UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

2011 Saskatchewan High School Physics Scholarship Competition

May 18, 2011 Time: 90 minutes

This competition is based on the Saskatchewan High School Physics Curriculum for Physics 20 and Physics 30.

INSTRUCTIONS:

1. You should have a test paper and an OMR (Optical Machine Readable) or Computer scan sheet. The test paper consists of 10 pages. **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 **both** this cover page **and** the OMR sheet must be submitted.
5. All questions are of equal value.
6. 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.

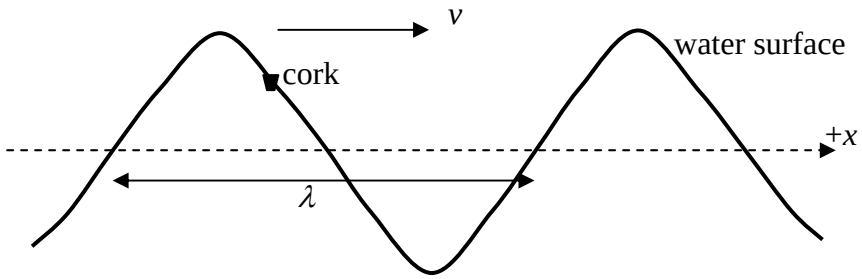
1. A unit of length known as the angstrom is defined by, 1 angstrom = 1 Å = 10^{-10} m, and another unit of length known as the Fermi is defined by, 1 fermi = 1 fm = 10^{-15} m. It follows that

(A) 1 fm = 10^{5} Å
(B) 1 fm = 10^{25} Å
(C) 1 fm = 10^{-5} Å
(D) 1 fm = 10^{-25} Å
(E) 1 fm = 10^{-15} Å

2. Given that the quantities *a* and *b* both have units of m (metre), and that the equation $x = c^2 + 2ab$ is a dimensionally correct equation, what are the units of the quantity *x*?

(A) m
(B) m^2
(C) $2m^2$
(D) unitless
(E) The answer cannot be determined without being told the units of *c*.

3. The diagram shows a snapshot of a wave travelling along the surface of water. The wave is moving to the right (the $+x$ direction). A cork floating on the surface of the water is at the position shown at this instant in time.



At this instant in time the cork is
(A) moving up.
(B) moving down.
(C) moving to the right.
(D) moving to the left.
(E) not moving.

4. The wavelength of the water wave in the previous question is λ as shown in the diagram above. The speed of propagation of the wave is *v*. The time it takes for the cork to go through one complete cycle of its motion is *T*. The relationship between these quantities is

(A) $v = \frac{T}{\lambda}$ (B) $v = \lambda T$ (C) $v = 2\lambda T$
(D) $v = \frac{\lambda}{T}$ (E) $v = \lambda T^2$

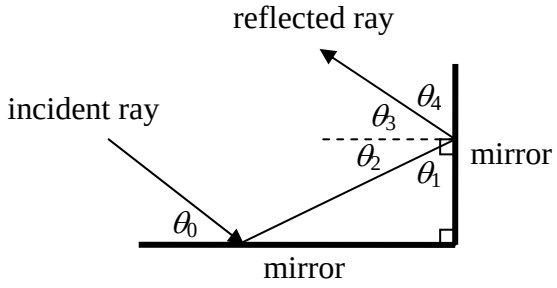
5. Which one of the following lists the electromagnetic waves from longest wavelength to shortest wavelength?

(A) X-rays, ultraviolet light, visible light.
(B) Visible light, infrared light, X-rays.
(C) Microwaves, visible light, infrared light.
(D) Infrared light, visible light, ultraviolet light.
(E) X-rays, visible light, ultraviolet light.

6. The wavelength of the light emitted from a certain element is known to be 500 nm when measured for a stationary light source. An astronomer observes the light from this element emitted from a distant star to have a wavelength of 501 nm. The star is

(A) moving toward the astronomer.
(B) moving away from the astronomer.
(C) stationary.
(D) expanding.
(E) None of the above conclusions can be made.

7. A ray of light is incident on a plane mirror which is perpendicular to another mirror as shown. The angle between the incident ray and the surface of the mirror is θ_0.



Which of the angles θ_1, θ_2, θ_3, and θ_4 in the diagram are equal to θ_0?

(A) θ_1 and θ_3.
(B) θ_1 and θ_4.
(C) θ_2 and θ_3.
(D) θ_2 and θ_4.
(E) θ_4 only.

8. A curved mirror has a focal length of magnitude *f*. An object is placed at a distance less than *f* from the mirror. A student reports that the image of the object is upright and larger than the object. From this we know that

(A) the mirror must be a concave mirror.
(B) the mirror must be a convex mirror.
(C) the student has made a mistake because an upright image must always be smaller than the object regardless of the mirror type.
(D) the student has made a mistake because an enlarged image must always be upside down regardless of the mirror type.

9. A light ray travelling in water hits the interface between the water and the air. Which one of the following statements is correct concerning what happens to the light?

(A) Total internal reflection always occurs, regardless of the angle of incidence.
(B) If total internal reflection does not occur, all the light passes into the air.
(C) If total internal reflection does not occur, the angle of refraction of the light that passes into the air is less than the angle of incidence.
(D) If total internal reflection does occur, the angle of reflection is equal to the angle of incidence.
(E) Total internal reflection can never occur, for any angle of incidence.

10. When a light wave passes from one medium into another with a different index of refraction its

(A) speed, frequency and wavelength all change.
(B) speed and frequency change but its wavelength remains the same.
(C) speed and wavelength change but its frequency remains the same.
(D) frequency and wavelength change but its speed remains the same.
(E) frequency changes but its speed and wavelength remain the same.

11. The latent heat of melting for water is 80 cal/g and the specific heat capacity of water is 1 cal/g/K. A thermally isolated enclosure initially contains 100 g of ice at 0ºC. Water at an initial temperature of 40ºC is then poured into it. The smallest amount of added water that will guarantee that all the ice is melted is

(A) 40 g.
(B) 80 g.
(C) 100 g.
(D) 200 g.
(E) 800 g.

12. By what primary heat transfer mechanism does one end of an iron bar become hot when the other end is placed in a flame?

(A) natural convection.
(B) forced convection.
(C) radiation.
(D) conduction.
(E) The mechanism depends on the orientation of the bar with respect to the flame.

13. A diverging lens in eyeglasses is useful in correcting for

(A) nearsightedness.
(B) farsightedness.
(C) lack of accommodation.
(D) astigmatism (distortion in the cornea).
(E) colour blindness.

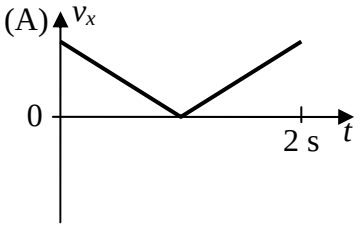
14. Displacement $\vec{\mathbf{A}}$ has a horizontal component of 3 metres and a vertical component of 4 metres. Displacement $\vec{\mathbf{B}}$ has a horizontal component of 1 metre and a vertical component of –1 metres. Displacement $\vec{\mathbf{C}}$ has a horizontal component of –2 metres and a vertical component of –3 metres. The magnitude of the total displacement $\vec{\mathbf{A}} + \vec{\mathbf{B}} + \vec{\mathbf{C}}$ is

(A) zero.
(B) 2 metres.
(C) 4 metres.
(D) 10 metres.
(E) 14 metres.

15. A box slides in a straight line across the floor. It starts out at a speed of 10 m/s and at a time of 2 seconds later it has a speed of 4 m/s. Assuming that the acceleration of the box is constant, how far did the box move in the these 2 seconds?

(A) 6 m
(B) 8 m
(C) 12 m
(D) 14 m
(E) 20 m

16. A rock is thrown vertically upward. Air resistance can be neglected. The rock comes back to the height from which it was thrown in a time of 2 seconds. If upwards is chosen as the positive x direction, which graph best represents the velocity of the rock in the x-direction (v_x) as a function of time?

(A)


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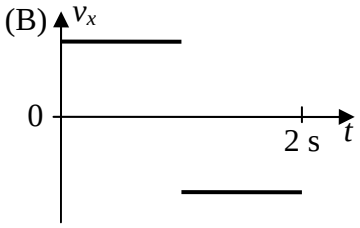

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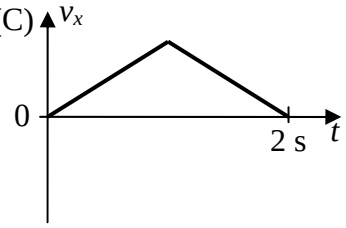

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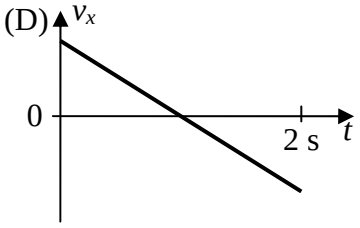
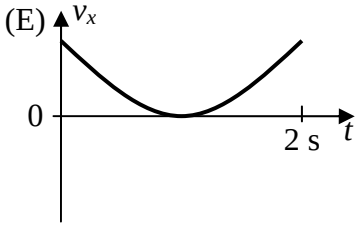


(E)


17. A rifle fires a bullet horizontally at a speed v from the top of a tall tower. If we ignore the effects of air resistance, which is the best description of the position of the bullet at a time t after it was fired.

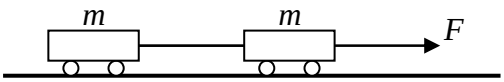
(A) The bullet is a horizontal distance vt, and a vertical distance $\frac{1}{2}gt^2$ down, from where it was fired.
(B) The bullet is a horizontal distance $\frac{1}{2}vt$, and a vertical distance gt down, from where it was fired.
(C) The bullet is a horizontal distance vt, and a vertical distance $2gt$ down, from where it was fired.
(D) The bullet is a horizontal distance vt^2, and a vertical distance $2gt^2$ down, from where it was fired.
(E) The bullet is a horizontal distance vt, and a vertical distance $vt + \frac{1}{2}gt^2$ down, from where it was fired.

18. A net force of constant magnitude and direction acts on a brick. Which statement about the motion of the brick is correct?

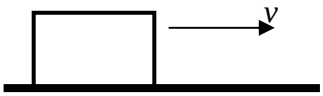
(A) The brick undergoes a constant acceleration.
(B) The brick maintains a constant velocity.
(C) The brick maintains a constant speed.
(D) The brick accelerates at an ever increasing rate.
(E) The brick accelerates but the acceleration changes in a way that depends on the initial velocity of the brick.

19. Two toy train cars, each with the same mass m, are joined with a string. The first car is pulled with a horizontal force of magnitude F as shown. We can ignore friction between the cars and the track. The tension in the string joining the two cars is

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



20. A box is sliding over a horizontal floor with an initial speed v. Friction causes the box to slow down and it is found that it slows down with an acceleration that has a magnitude a. The coefficient of kinetic friction between the box and the floor is



(A) $\mu = \dfrac{a}{2g}$

(B) $\mu = \dfrac{va}{g^2}$

(C) $\mu = \dfrac{a}{g}$

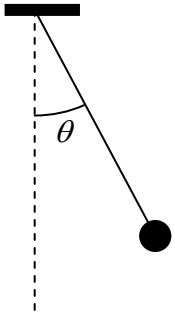
(D) $\mu = \dfrac{g}{a}$

(E) None of the above answers can be correct since the answer must depend on the mass of the box.

21. You slam on the brakes of your car in a panic and skid a certain distance on a straight and level road. If you had been travelling four times as fast, what distance would you have skidded under the same conditions?

(A) You would have skidded 2 times further.
(B) You would have skidded 4 times further.
(C) You would have skidded 12 times further.
(D) You would have skidded 16 times further.
(E) It is impossible to tell from the information given.

22. Consider four simple pendulums. Pendulum A has a length L and a mass M, pendulum B has a length $2L$ and a mass M, pendulum C has a length L and a mass $2M$, and pendulum D has a length $2L$ and a mass $2M$. Each pendulum is displaced by the same angle θ from the vertical and then released from rest at that position. Compare the maximum speed that each pendulum has as it passes through the lowest point in its swing.



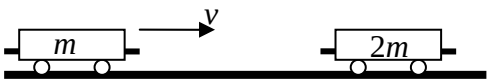
(A) Pendulum A has the largest speed.
(B) Pendulum D has the largest speed.
(C) Pendulums B and D have equal speeds that are larger than the others.
(D) Pendulums A and C have equal speeds that are larger than the others.
(E) All pendulums will have the same speed.

23. A large truck collides head on with a small car. Which one of the following statements about the magnitude of the force experienced by each vehicle during the collision is correct?

(A) The truck experiences the larger magnitude force.
(B) The car experiences the larger magnitude force.
(C) Both vehicles will experience the same magnitude force.
(D) The vehicle that is moving fastest just before the collision will experience the larger magnitude force.
(E) The vehicle that has the larger magnitude momentum just before the collision will experience the larger magnitude force.

24. A train car of mass m is moving along a straight horizontal track at speed v. It is moving toward another train car, with mass $2m$, which is stationary. When the two cars collide they couple together and afterwards move as one. What is the speed of the pair of cars just after the collision?

(A) $\frac{1}{3}v$
(B) $\frac{1}{2}v$
(C) $\frac{1}{\sqrt{2}}v$
(D) $\frac{1}{\sqrt{3}}v$
(E) v



25. Suppose that the distance between two stars were increased by a factor of 10. What effect would this have on the gravitational force between the two stars.

(A) The force would be unaffected since their masses do not change.
(B) The force would be smaller by a factor of 2.
(C) The force would be smaller by a factor of 4.
(D) The force would be smaller by a factor of 10.
(E) The force would be smaller by a factor of 100.

26. Two planets have the same acceleration due to gravity on their surfaces, but one planet has twice the mass of the other. If r is the radius of the smaller mass planet, what is the radius of the larger mass planet?

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

27. Two satellites orbiting the Earth in circular orbits have the same

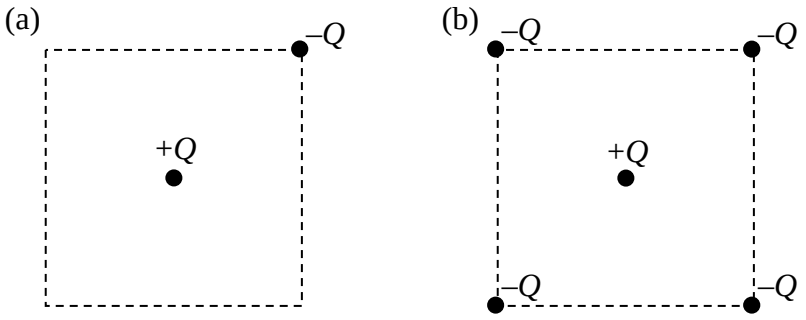
(A) orbital period to orbit radius ratio.
(B) orbital period to orbit radius squared ratio.
(C) orbital period squared to orbit radius squared ratio.
(D) orbital period to orbit radius cubed ratio.
(E) orbital period squared to orbit radius cubed ratio.

28. A cubic submarine is fully immersed under the water. The pressure is greatest

(A) on the top of the cube.
(B) on the sides of the cube.
(C) on the bottom of the cube.
(D) None of the above, the pressure is the same on all six sides of the cube.

29. A point positive charge, $+Q$, is placed at the centre of a square and an equal magnitude negative charge, $-Q$, is placed at one of the corners of the square, as shown in diagram (a) below. It is observed that an electric force of magnitude F acts on the positive charge in the centre. Now three identical negative charges, $-Q$, are placed at the other three corners, as shown in diagram (b). What is magnitude of the electric force on the charge in the centre now?

(A) Zero
(B) F
(C) $2F$
(D) $3F$
(E) $4F$



30. A piece of wood floats on the surface of water with half its volume submerged below the surface of the water. The same piece of wood is placed on the surface of some oil. The density of the oil is about 0.8 times the density of water. What faction of the wood is submerged below the surface of the oil?

(A) Less than half.
(B) Still one half.
(C) More than half.
(D) All of it (the wood would sink).
(E) We cannot decide between the above answers; the answer depends on the mass of the wood.

31. Three identical resistors are connected in series to a 12 V battery. The voltage across any one of the resistors is

(A) 36 V.
(B) 12 V.
(C) 6 V.
(D) 4 V.
(E) None of the above since the voltage across each of the three resistors will be different.

32. A 500 W device is connected to a 100 V battery. What current flows through this device?

(A) 50,000 A
(B) 0.2 A
(C) 5 A
(D) 20 A
(E) 25 A

33. During the radioactive decay of an unstable nucleus in which a positron (β^+ particle) is emitted

(A) a neutron is transformed into a proton within the nucleus.
(B) a neutron is transformed into an electron within the nucleus.
(C) a proton is transformed into a neutron within the nucleus.
(D) a proton is also ejected from the nucleus.
(E) a neutron is also ejected from the nucleus.

34. The nucleus $^{214}_{83}\mathrm{Bi}$ has

(A) 83 protons and 214 neutrons.
(B) 214 protons and 83 neutrons.
(C) 131 protons and 83 neutrons.
(D) 83 protons and 131 neutrons.
(E) 131 protons and 214 neutrons.

END OF EXAMINATION