2020 Academic Challenge

PHYSICS TEST – REGIONAL

Physics Test Production Team

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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. One oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

Be sure ovals are marked as ●, not ⊙, ⦶, ◐, etc.

If you wish to change an answer, erase your first mark completely before marking your new choice.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

Time: 40 Minutes Number of Questions: 35

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Fundamental Constants

Quantity	Symbol	Value
Avogadro's number	N_A	6.022×10^{23}/mol
Boltzmann's constant	k	1.381×10^{-23} J/K
Electron charge magnitude	e	1.602×10^{-19} C
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ T·m/A
Permittivity of free space	ϵ_0	8.854×10^{-12} $C^2/(N \cdot m^2)$
Electrostatic Constant	$k = (4\pi\epsilon_0)^{-1}$	8.988×10^9 $N \cdot m^2/C^2$
Planck's constant	h	6.626×10^{-34} J·s
Electron mass	m_e	9.1094×10^{-31} kg
Neutron mass	m_n	1.6749×10^{-27} kg
Proton mass	m_p	1.6726×10^{-27} kg
Speed of light in vacuum	c	2.9979×10^8 m/s
Universal gravitational constant	G	6.673×10^{-11} $N \cdot m^2/kg^2$
Universal gas constant	R	8.3145 J/(mol·K)

Other information:

Acceleration due to gravity at Earth's surface: $g = 9.80$ m/s^2

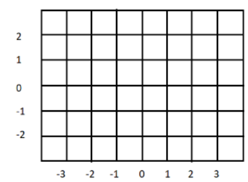
0.00 ^oC = 273.15 K

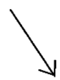
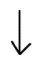
Academic Challenge
2020 Regional Physics Exam

1. A new unit called a Warg has been defined. It is given by $1.0\ \text{Warg} = 2.0\ \frac{\text{N}\cdot\text{s}}{\text{J}}$. What are the dimensions of the Warg?

a. $\frac{1}{[\text{T}]}$ b. $[\text{M}][\text{L}]$ c. $\frac{[\text{L}]}{[\text{T}]}$ d. $\frac{[\text{M}]}{[\text{T}]}$ e. $\frac{[\text{T}]}{[\text{L}]}$

2. Consider three vectors given by **A** = 1.50 at 15°, **B** = 2.50 at 110° and **C** = 1.35 at 310°. Given the figure to give you some sense of scale, which vector sketched below is most likely the vector **D** where **D** = **A** – **B** + **C**?



a.  b.  c.  d.  e. 

3. A very special steel, called valyrian steel, has a density of 4.30 g/cm^3. Swords made from this steel start from an ingot that is a cylinder 17.0 cm long with a radius of 2.90 cm. What is the mass of this ingot?

a. 104 g b. 212 g c. 615 g d. 1930 g e. 2630 g

4. A basketball is rolling across the floor with a constant speed of 1.18 m/s in the negative x direction. At time t = 0.00, it is located at x = +4.25 m. What is its position at time t = 2.25 s?

a. –17.9 m b. –2.66 m c. 1.60 m d. 2.66 m e. 6.91 m

5. The high-speed trains in China can travel at 350 km/h. At this speed, how long does it take to travel from Charleston to Chicago, given that the distance from Charleston to Chicago is 186 mi and 1 mi is equal to 1610 m?

a. 44.3 min b. 51.4 min c. 26.3 min d. 154 min e. 30.0 min

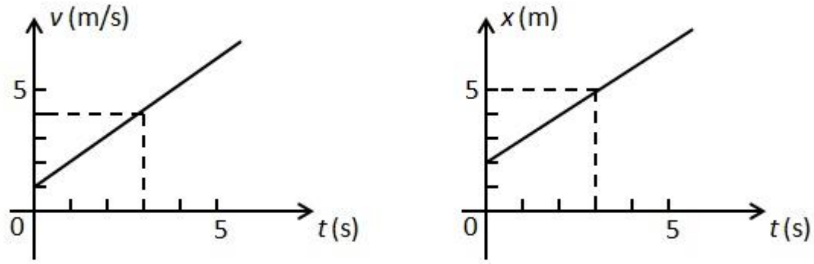
6. Sadie is a 2.35 kg cat. She is able to jump from the floor straight to the top of the fridge, 1.85 m above. What velocity must she have when she leaves the floor in order to make this jump?

a. 4.26 m/s b. 6.02 m/s c. 8.88 m/s d. 18.1 m/s e. 78.9 m/s

7. As a continuation of problem 6, what is Sadie's speed as she passes the handle of the fridge 1.20m above the floor?

a. 3.57 m/s b. 4.00 m/s c. 7.44 m/s d. 15.6 m/s e. 17.4 m/s

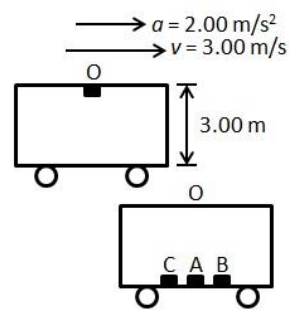
8. Two particles move along the *x* axis. The velocity-versus-time graph for particle 1 is shown on the left and the position-versus-time graph for particle 2 is shown on the right. Which statement is true about the motions of the two particles?



Particle 1 Particle 2

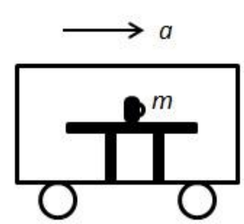
a. The motions of the two particles are identical.
b. The two particles have the same acceleration.
c. The two particles have the same initial velocity at $t = 0$.
d. The two particles have the same initial position at $t = 0$.
e. The two particles have the same initial velocity, but different initial positions at $t = 0$.

9. A small object falls from the midpoint O of the ceiling of a moving truck, as shown in the diagram (not drawn to scale). The vertical distance from the ceiling to the floor is 3.00 m. The truck is moving with a constant acceleration of 2.00 m/s^2 and has a velocity of 3.00 m/s at the instant when the object falls. Where does the object land on the floor? Ignore air resistance.



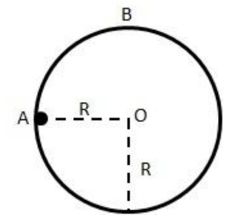
a. It lands at point A directly below point O.
b. It lands at point B, a horizontal distance of 0.612 m ahead of point O.
c. It lands at point C, a horizontal distance of 0.612 m behind point O.
d. It lands at point B, a horizontal distance of 0.306 m ahead of point O.
e. It lands at point C, a horizontal distance of 0.306 m behind point O.

10. A cup of mass *m* sits on a table in a moving train, as shown in the diagram. The train moves with constant acceleration *a*. If the cup remains at rest relative to the table (and the train), what is true about the friction between the cup and the table?



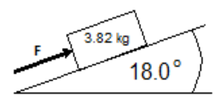
a. There is no friction between the cup and the table.
b. The force of static friction between the cup and the table must be greater than *ma*.
c. The force of static friction between the cup and the table must be less than *ma*.
d. The minimum coefficient of static friction between the cup and the table depends on *m*, *a*, and *g*.
e. The minimum coefficient of static friction between the cup and the table depends on *a* and *g* only and is independent of *m*.

11. A small puck slides without friction along the inner surface of a circular ring of radius *R*, as shown in the diagram. The puck is moving downwards with kinetic energy *K* at point A and then moves around the ring to the top at point B. If it just makes it to the top at point B, what is the value for *K*? Ignore rotation.



a. (3/2)*mgR*   b. 3*mgR*   c. 2*mgR*   d. (5/2)*mgR*   e. 4*mgR*

12. A box is placed on an inclined plane. A force **F** is applied parallel to the inclined plane, as shown in the diagram. The mass of the box is 3.82 kg, the angle between the inclined plane and the horizontal is 18.0°, and the coefficient of kinetic friction between the box and the inclined plane is 0.130. What is the magnitude of force **F** that will give the mass an acceleration of 1.47 m/s^2 up the incline?



a. 5.62 N   b. 10.5 N   c. 12.6 N   d. 17.2 N   e. 21.8 N

13. For the situation in problem 12, what will be the momentum of the mass 25.1 s after it starts from rest?

a. 141 kg m/s   b. 264 kg m/s   c. 316 kg m/s   d. 429 kg m/s   e. 547 kg m/s

14. A 15.0 kg mass makes a head-on collision with a 25.0 kg mass that is initially at rest. As a result of the collision, the 25.0 kg mass acquires a speed of 16.0 m/s, and the 15.0 kg mass rebounds in the direction opposite to its initial velocity, with a speed of 5.00 m/s. The initial speed of the 15.0 kg mass, prior to the collision was:

a. 29.5 m/s   b. 36.8 m/s   c. 18.6 m/s   d. 21.7 m/s   e. 12.0 m/s

15. For the situation in problem 14, if the contact time between the 15.0 kg mass and the 25.0 kg mass is 0.300 s, what is the magnitude of the average force acting on the 25.0 kg mass due to contact with the 15.0 kg mass?

a. 125 N   b. 186 N   c. 1168 N   d. 1330 N   e. 1500 N

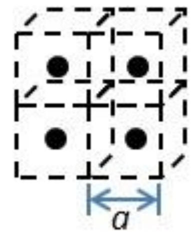
16. A rocket is launched from the surface of Planet X. Given that the mass of Planet X is 5.00×10^{24} kg and its radius is 6.00×10^{6} m, what is the escape speed of Planet X?

a. 1.05×10^{4} m/s
b. 7.46×10^{3} m/s
c. 2.62×10^{4} m/s
d. 8.65×10^{3} m/s
e. 1.05×10^{3} m/s

17. A satellite orbits about the Earth in uniform circular motion with orbital radius *r*. If *r* increases, which quantity of the satellite also increases?

a. Kinetic energy b. Speed c. Weight d. Period e. Acceleration

18. Solid X is made up atoms of the same element. The atoms in solid X are arranged in a periodic manner. Each atom occupies a cubic cell of length *a*, as shown in the diagram (four cells are shown). If $a = 2.00 \times 10^{-10}$ m and the atomic mass of each atom is 25 *u*, where *u* is the atomic mass unit and 1 $u = 1.66 \times 10^{-27}$ kg, what is the density of solid X?



a. 5.19×10^3 kg/m^3
b. 4.26×10^3 kg/m^3
c. 7.13×10^3 kg/m^3
d. 1.93×10^4 kg/m^3
e. 1.00×10^3 kg/m^3

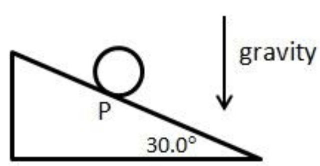
19. A centrifuge has a rotation rate of 15000 rotations per minute. The holder for the material is 6.00 cm long and rotates at a radius, *r*, from the center of rotation of the centrifuge. What is the magnitude of the difference in centripetal acceleration between the top of the holder (rotating at a radius of 11.5 cm) and the bottom of the holder (rotating at a radius of 17.5 cm)?

a. 9.43×10^1 m/s^2
b. 1.48×10^5 m/s^2
c. 2.84×10^5 m/s^2
d. 4.32×10^5 m/s^2
e. 1.35×10^7 m/s^2

20. A slingshot uses an elastic band to accelerate a 55.0 g stone over a length of 34.5 cm. The stone leaves the slingshot with a speed of 44.0 m/s. What is the magnitude of the average reaction force on the slingshot?

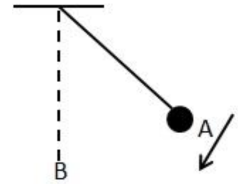
a. 0.00 N b. 1.54 N c. 1.54×10^2 N d. 1.54×10^3 N e. 1.54×10^5 N

21. A uniform disk of diameter 32.0 cm and mass 2.50 kg rolls without slipping down a plane inclined at an angle of 30.0° with respect to a horizontal table surface on the Earth. How much torque does Earth's gravity produce with respect to point P, the contact point between the disk and plane?



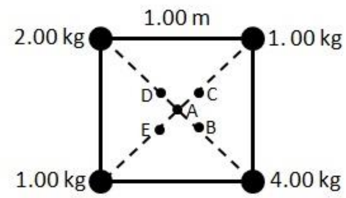
a. 1.96 Nm b. 2.45 Nm c. 3.39 Nm d. 4.92 Nm e. 7.84 Nm

22. A simple pendulum swings downward from point A to point B, as shown in the diagram. Which quantity decreases during the motion of the pendulum from A to B? Ignore air resistance.



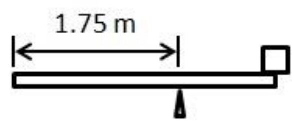
a. Linear speed of the pendulum.
b. Centripetal acceleration of the pendulum.
c. Angular speed of the pendulum.
d. Tension in the string.
e. Time rate of change of the linear speed of the pendulum.

23. A machine part consists of light connecting rods and four point masses, located at the four corners of a square, as shown in the diagram. Which point in the diagram represents the position of the center-of-mass?



a. Point A b. Point B c. Point C d. Point D e. Point E

24. A uniform density board has a mass of 25.0 kg and rests on a fulcrum that is 1.75 m from the left end of the board. A 6.00 kg mass rests with center of gravity at the right end of the board. If the board and mass are balanced on the fulcrum, what is the length of the board?

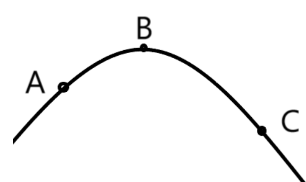


a. 3.65 m b. 2.25 m c. 2.93 m d. 4.86 m e. 3.25 m

25. A motorboat is traveling at a speed of 25.0 km/h. The mass of the motorboat is 378 kg. When the engine is cut off it takes the boat 7.35 m to come to a stop. What is the magnitude of the net force acting to stop the motorboat?

a. 3.28 N b. 1240 N c. 2480 N d. 3700 N e. 1.61×10^4 N

26. A ball is thrown so that it follows the trajectory shown in the figure. At the highest point, B,



a. the velocity is zero and the acceleration is zero.
b. the velocity is not zero and the acceleration is zero.
c. the velocity is not zero and the acceleration is not zero.
d. the speed is more than at A and less than at C.
e. the speed is the same as at A and at C.

27. In thermodynamics, the calorie is a unit of

a. Heat of combustion.
b. Thermal Conductivity.
c. Specific heat.
d. Energy.
e. Food measure.

28. In optics, in two dimensions retroreflection refers to a phenomenon where

a. light returns along its original path after being reflected from a plane mirror.
b. light returns along its original path after being reflected from a concave mirror.
c. light returns along its original path after being reflected from a convex mirror.
d. light returns to the source parallel to its original path after being reflected by two mirrors that are perpendicular to each other.
e. light returns to the source parallel to its original path after being reflected from two mirrors that make 120° with each other.

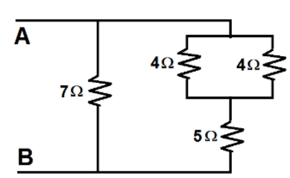
29. In the special theory of relativity, length contraction refers to a phenomenon where

a. all dimensions of an object become shorter when measured by an observer who is moving relative to the object.
b. the dimension of the object that is parallel to the direction of the relative motion between the object and the observer is shortened.
c. the dimension of the object that is perpendicular to the direction of the relative motion between the object and the observer is shortened.
d. the length of the object is shortened when measured by an observer who is at rest relative to the object.
e. it occurs only when the speed of the observer has reached 99.9% of the speed of light.

30. Consider two charges on the *x* axis. One, with charge –2.30 μC, is placed at 10.0 cm on the axis. The other, with a charge –5.70 μC, is placed at 70.0 cm on the axis. At what position would you place a +1.15 μC charge so that the net force from these charges is zero?

a. 13.3 cm b. 33.3 cm c. 40.0 cm d. 46.7 cm e. there is no such location.

31. Consider the circuit shown, containing resistances of 7.00 Ω, 4.00 Ω, 4.00 Ω, and 5.00 Ω. What is the equivalent resistance between points A and B?



a. 1.19 Ω b. 3.50 Ω c. 4.92 Ω d. 10.1 Ω e. 20.0 Ω

32. Blue light of wavelength 465 nm propagates in a piece of diamond. The angle for total internal reflection at a diamond/water interface is 33.0˚. The index of refraction of air is 1.00 and the index of refraction of water is 1.34 at that wavelength. Based on this data, what is the index of refraction of diamond at 465 nm?

a. 1.34 b. 1.60 c. 1.84 d. 2.34 e. 2.46

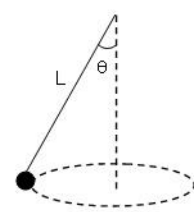
33. An electron of mass 9.11×10^{-31} kg is moving with a speed of 2.75×10^{8} m/s. What is its total energy in MeV (note that 1MeV = 1.602×10^{-13} J)?

a. 0.215 MeV b. 2.50 MeV c. 1.28 MeV d. 1.77 MeV e. 215000 MeV

34. An atom has the quantum numbers (n, ℓ, m_ℓ, m_s). How many possible sets of quantum numbers are there for this atom if $n = 3$?

a. 3 b. 18 c. 28 d. 32 e. 34

35. A small object is tied to a string and moves along a circle in a horizontal plane at a constant speed, as shown in the diagram. The string has length L and makes an angle θ with respect to the vertical. The magnitude of the acceleration due to gravity is g. What is the linear speed of the object?



a. $(Lg \sin\theta \tan\theta)^{1/2}$ b. $(Lg \tan\theta)^{1/2}$ c. $(L \tan\theta)^{1/2}$ d. $(Lg)^{1/2}$ e. $(gL\cos \theta)^{1/2}$