

HOUR TEST #1

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HONOR PLEDGE:

In completing this test, I have neither given nor received unauthorized assistance.

(signature)
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- This is a closed-book, closed-notes test. No written material is allowed.
- You are permitted to use an electronic calculator only to assist with numerical work.
- Assume that the given quantities are accurate enough to justify three (and only three) figures in your final answers.
- **Show your work, especially on the problems!** Credit, especially partial credit on problems where your final answer is incorrect, will depend on the work shown.

The test consists of 15 questions and 2 problems. Perfect score is 100.

Questions 1-15 count 4 points each. (60%)

Problems 1-2 count 20 points each. (40%)

Possibly useful information.

terrestrial acceleration due to gravity: $g = 9.80 \text{ m/s}^2$
 $\pi = 3.14159265$ $e = 2.71828183$ $\log_{10}e = 0.43429448$
 $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ $1 \text{ year} = 3.156 \times 10^7 \text{ sec}$
astronomical unit (AU) = $1.496 \times 10^{11} \text{ m}$
speed of light in vacuum: $c = 2.998 \times 10^8 \text{ m/s}$
constant of gravitation: $G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
Planck's constant: $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$
"h-bar" $\hbar \equiv h/2\pi = 1.055 \times 10^{-34} \text{ J}\cdot\text{s} = 6.583 \times 10^{-16} \text{ eV}\cdot\text{s}$
Boltzmann constant: $k = 1.381 \times 10^{-23} \text{ J/K} = 8.617 \times 10^{-5} \text{ eV/K}$
Avogadro's number $N_A = 6.022 \times 10^{23} \text{ particles/mole}$
Universal gas constant: $R = N_A k = 8.315 \text{ J/(mol}\cdot\text{K)}$
Stefan-Boltzmann constant: $\sigma = 5.671 \times 10^{-8} \text{ W/(m}^2\text{K}^4)$
unified mass unit (dalton): $(1 \text{ u}) = 1.661 \times 10^{-27} \text{ kg}$
energy equivalent of 1 dalton: $(1 \text{ u})c^2 = 1.493 \times 10^{-10} \text{ J} = 931.9 \text{ MeV}$
proton (rest) mass: $m_p = 1.673 \times 10^{-27} \text{ kg}$
rest energy of proton: $m_p c^2 = 1.504 \times 10^{-10} \text{ J} = 938.6 \text{ MeV}$
electron (rest) mass: $m_e = 9.109 \times 10^{-31} \text{ kg}$
rest energy of electron: $m_e c^2 = 9.187 \times 10^{-14} \text{ J} = 0.5111 \text{ MeV}$
elementary unit of charge: $e = 1.602 \times 10^{-19} \text{ C}$
product of h and c: $hc = 1.987 \times 10^{-25} \text{ J}\cdot\text{m} = 1.240 \times 10^{-6} \text{ eV}\cdot\text{m} = 1240 \text{ eV}\cdot\text{nm}$
standard temperature: $T = 0^\circ\text{C} = 273.15 \text{ K}$
standard pressure: $P = 1.000 \text{ atmosphere} = 1.013 \times 10^5 \text{ N/m}^2$

Questions 1-15. (4 points each) On many of these questions, partial credit is not available. You do not need to show your work.

Q1. What is the value of the terrestrial acceleration due to gravity at a distance of 5.00 Earth radii from the center of the Earth? (Ignore all gravitating bodies other than the Earth.) Give your answer in SI units.

Q1. _____

Q2. The semi-major axis of Earth's orbit is 1.00 AU. The semi-major axis of Neptune's orbit is 30.1 AU. How many Earth-years does it take for Neptune to complete one orbit of the Sun?

Q2. _____

Q3. At what point in its orbit is the Earth's orbital speed the greatest?

- (A) aphelion
- (B) autumnal equinox
- (C) perihelion
- (D) summer solstice
- (E) vernal (spring) equinox
- (F) winter solstice
- (G) All of the above: the Earth's orbital speed is a constant.

Q3. _____

Q4. What is the defining characteristic of a conservative force?

Q5. What is the defining characteristic of a rigid body?

Q6. The _____ at any point P is defined as the ratio of the net gravitational force to the mass of a test particle placed at P.

- (A) gravitational field
- (B) gravitational flux
- (C) gravitational potential
- (D) gravitational potential energy
- (E) None of the above answers is correct.

Q6. _____

Q7. In fluid mechanics, the equation that directly expresses the conservation of matter is _____.

- (A) Bernoulli's equation
- (B) the equation of continuity
- (C) Pascal's law
- (D) the barometric equation
- (E) None of the above answers is correct.

Q7. _____

Q8. What is the defining characteristic of a stable equilibrium?

Q9. Kepler's 2nd Law (law of equal areas) is equivalent to the statement that a planet's _____ per unit mass remains constant as the planet orbits.

- (A) orbital kinetic energy
- (B) orbital potential energy
- (C) total energy
- (D) orbital angular momentum
- (E) total linear momentum

Q9. _____

Q10. The SI unit of stress is _____.

Q10. _____

Q11. Describe a situation in which the classical work-energy (CWE) "theorem" fails. You needn't explain the failure in detail – just give one specific example.

Q12. If a force has an associated potential energy, the force at any location always points

- _____.
- (A) in the direction in which the potential energy increases most rapidly with distance
 - (B) in a direction in which the potential does not vary with distance
 - (C) in the direction in which the potential energy decreases most rapidly with distance
 - (D) None of the above answers is correct: There's no general relationship between the direction of the force and the spatial variation of the associated potential energy.

Q12. _____

Q13. A particle of mass 3.00 kg has instantaneous position $\vec{r} = (4.00m)\hat{i}$ and instantaneous velocity $\vec{v} = (2.00m/s)\hat{i} + (5.00m/s)\hat{j}$. What is the magnitude of its instantaneous orbital angular momentum about the origin?

- (A) 24.0 kg-m/s
- (B) 60.0 kg-m/s
- (C) 64.6 kg-m/s
- (D) 84.0 kg-m/s
- (E) This can't be determined without more information.

Q13. _____

Q14. A wheel of radius 0.200 m is rolling without slipping along the floor. It is observed to complete 3.00 rotations each second. What is the translational speed of the center of the wheel?

- (A) 6.67×10^{-2} m/s
- (B) 0.600 m/s
- (C) 3.77 m/s
- (D) This can't be determined without more information.

Q14. _____

Q15. When a 100 kg object is hung from an elastic cable, the cable is observed to stretch by 6.00 millimeters. If the same object were suspended from 4 such cables arranged side by side (to share the load equally), how much would each one of the cables stretch?

Q15. _____ millimeters

Problem 1. (20 points) Show your work. Partial credit will depend on that.

The planet Gorgon has mass M and radius R . (Assume that it is not rotating, that it has a spherically symmetric mass distribution, and that its atmosphere is so thin that it can be neglected.) Express all your answers in terms of G , M , R , and other given quantities.

(A)-(B) A visiting spaceship (commanded by Captain Goofball) is hovering at a distance $3R$ from the center of the planet, and it releases a probe (actually a waste canister!) of mass m_w which free-falls toward the planet's surface. (Neglect the gravitational attraction between the spaceship and the canister.)

(A) Find the kinetic energy of the canister just before it hits the surface.

(B) Find the speed of the canister just before it hits the surface.

(Problem 1 continues on the next page.)

Problem 1. (continued)

(C)-(D) The hovering spaceship fires another canister of the same mass m_w forward into a circular orbit of radius $3R$ around the planet.

(C) What is that canister's kinetic energy?

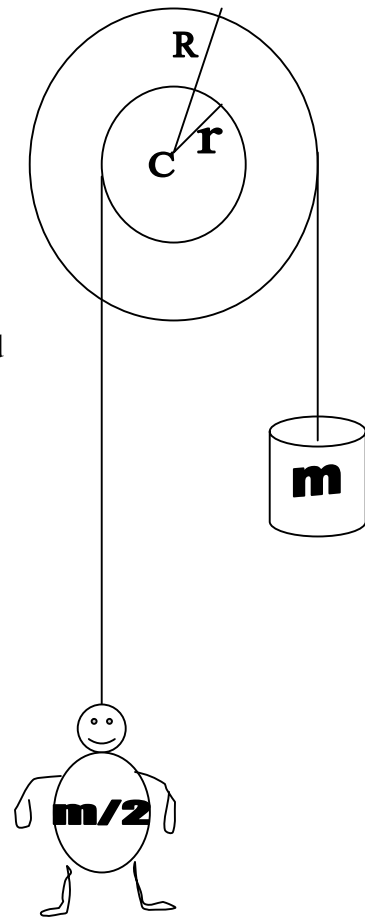
(D) Assuming that the spaceship has fired rockets to prevent recoil from the launch of the second canister and is still hovering over Gorgon, find out how much time Captain Goofball has available to get out of the way before the orbiting canister crashes into the spaceship.

Problem 2. (20 points) Show your work. Partial credit will depend on that.

In the figure at the right, the two disks (of one radius r , the other of radius R) are joined together and they freely rotate as a unit about the fixed horizontal axis C . The disk assembly by itself has rotational inertia I_D about the symmetry axis C . There are two cords. The cord holding the canister of mass m is wrapped around the outside rim and unwinds if the system moves clockwise. The cord holding the gumby (which has mass $m/2$) is wrapped around the inner rim (radius r) and winds up if the system turns clockwise. The system is released from rest, and the canister descends with constant acceleration.

The radius of the inner rim $r = R/2$.

(A) What is the rotational inertia of the whole system with respect to the fixed axis C ?



(B) Find the net external torque about the axis C exerted on the system by Earth's gravity?

Problem 2 continues on the next page.

Problem 2. (*continued*)

(C) Find the angular acceleration of the disk assembly

At the instant when the canister has descended a distance h , . .

(D) . . . how far has the gumby ascended?

(E) . . . what is the total kinetic energy of the system? (HINT: The CWE theorem can be used here.)