UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

2013 Saskatchewan High School Physics Scholarship Competition

May 8, 2013 Time: 90 minutes

This competition is based on the Saskatchewan High School Physics Curriculum for Physics 20 and Physics 30 including a few questions from the optional units.

INSTRUCTIONS:

1. You should have a test paper and an OMR (Optical Machine Readable) or Computer scan sheet. The test paper consists of 9 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: _____

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. When I calculate the quantity $(0.82 + 0.042) \times (4.4 \times 10^3)$ with my calculator it reads 3792.80. Which of the following is the best way to write this result to the correct number of significant figures?

(A) 4×10^3
(B) 3.7×10^3
(C) 3.8×10^3
(D) 3.79×10^3
(E) 3793

2. The position, *x*, of an object moving in a straight line along the *x*-axis is described as a function of time, *t*, by the equation $x = at^3$. If *t* is in seconds and *x* is in metres, what must be the units of the constant *a*?

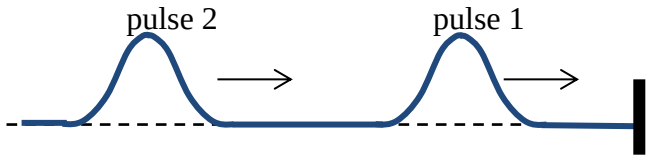
(A) m/s
(B) m^3/s^3
(C) $m.s^3$
(D) m/s^3
(E) the constant must have no units.

3. A wave is made to travel along a stretched string by wiggling one end of the string up and down at a certain frequency. We now wiggle the string at a rate that is three times faster without changing anything else. Which of the following changes are we certain to observe?

(A) The amplitude of the wave will be three times the earlier value.
(B) The amplitude of the wave will be one-third times the earlier value.
(C) The wavelength of the wave will be three times the earlier value.
(D) The wavelength of the wave will be one-third times the earlier value.
(E) The propagation speed of the wave will be three times the earlier value.

4. Consider two identical and symmetrical wave pulses on a string which initially are both moving to the right as shown in the diagram. Suppose the pulse 1 reaches the fixed end of the string and is reflected back and then meets the pulse 2. When the two pulses overlap exactly, the superposition principle predicts that the amplitude of the resultant pulse, at that moment, will be what factor times the amplitude of one of the original pulses?

(A) 0
(B) 1
(C) 2
(D) 3
(E) 4



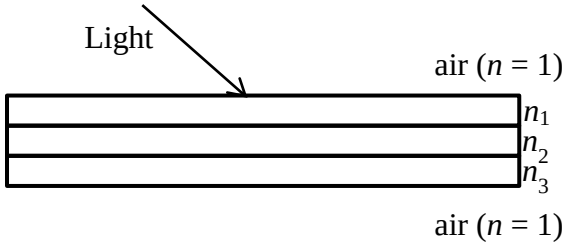
5. It is found that when light travels through a certain type of crystal it moves with a speed which is one-half of the speed of light in a vacuum. What is the index of refraction for the crystal?

(A) 0.5
(B) 1.0
(C) 1.5
(D) 2.0
(E) 2.5

6. A beam of monochromatic light goes from material 1 with index of refraction n_1 into material 2 with index of refraction n_2. The frequency of light in material 1 is f_1 and in material 2 is f_2. What is the ratio of f_1/f_2?

(A) n_1/n_2
(B) n_2/n_1
(C) $\sin(n_1)/\sin(n_2)$
(D) $\sin(n_2)/\sin(n_1)$
(E) 1

7. Three flat layers of transparent materials are stacked upon one another. The top layer has index of refraction n_1, the middle one n_2 and the bottom one n_3. There is air (n = 1) above and below the stack of materials. If $n_1 > n_2 > n_3$, and a ray of light in air strikes the top layer, at which surface is it possible that total internal reflection can occur first?



(A) The top surface.
(B) The surface between materials with indices n_1 and n_2.
(C) The surface between materials with indices n_2 and n_3.
(D) The bottom surface.
(E) At no surface.

8. A man wishes to use a plane mirror on a wall to view both his head and his feet as he stands in front of the mirror. (The mirror can be located at any position above the floor.) The required height of the mirror

(A) is equal to the height of the man.
(B) is equal to one half the height of the man.
(C) must be larger than the height of the man.
(D) depends on the distance the man stands from the mirror.
(E) depends on both the height of the man and the distance from the man to the mirror.

9. An object is placed in front of a concave mirror which has a focal length of 20 cm. A real image of the object is formed at a distance from the mirror of 60 cm. How far from the mirror is the object?

(A) 3 cm.
(B) 5 cm.
(C) 10 cm.
(D) 15 cm.
(E) 30 cm.

10. For the situation described in the previous question, the image is

(A) larger than the object and right-side up.
(B) smaller than the object and right-side up.
(C) larger than the object and upside down.
(D) smaller than the object and upside down.
(E) not able to be completely described without more information being provided.

11. A diverging lens has a focal length of magnitude F. At which of the following distances from this lens would a real object give an inverted virtual image?

(A) $\frac{1}{2}F$
(B) F
(C) $2F$
(D) Any value greater than $2F$.
(E) This cannot be done with a diverging lens.

12. Some bats use sound frequency to help them navigate. A bat flying towards a wall emits a chirp of frequency $f_0 = 50.0$ kHz. A bird perched on the wall hears a frequency f_1. The frequency of the sound reflected from the wall and heard by the bat is f_2. Which statement about these frequencies is correct?

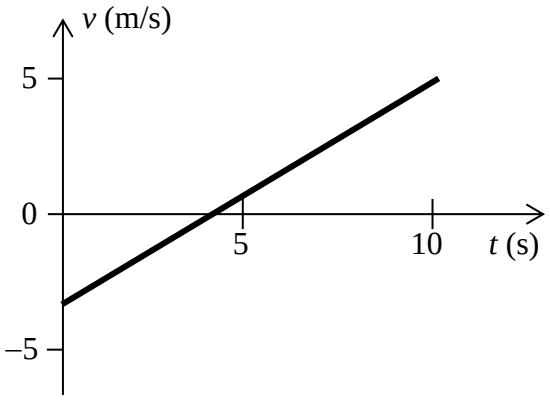
(A) $f_1 > f_0$ and $f_2 > f_1$
(B) $f_1 < f_0$ and $f_2 > f_1$
(C) $f_1 > f_0$ and $f_2 < f_1$
(D) $f_1 < f_0$ and $f_2 < f_1$
(E) $f_1 > f_0$ and $f_2 = f_1$

13. In a calorimeter, which does not allow any heat to enter or escape, there is 100 g of a fluid at 20°C. Into this is placed 20 g of a solid that is initially at 70°C. Thermal equilibrium is established at 30°C. From this information we can tell that the specific heat capacity of the solid is

(A) greater than that of the fluid.
(B) equal to that of the fluid.
(C) less than that of the fluid.
(D) No statement can be made because there is not enough information given.
(E) No statement can be made since we cannot compare a solid to a fluid.

14. A train moves along a straight track. The graph below shows the velocity of the train as a function of time. During the 10-second time interval shown, we can say that the speed of the train

(A) is constant.
(B) is always increasing.
(C) is always decreasing.
(D) is first increasing and then decreasing.
(E) is first decreasing and then increasing.

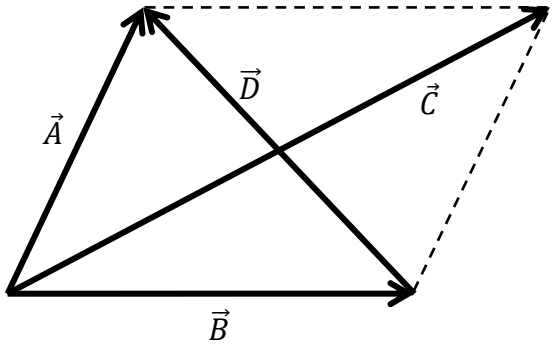


15. Arthur and Betty start walking toward each other when they are 100 m apart. Arthur has a speed of 3.0 m/s and Betty has a speed of 2.0 m/s. Their dog, Spot, starts by Arthur's side at the same time that Arthur and Betty start walking, and he runs to Betty then back to Arthur. He continues this back and forth running until Arthur and Betty meet. When Arthur and Betty meet, what is the magnitude of Spot's displacement from his initial position?

(A) 30 m
(B) 40 m
(C) 50 m
(D) 60 m
(E) 70 m

16. Consider the four vectors $\vec{A}$, $\vec{B}$, $\vec{C}$ and $\vec{D}$ shown in the parallelogram below. Which one of the following choices shows two correct relationships between the vectors?

(A) $\vec{C} = \vec{A} + \vec{D}$ and $\vec{D} = \vec{A} - \vec{B}$.
(B) $\vec{C} = \vec{A} + \vec{B}$ and $\vec{D} = \vec{B} - \vec{A}$.
(C) $\vec{A} = \vec{B} + \vec{D}$ and $\vec{C} = \vec{A} - \vec{B}$.
(D) $\vec{B} = \vec{A} + \vec{D}$ and $\vec{B} = \vec{C} - \vec{A}$.
(E) $\vec{B} = \vec{C} - \vec{A}$ and $\vec{D} = \vec{A} - \vec{B}$.



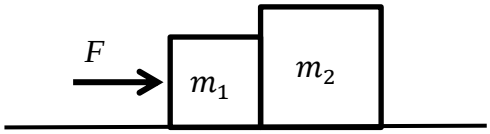
17. A ball rolls down an incline, starting from rest. If the total time it takes to reach the end of the incline is *T*, how much time has elapsed when it is halfway down the incline?

(A) $\frac{1}{4}T$
(B) $\frac{1}{2}T$
(C) $\frac{1}{\sqrt{2}}T$
(D) $\frac{1}{\sqrt{3}}T$
(E) There is not enough information to determine which of the above answers is correct.

18. For projectile motion where air resistance can be neglected, which statement is correct when the projectile is at the highest point in its motion?

(A) Its acceleration is zero.
(B) Its velocity is perpendicular to its acceleration.
(C) Its velocity and acceleration are both zero.
(D) The horizontal and vertical components of its velocity are both zero.
(E) Only the horizontal component of its velocity is zero.

19. Two boxes, with masses m_1 and m_2 rest on a horizontal frictionless surface. A constant horizontal force of magnitude *F* is applied to box 1.

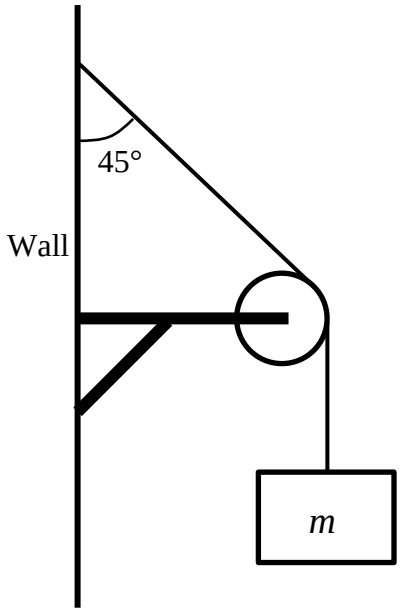


The magnitude of the force of box 1 on box 2 is

(A) F
(B) $\dfrac{F}{m_1 + m_2}$
(C) $\dfrac{m_1 F}{m_1 + m_2}$
(D) $\dfrac{m_2 F}{m_1 + m_2}$
(E) $\dfrac{(m_1 + m_2)F}{m_2}$

20. A box of mass *m* is hanging from a light string which passes over a massless and frictionless pulley which is attached to the wall. The string is also attached to the wall, making an angle of 45° with the wall as shown. The magnitude of the force with which the string pulls on the wall is

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



21. Two blocks are released from rest from the top of a building. One falls straight down while the other slides down a smooth ramp. If all friction is ignored, which block is moving faster when it reaches the bottom?

(A) The block that slid down the ramp.
(B) The block that was dropped.
(C) They are both moving at the same speed when they reach the bottom.
(D) There is insufficient information given. We need to know which block has the greater mass.

22. Box A is initially at rest on a horizontal frictionless surface. It is pushed with a constant horizontal force until the box has moved a horizontal distance *d* and then released. The same experiment is done with another box B; the only difference is that box B has four times the mass of box A. How do the final speeds of the two boxes compare?

(A) $v_B = 2v_A$
(B) $v_B = \frac{1}{2}v_A$
(C) $v_B = 4v_A$
(D) $v_B = \frac{1}{4}v_A$
(E) $v_B = v_A$

23. The kinetic energy of an object is doubled. This means that the magnitude of the object's momentum changes by a factor of

(A) $\sqrt{2}$
(B) 2
(C) $2\sqrt{2}$
(D) 4
(E) 1, i.e. there is no change in the momentum.

24. An egg dropped on the road usually breaks, while one dropped on the grass usually doesn't break. This is because, for the egg dropped on the grass,

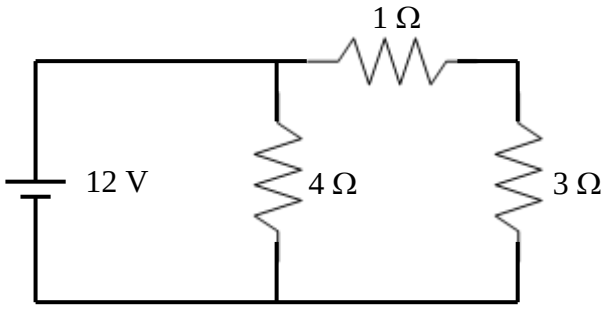
(A) the change in momentum of the egg is less.
(B) the change in momentum of the egg is greater.
(C) the time interval over which the egg comes to rest is less, and hence the average force exerted on the egg is less.
(D) the time interval over which the egg comes to rest is greater, and hence the average force exerted on the egg is greater.
(E) the time interval over which the egg comes to rest is greater, and hence the average force exerted on the egg is less.

25. If a certain resistor obeys Ohm's law, its resistance will

(A) change when the voltage across the resistor is changed.
(B) change when the current passing through the resistor is changed.
(C) change when the power dissipated in the resistor changes.
(D) not change when the voltage, current or power is changed.

26. In the circuit shown, the battery may be considered to be an ideal battery. What is the current passing through the 3 Ω resistor?

(A) 1 A
(B) 2 A
(C) 3 A
(D) 4 A
(E) 6 A



27. A light bulb in your home is replaced with one that is more energy efficient. The new light bulb uses only one-tenth the power of the original bulb. If the resistance of the original bulb was *R*, what is the resistance of the new light bulb?

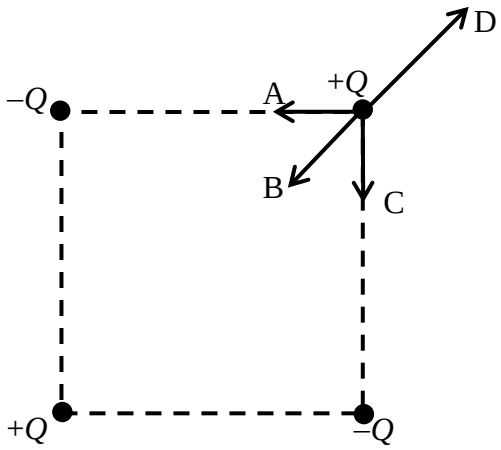
(A) $\frac{1}{100}R$
(B) $\frac{1}{10}R$
(C) $2R$
(D) $10R$
(E) $100R$

28. A radioactive nucleus decays by alpha emission. How does the daughter nucleus differ from the parent nucleus?

(A) The nucleon number has decreased by 4 and the atomic number has decreased by 2.
(B) The nucleon number has decreased by 2 and the atomic number has decreased by 1.
(C) The nucleon number has decreased by 4 and the atomic number has decreased by 1.
(D) The nucleon number has not changed and the atomic number has decreased by 1.
(E) The nucleon number has not changed and the atomic number has increased by 1.

29. Four charges of equal magnitude are placed at the four corners of a square. Two of the charges are positive and two of the charges are negative as shown. Which arrow best shows the direction of the net force on the positive charge in the corner?

(A) A
(B) B
(C) C
(D) D
(E) The net force will be zero.



30. The acceleration due to gravity on the Earth's surface is g. Calling R the radius of the Earth, at what distance from the centre of the Earth will the acceleration due to gravity be $g/16$?

(A) $2R$
(B) $4R$
(C) $8R$
(D) $16R$
(E) Not at any distance, since the acceleration due to gravity is a constant.

31. A cup of water has an ice cube floating on the surface of the water. As the ice melts, you observe that

(A) the water level in the glass goes up.
(B) the water level in the glass goes down.
(C) the water level in the glass stays the same.
(D) the water level in the glass might go up or down depending on the mass of the ice cube.

END OF EXAMINATION