball's speed is less than at B, but its acceleration is smaller than at B.
(E) At point A the ball's velocity and acceleration are perpendicular to each other.

21. A horizontal force accelerates a box which is on a horizontal surface. There is friction between the box and the surface. The resulting acceleration of the box is constant. All conditions remain the same with the exception that the magnitude of the horizontal force is doubled. What happens to the box's acceleration?

(A) It increases to exactly double its original value.
(B) It increases to more than double its original value.
(C) It increases to less than double its original value.
(D) It increases to nearly four times its original value.
(E) It decreases.

22. The net work expended on a car to accelerate it from 0 to 30 m/s is

(A) less than that required to accelerate the car from 30 m/s to 60 m/s.
(B) equal to that required to accelerate the car from 30 m/s to 60 m/s.
(C) more than that required to accelerate the car from 30 m/s to 60 m/s.
(D) The answer depends on the time taken to achieve the change in speed.

23. The pilot of a plane pulls out of a dive by flying in a vertical circle of radius R as shown in the diagram. The speed of the plane as it flies through this partial circle is constant and has magnitude V. The pilot of the plane has mass m. What is the magnitude of the force exerted on the pilot by his seat at the lowest point in the circle?

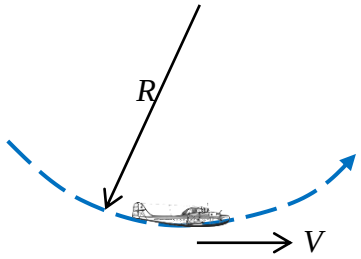
(A) $m\left(g+\frac{V^2}{R}\right)$

(B) $m\left(g-\frac{V^2}{R}\right)$

(C) $m\left(\frac{V^2}{R}-g\right)$

(D) mg

(E) $m\frac{V^2}{R}$



24. A pendulum bob, of mass m, is suspended from a string of length L. The bob is pulled to one side so that it is a height $L/4$ above its freely hanging level, as shown. If the bob is now released from rest, the speed of the bob when it is at its lowest point is given by

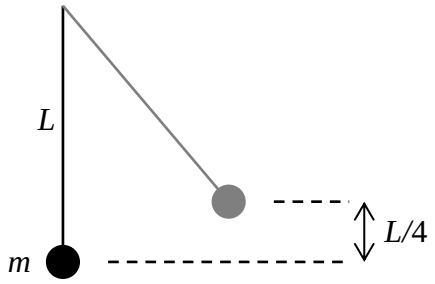
(A) $v=\frac{mgL}{8}$.

(B) $v=\sqrt{\frac{gL}{8}}$.

(C) $v=\sqrt{\frac{gL}{2}}$.

(D) $v=\sqrt{\frac{mgL}{2}}$.

(E) $v=\frac{gL}{2}$.



25. A constant horizontal force of 6 N acts for 4 s on a 12 kg block, which is moving on a frictionless horizontal surface. What is this block's change in momentum during this 4 s time interval?

(A) zero (B) 2 kg·m/s (C) 24 kg·m/s (D) 48 kg·m/s (E) 288 kg·m/s

26. You hold a slingshot at arm's length, pull the light elastic band back to your chin, and release it to launch a pebble horizontally with a speed V. With the same procedure, you fire a bean with a speed of $3V$. What is the ratio of the mass of the pebble, m_{pebble}, to the mass of the bean, m_{bean}?

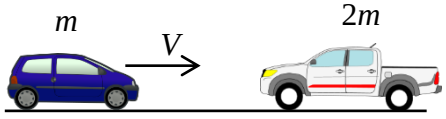
(A) $\frac{m_{pebble}}{m_{bean}}=9$ (B) $\frac{m_{pebble}}{m_{bean}}=3$ (C) $\frac{m_{pebble}}{m_{bean}}=1$ (D) $\frac{m_{pebble}}{m_{bean}}=\frac{1}{3}$ (E) $\frac{m_{pebble}}{m_{bean}}=\frac{1}{9}$

27. A ping-pong ball moving to the East collides with a stationary bowling ball. The ping-pong ball bounces back to the West and the bowling ball moves very slowly in the East. Which object experienced the greater magnitude force during the collision?

(A) Neither, both experienced the same magnitude force.
(B) The bowling ball.
(C) The ping-pong ball.
(D) The answer depends on the initial speed of the ping-pong ball.

28. A car, with mass m, moving on a horizontal road with speed V, collides head on with a stationary pick-up truck which has a mass $2m$. After the collision the two vehicles are stuck together and move as one. You may ignore friction with the ground. What is the total kinetic energy of the car and truck just after the collision?

(A) $\frac{1}{2}mV^2$ (B) $\frac{1}{3}mV^2$ (C) $\frac{3}{8}mV^2$
(D) $\frac{1}{4}mV^2$ (E) $\frac{1}{6}mV^2$

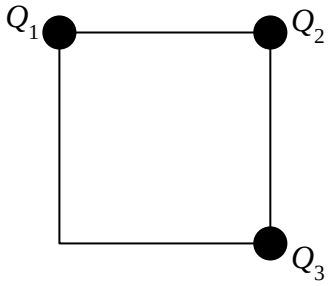


29. The radius of the Earth is R_E. On the surface of the Earth the acceleration due to gravity is g. At a height above the Earth's surface of h the gravitational field strength is

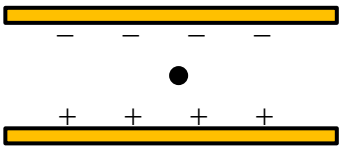
(A) g (B) $\frac{R_E}{R_E+h}g$ (C) $\left(\frac{R_E}{R_E-h}\right)^2 g$ (D) $\frac{R_E^2}{R_E^2+h^2}g$ (E) $\left(\frac{R_E}{R_E+h}\right)^2 g$

30. Three <u>equal</u> charges are placed at three corners of a square as shown. If we ignore the charge Q_3 the force on charge Q_1 has magnitude F. The magnitude of the net force on the charge Q_2 is

(A) $\sqrt{2}F$
(B) $2F$
(C) zero
(D) $3F$
(E) $(1+\sqrt{2})F$



31. The figure shows a side view of two charged horizontal conducting plates. The upper plate has a negative charge and the lower plate has a positive charge. A small charged pellet, with mass m is suspended between the two plates. Which one of the following statements is **<u>FALSE</u>**?



(A) The electric field between the plates points up.
(B) The pellet must have a negative charge.
(C) The magnitude of the electrostatic force on the pellet is equal to mg.
(D) The electric field lines between the plates are approximately straight lines.

END OF EXAMINATION