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## **”I am the Champion” Physics Competition**

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## Rules

- There are 6 sections; each section has 10 questions and 20 minutes time limit, with a 10 minute break in between.
- This test is in English. We cannot help you translate or clarify.
- Each competitor gets one Competition Number and two answer strips; carefully divide them into six equal pieces. For each section write your answers only, nothing else, *neatly* in any group of ten boxes from top to bottom. Write your Competition Number on the back side.
- Each question is to be answered *numerically* (e.g. 1.7, not  $\sqrt{3}$ ) on your answer sheet *in terms of the units given*. For example, if your answer is 12 ms and the units are [s], write "0.012". [] means no units
- You must be correct to  $\pm 10\%$  for credit (1 point). *Hint: some problems are quite difficult and you may have to just guess an answer based on physical intuition.*
- Please work quietly and individually. When section time is called answer sheets will be collected.
- If you are caught cheating you forfeit your right to compete.

## Prizes

- FIRST PRIZE(1) Electronic Dictionary (900 RMB Value!)
- SECOND PRIZES(5): Cool T-Shirts
- THIRD PRIZES(8): Mystery Grab-Bags

**GOOD LUCK !**

## Section I

1. Determine the length of a simple pendulum whose period is 1 second at sea level. [cm]
2. A 66 *kg* crate, starting from rest, is pulled across a floor with a constant horizontal force of 225 *N*. For the first 11 *m* the floor is frictionless, and for the next 10 *m* the coefficient of friction is 0.2. What is the final speed of the crate? [m/s]
3. What is the minimum velocity need by an object to escape the Earth? [km/s]
4. You stand at the top of Emei Mountain. At what angle to the horizontal would you throw a stone so it goes the farthest? [degrees]
5. Calculate the velocity of a satellite moving in a stable circular orbit about the Earth at a height of 5200 *km*. [km/s]
6. Suppose we fill a cylindrical tank (radius 1 meter) with 1000 liters of water. We then drill a small hole in the bottom of the tank; what is the speed of the water that shoots out? [m/s]
7. A mass connected to 10 cm of a certain spring oscillates with a period of 2 s. What would this period be for a 30 cm spring? [s]
8. A cube of side 1 *m* rests on a rough floor. It is subjected to a steady horizontal pull, *F*, exerted a distance 60 *cm* above the floor. As *F* is increased, the cube will either begin to slide or begin to tip over. What is the maximum coefficient of static friction such that the cube will slide rather than tip? []
9. An iceberg ( $\rho_{ice} = 900 \text{ kg/m}^3$ ) in the form of a regular pyramid floats in still water such that 10m is above water. If it is pushed down slightly, with what period will it oscillate? [s]
10. There are 5 bricks (length 20cm each) on a table. If you stack them on top of each other, how far can the last brick extend beyond the edge of the table? [cm]

## Section II

1. A diver shines a flashlight upward from beneath the water at a  $32.5$  degree angle to the vertical. At what angle does the light leave the water? [deg]
2. An electric field of  $640$  V/m is desired between two parallel plates  $11$  mm apart. How large a voltage is required? [V]
3. A  $7.2$  cm diameter loop of wire is initially oriented perpendicular to a  $1.3$  T magnetic field. It is rotated so that its plane is parallel to the field direction in  $0.2$  s. What is the average induced emf? [mV]
4. The Earth's magnetic field is essentially that of a magnetic dipole. If the field near the North Pole is about  $100 \mu T$ , what will it be  $13000$  km above the North Pole? [ $\mu T$ ]
5. A proton (mass  $1$  GeV) with  $5$  MeV kinetic energy enters a  $0.2$  T magnetic field, in a plane perpendicular to the field. What is radius of its path? [m]
6. How many times brighter is the Sun compared to the Moon, as seen on Earth? Assume the coefficient of reflection for the moon's surface is  $0.07$  []
7. A positive ion travels at  $2 \cdot 10^8$  m/s inside a tank of water. At what angle to its momentum does it emit light? [deg]
8. White light at normal incidence to a diffraction grating (300 lines per mm) results in both red (640-750nm) and violet (360-490nm) maxima at  $24.46$  degrees. At what other angle do only these maxima appear together? [deg]
9. Consider an inductor ( $L = 1$  H) and resistor ( $R = 10 \Omega$ ) connected in series to a  $5$ V battery, switch open. When the switch is closed, current begins to flow: when does the power dissipated in the resistor maximize? [ms]
10. A  $10^{-3}C$  point charge is placed inside a thin metal shell (radius  $10$  cm) at a position  $1$  cm from the center. With what force will the charge be attracted to the shell? [N]

## Section III

1. How many people are taking this exam? []
2. If you flip a coin 10 times what is the probability of getting exactly 8 heads? []
3. The half-life of Uranium-238 is about 4.5 billion years. After 10 billion years what percent of a sample of U-238 remains? [%]
4. Approximately what length on the surface of a typical 650MB CD holds 1 bit of information? [ $\mu m$ ]
5. Photons in the Sun have a mean free path of about 1 mm. Taking the solar radius to be  $6.96 \cdot 10^8 m$ , how long does it take a photon to escape from the center of the Sun to its surface? [y]
6. An experiment reports  $x = 10.0 \pm 1.0 \text{ cm}$  and  $y = 5.0 \pm 2.0 \text{ cm}$  How should we report the error  $\sigma$  on  $z = x + y$ :  $z = 15.0 \pm \sigma \text{ cm}$  [cm]?
7. The average score on a physics exam was 75 out of 100 with a standard deviation of 16. Approximately what percent of the class passed (passing = 60)? [%]
8. When a detector is placed 4 cm from a radioactive source, it reads 100 counts/sec. What will it read 20 cm from the source? [count/sec]
9. The number of distinct games of Wei-Qi on a 19x19 board is approximately  $10^N$ . N=? []
10. The minute hand of a certain clock is twice as long as the hour hand. How many minutes after 12:00 will the distance between the tips of the hands be increasing the fastest? [min]

## Section IV

1. A stone is dropped from the top of a cliff. The splash it makes when it hits the water below is heard 3.5 seconds later. How high is the cliff? [m]
2. A deep ocean wave has a wavelength of 60 m. If a boat is located 100 m away, how long does it take for the wave to rock the boat? [s]
3. A particular violin string plays at a frequency of 294 Hz. If the tension in the string is increased by 10 percent, what will the new frequency be? [Hz]
4. If a balloon is filled with 1 mol of He in standard conditions its radius is only 5 cm. What pressure difference does the surface of the balloon withstand? [atm]
5. A volume of He is slowly adiabatically expanded until its pressure is reduced by half. By what factor does its volume change? []
6. A red-hot iron ball cools to room temperature through radiation in 10 minutes. If it were cut into two equal halves, how fast would they cool? [min]
7. The pendulum in a grandfather clock is made of brass and keeps perfect time at 17 C. How much time is lost in a year if the clock is kept at 25 C? [min]
8. Oxygen molecules move about 480 m/s at room temperature. How fast do they go at -100 C? [m/s]
9. One mol of an ideal monatomic gas at 300 K and 3 atm expands adiabatically to a final pressure of 1 atm. How much work does the gas do in the expansion? [J]
10. Air at 271K is above the water of a lake at 273K. If we take the thermal conductivities of air and water to be 0.56 and 2.3 [W/(mK)] ,respectively , how many hours does it take for 10 cm of ice to form on the surface of the lake? [h]

## Section V

1. The Sun-Earth distance is about  $1.5 \cdot 10^{11}m$ . How long does it take light from the Sun's surface to reach us? [min]
2. How long does it take visible light to travel through 1 foot of water? [ns]
3. A proton of energy  $E$  collides with a stationary proton, producing an antiproton as follows:  $p + p \rightarrow p + p + p + \bar{p}$ . What is the minimum value of  $E$  ? [GeV]
4. Muons are produced in the atmosphere over 10 km above us. At least what fraction of the speed of light must they be going? The muon lifetime is about  $2\mu s$ . []
5. A certain exotic particle (mass  $200 GeV/c^2$ ) decays at rest into an electron and another particle (mass  $100 GeV/c^2$ ). How much kinetic energy does the electron have? [GeV]
6. At what fraction of the speed of light  $c$  will an object's relativistic mass be twice its rest mass? []
7. A gold nucleus (mass 197 a.m.u.) is roughly spherical at rest, but when moving at  $9/10$  the speed of light it is squashed to what thickness? [fm]
8. A spaceship traveling directly away from you at  $0.5c$  fires a module at right angles to its trajectory at  $0.5c$  (in its frame). With what speed do you see the module moving? [c]
9. An atomic clock is taken to the North Pole, while another stays at the Equator. How far will they be out of synchronization after a year has elapsed? [ $\mu s$ ]
10. A star is seen to emit red light of wavelength 650 nm. If we know this light comes from a certain atomic transition with wavelength 600 nm, what % of the speed of light is the star moving away from us? [%]

## Section VI

1. The human eye can respond to as little as  $10^{-18}$  J of light energy. If the wavelength of such light is 550nm, what is the minimum number of photons you can see? []
2. A proton is travelling at  $(4.825 \pm 0.012) \cdot 10^5$  m/s. How precisely can its position be measured? [nm]
3. A neutron usually decays into how many particles? []
4. How hot is a metal being welded if it radiates most strongly at 440 nm? [K]
5. An electron approaches a potential barrier 10 eV high and 0.5nm wide. If the electron has a 1 percent probability of tunneling through, what must its energy be? [eV]
6. The "Planck Mass" can be constructed from the simplest combination of the constants  $h, c,$  and  $G_N$ . It is approximately  $m_P = 10^N$  GeV/c<sup>2</sup>. Find N.[]
7. Estimate the wavelength for an n=2 to n=1 transition in iron (Fe) [nm]
8. Assume the radial wavefunction for an electron in Hydrogen is  $\psi(r) = \frac{1}{\sqrt{\pi a^3/2}} e^{-r/a}$ , with  $a = 1\text{\AA}$ . What is the probability the electron is a distance  $2\text{\AA}$  from the proton? []
9. If the spin of an electron is known to be along the z-axis, what is the probability of finding it along an axis 60 degrees to the z-axis?[]
10. A certain black hole has ten times more mass than the Sun. How close can you approach it without falling in forever? [km]