# UNIVERSITY OF SASKATCHEWAN
## Department of Physics and Engineering Physics

## 2018 Saskatchewan High School Physics Scholarship Competition

Wednesday May 9, 2018 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 32 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: _____

_____

_____

Postal Code: _____

Telephone: _____

Email address: _____

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**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.** Given that water has a density of 1 g/cm$^3$, what is the mass of one cubic metre of water in kilograms?

(A) 0.1 kg
(B) 1 kg
(C) 10 kg
(D) 100 kg
(E) 1000 kg
(F) 10,000 kg

**2.** It is a well-known fact that water has a higher specific heat capacity than iron. Consider equal masses of water and iron which are initially in thermal equilibrium. The same amount of heat is added to each. Which statement is true?

(A) They remain in thermal equilibrium.
(B) They are no longer in thermal equilibrium; the iron is warmer.
(C) They are no longer in thermal equilibrium; the water is warmer.
(D) The result cannot be determined without knowing the exact specific heat capacities and masses involved.

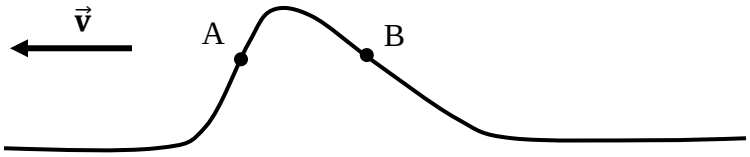
**3.** A substance is initially in the form of a vapor. What change takes place as the substance condenses and turns into a liquid?

(A) The temperature of the substance increases.
(B) The temperature of the substance decreases.
(C) Heat energy leaves the substance.
(D) Heat energy enters the substance.
(E) No changes take place during the phase change.

**4.** From the definition of a mole we know that there is about one mole of carbon atoms in 12 g of carbon. The mass of a helium atom is about one-third the mass of a carbon atom. Approximately how many moles of helium atoms are there in 12 g of helium?

(A) 1/4 mole.
(B) 1/3 mole.
(C) 1 mole.
(D) 3 mole.
(E) 4 mole.

**5.** The figure shows a snapshot of a wave pulse moving along a string to the left with velocity $\vec{\mathbf{v}}$ as shown. At the instant that the snapshot is taken, in what directions are the points A and B moving?




(A) They are both moving to the left.
(B) They are both moving up.
(C) Point A is moving up and point B is moving down.
(D) Point A is moving down and point B is moving up.
(E) They are both moving down.

**6.** A periodic wave passes by an observer who notices that the time between two consecutive wave crests is 2 seconds. Which one of the following statements about the wave is true?

(A) It has a wavelength of 2 metre.
(B) It has a period of ½ second.
(C) It has a frequency of ½ Hz.
(D) It has a speed of 2 m/s.
(E) It has an amplitude of 2 m.

**7.** Consider the standing wave in a guitar string and the sound wave produced by that guitar string as a result of its vibration. What do these two waves have in common?

(A) They are both transverse waves.
(B) They have the same wavelength.
(C) They have the same speed of propagation.
(D) They have the same frequency.
(E) They have nothing in common.

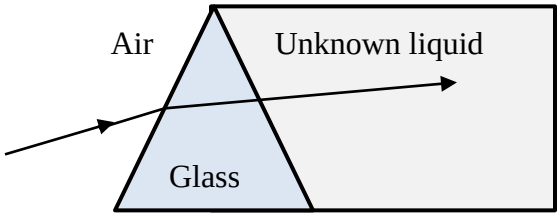
**8.** A diffraction grating consists of a large number of parallel, narrow, evenly-spaced slits. Consider two gratings, identical except that one has more slits per centimetre than the other. They are both illuminated with light from identical monochromatic sources. Which one of the following statements correctly describes the interference pattern for the grating with more slits per centimeter compared to the pattern for the grating with fewer slits per centimetre?

(A) The bright fringes are closer together and narrower.
(B) The bright fringes are further apart and narrower.
(C) The bright fringes are closer together and wider.
(D) The spacing of the bright fringes is the same but the fringes are narrower.
(E) The spacing of the bright fringes is the same but the fringes are wider.

**9.** A concave mirror has a focal length *f*. An object is placed at a distance between *f* and 2*f* from the front face of the mirror. Which statement is correct about the image formed?

(A) The image is at a distance between *f* and 2*f* from the mirror's surface and is real.
(B) The image is at a distance between *f* and 2*f* from the mirror's surface and is virtual.
(C) The image is at a distance less than *f* from the mirror's surface and is real.
(D) The image is at a distance less than *f* from the mirror's surface and is virtual.
(E) The image is at a distance greater than 2*f* from the mirror's surface and is real.
(F) The image is at a distance greater than 2*f* from the mirror's surface and is virtual.

**10.** A ray of green light travels through air and is refracted as it enters a glass prism as shown in the diagram. An unknown liquid is in contact with the right side of the prism. The light follows the path shown. Which one of the following statements is true?




(A) The frequency of the light inside the prism is different from the frequency in the air or in the unknown liquid.
(B) The index of refraction of the glass is smaller than that of the air.
(C) The index of refraction of the unknown liquid is the same as that of the glass.
(D) The speed of light is larger in the unknown liquid than in the glass.
(E) The index of refraction of the unknown liquid is the same as that of the air.

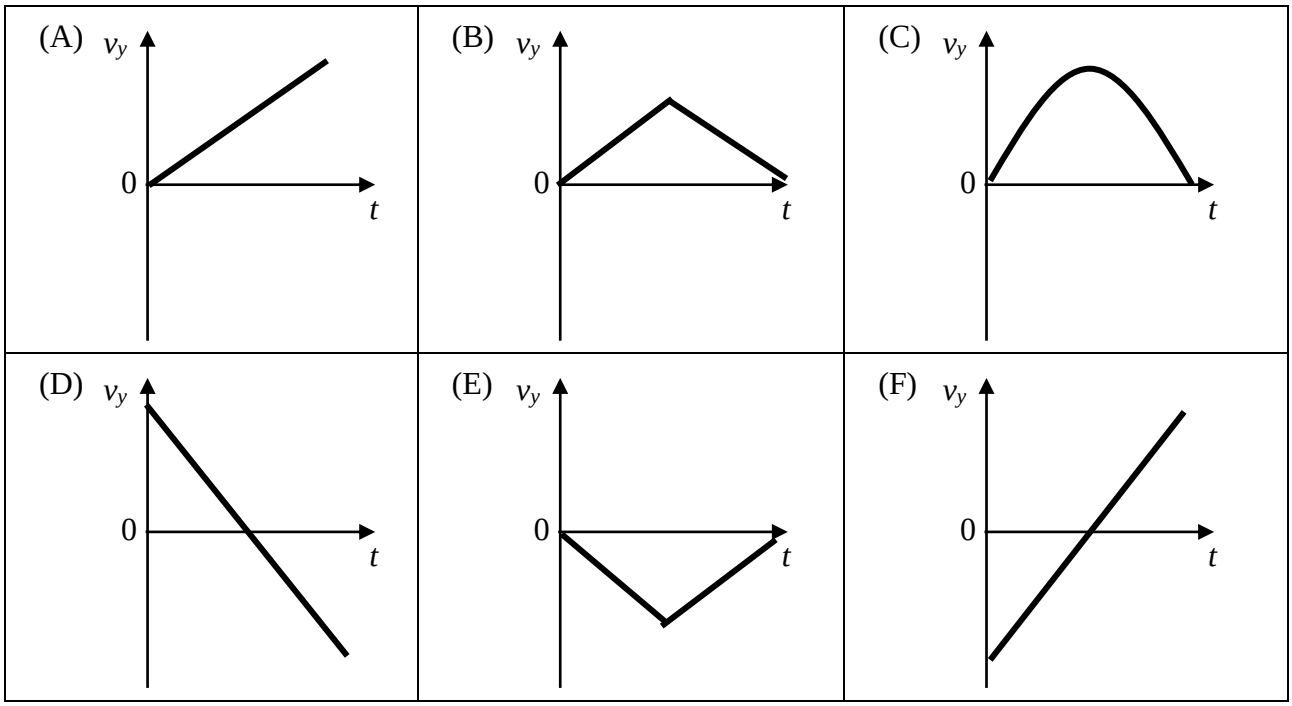
**11.** You wish to buy a lens to use as a magnifying glass. When you hold the lens near your eye you should see an image which is 24 cm from the lens (on the other side of the lens from your eye), and the height is the image you see should be 4 times the height of the object you are looking at. What focal length lens should you buy?

(A) 8 cm.
(B) 7 cm.
(C) 6 cm.
(D) 5 cm.
(E) 4 cm.

**12.** A brick is dropped from rest and a rock is thrown horizontally. Both objects are released from the top of a vertical cliff at the same instant. Compare the time it takes each object to reach the level ground at the base of the cliff. Neglect any effects due to air resistance. Which statement is correct?

(A) The brick reaches the ground first.
(B) The rock reaches the ground first.
(C) Which object reaches the ground first depends on the speed with which the rock is thrown. If the rock is thrown faster than a certain value, the brick will reach the ground first.
(D) Which object reaches the ground first depends on the speed with which the rock is thrown. If the rock is thrown faster than a certain value, the rock will reach the ground first.
(E) Both objects reach the ground at the same time.

**13.** Which one of the following graphs best depicts the velocity versus time for a ball that is thrown vertically upward? (Ignore air resistance and assume that UP has been chosen as the positive *y* direction.)



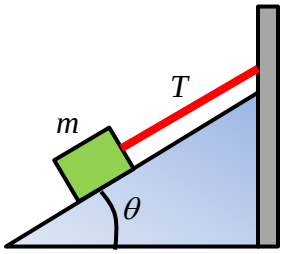

**14.** Isobel Newton is conducting her famous elevator experiments. Isobel stands on a scale and reads the scale while ascending and descending in an elevator. Isobel weighs 600 N, but notices that the scale readings depend on the motion of the elevator. Which one of the following statements is correct?

(A) When the elevator is going up at a constant speed, the scale reads more than 600 N.
(B) When the elevator is going up and slows as it approaches the top of the building, the scale reads less than 600 N.
(C) When the elevator is going down and slows as it approaches the ground floor, the normal force that the scale exerts on Isobel decreases.
(D) When the elevator is moving downward at a constant speed, the magnitude of the normal force that the scale exerts on Isobel is less than 600 N.
(E) If the cable supporting the elevator were to break and the elevator were to fall, the scale would still read 600 N.

**15.** The only force experienced by each of two objects in deep space is the mutual gravitational force of attraction between them. Let the mass and acceleration of object 1 be denoted by $m_1$ and $a_1$, and the mass and acceleration of object 2 be denoted by $m_2$ and $a_2$. Which one of the following is correct for the ratio of their accelerations, $\frac{a_1}{a_2}$?

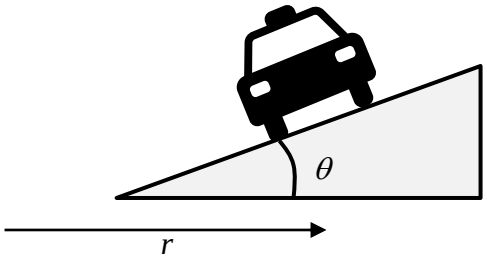
(A) $\frac{a_1}{a_2} = \frac{m_1}{m_2}$ (B) $\frac{a_1}{a_2} = \frac{m_2}{m_1}$ (C) $\frac{a_1}{a_2} = 1$ (D) $\frac{a_1}{a_2} = \left(\frac{m_1}{m_2}\right)^2$ (E) $\frac{a_1}{a_2} = \sqrt{\frac{m_2}{m_1}}$

**16.** A block, of mass *m*, is held motionless on a frictionless inclined plane by a string attached to a wall as shown in the drawing. The string is parallel to the plane which is at an angle, $\theta$, to the horizontal. What is the magnitude of the tension, *T*, in the string?



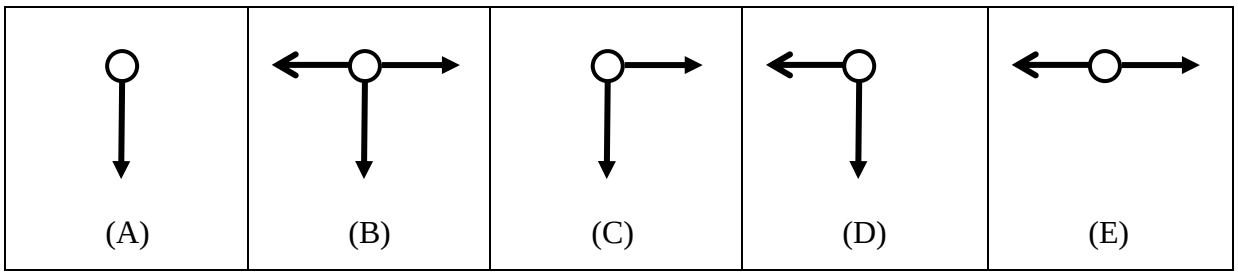

(A) zero
(B) $mg$
(C) $mg\cos\theta$
(D) $mg\sin\theta$
(E) $mg\tan\theta$

**17.** A car, with mass *m*, is driving around a circular curve with radius *r*. The road is banked at an angle $\theta$, and the road is covered with ice, so friction between the wheels and the road is negligible. The car drives at a speed, *v*, such that it does not slide, either down or up the banking. A second car with a mass $2m$ drives around the same banked curve. At what speed should the second car travel so that, it too, does not slide up or down the banking?




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

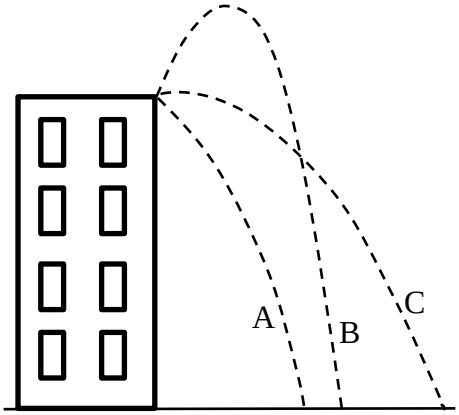
**18.** A golf ball is travelling through the air as a result of a powerful hit. In the diagrams below the ball is **travelling to the right**. Which diagram gives the best representation of the forces acting on the ball when it is at the highest point of its flight?



**19.** A ball is thrown against a wall. It rebounds with no change in speed. Which one of the following statements is true?

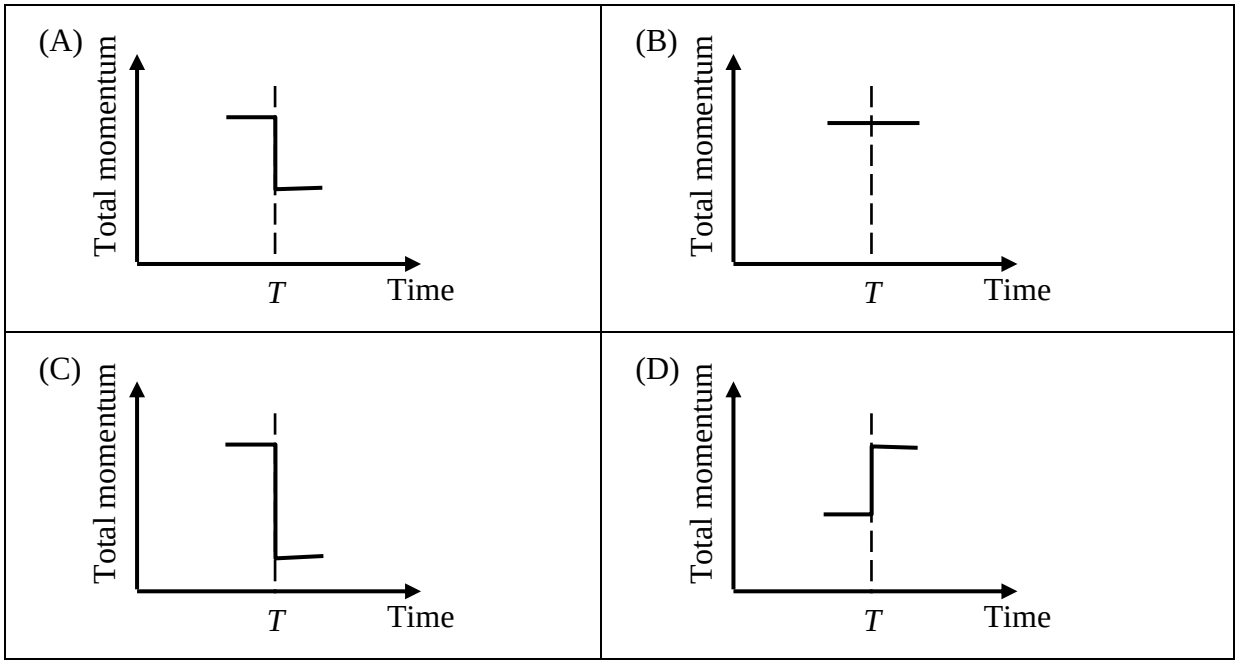
(A) The ball's kinetic energy is unchanged.
(B) The ball's momentum is unchanged.
(C) Both kinetic energy and momentum are unchanged.
(D) Both kinetic energy and momentum change.
(E) The question cannot be answered without more information.

**20.** A child throws water balloons from the top of a building. All the water balloons are thrown with the same initial speed but are launched at different angles. We can ignore air resistance in the motion of the water balloons. For the three water balloons whose paths are shown in the diagram, compare the speeds with which the water balloons hit the ground below.




(A) Water balloon A hits with the highest speed.
(B) Water balloon B hits with the highest speed.
(C) Water balloon C hits with the highest speed.
(D) All three water balloons hit the ground with the same speed.
(E) We cannot answer this question without knowing the masses of the water balloons.

**21.** An object with mass *m*, collides with a second object, also with mass *m*, which is initially stationary. The collision occurs at time *T*. The collision is inelastic, with 50% of the energy being dissipated as heat and sound. Which one of the following graphs best represents the total momentum of the two-object system immediately before and after time *T*?

**22.** A star of mass $M$ is attracted to another star of mass $2M$ with a force with magnitude $F$ when they are separated by a distance $d$. If the stars move closer together so that the distance between them is $d/3$, what is the magnitude of the force on the more massive star?

(A) $F$ (B) $3F$ (C) $9F$ (D) $6F$ (E) $18F$

**23.** A satellite is placed in a circular orbit around the Earth. The satellite has orbital speed $V$ and period $T$. In the following expressions; $G$ is the universal gravitational constant, $M$ is the mass of the Earth, and $m$ is the mass of the satellite. Which expression correctly represents the speed $V$ of the satellite.

(A) $V = \left( \frac{GM}{T} \right)^{\frac{1}{2}}$ (B) $V = \left( \frac{2\pi GM}{T} \right)^{\frac{1}{3}}$ (C) $V = \left( \frac{4\pi^2 GM}{T^2} \right)^{\frac{1}{2}}$

(D) $V = \left( \frac{2\pi GMm}{T} \right)^{\frac{1}{3}}$ (E) $V = \left( \frac{GMm}{T^2} \right)^{\frac{1}{2}}$

**24.** An Apollo space ship is travelling from the Earth to the Moon. At what point is the space ship beyond the pull of Earth's gravity?

(A) When it gets above the Earth's atmosphere.
(B) When it leaves Earth orbit and heads toward the Moon.
(C) When it is closer to the Moon than it is to the Earth.
(D) When the ratio of its distance to the Earth divided by its distance to the Moon is about 80, since that is approximately the ratio of the mass of the Earth to the mass of the Moon.
(E) It is never beyond the pull of Earths gravity.

**25.** Two spaceships are travelling through space, each at a speed of $0.6c$ relative to the Earth (where $c$ is the speed of light). If the space ships are headed directly toward each other, what is their approach speed as measured by an observer on one of the spaceships?

(A) $1.2c$
(B) $c$
(C) $0.6c$
(D) $0.3c$
(E) None of the above answers are correct.

**26.** The monochromatic light beam from a laser has a wavelength in a vacuum of $\lambda$. If $h$ is Planck's constant and $c$ is the speed of light in a vacuum, which of the following expressions is correct for the energy, $E$, contained in one photon of the laser light?

(A) $E = h\lambda$ (B) $E = \frac{hc}{\lambda}$ (C) $E = \frac{h}{\lambda}$ (D) $E = \frac{h\lambda}{c}$ (E) $E = \frac{h}{c\lambda}$

**27.** Ultra-violet light of a certain frequency contains photons, each of which has an energy of 6 eV (electron-volts). It is observed that, when this light falls on the surface of a metal, electrons are ejected from the metal's surface with kinetic energies that range between zero up to 4 eV. What is the minimum energy needed to separate an electron from an atom in the metal?

(A) 2 eV (B) 3 eV (C) 4 eV (D) 6 eV (E) 10 eV

**28.** The mass of a proton is $m_p$ and the mass of a neutron is $m_n$. It is possible for a neutron and proton to combine to from the stable nucleus of heavy hydrogen called a deuteron. Which statement is correct concerning the mass of a deuteron?

(A) It will be equal to $m_p + m_n$.
(B) It will be less than $m_p + m_n$.
(C) It will be more than $m_p + m_n$.
(D) It could be any of the above depending on the energy released when the neutron and proton combine.

**29.** A radioactive nucleus decays by alpha particle emission. How does the composition of the daughter nucleus compare to that of the parent nucleus following alpha decay?

(A) The atomic number has decreased by 2 and the mass number has decreased by 2.
(B) The atomic number has decreased by 4 and the mass number has decreased by 2.
(C) The atomic number has decreased by 2 and the neutron number has decreased by 4.
(D) The atomic number has decreased by 4 and the neutron number has decreased by 2.
(E) The atomic number has decreased by 2 and the neutron number has decreased by 2.

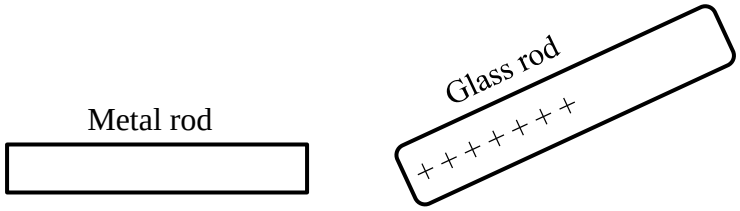
**30.** The activity of a radioactive sample (with a single radioactive nuclide) decreases to one eighth its initial value in a time interval of 96 days. What is the half-life of the radioactive nuclide?

(A) 32 days
(B) 24 days
(C) 16 days
(D) 12 days
(E) 8 days

**31.** The electric field at a distance $R$ from a charged particle has magnitude $E$. If the distance from the charged particle is increased to $3R/2$, what is the new magnitude of the electric field in terms of $E$?

(A) $\frac{9}{4}E$ (B) $\frac{4}{9}E$ (C) $\frac{9}{2}E$ (D) $\frac{3}{2}E$ (E) $\frac{2}{3}E$

**32.** A metal rod has no net charge on it. A positively charged glass rod is brought near to, but not touching, the metal rod as shown. The net electric force on the metal rod is now




(A) zero; the metal rod remains uncharged.
(B) zero; the induced charge on the metal rod is uniformly distributed.
(C) non-zero; the rod acquires a net positive charge.
(D) non-zero; the rod acquires a net negative charge.
(E) non-zero; the induced charge distribution on the rod has a non-uniform distribution.

***END OF EXAMINATION***