

Constants and Formulae for the Physics 2010 Final Exam

Useful Constants

k_B	$= R/N_A = 1.381 \times 10^{-23} \text{ J/K}$	R	$= 8.314 \text{ J/(K}\cdot\text{mol)}$
G	$= 6.673 \times 10^{-11} \text{ N m}^2 / \text{kg}^2$	$m_H = m_p$	$= 1.673 \times 10^{-27} \text{ kg}$
c	$= 3.00 \times 10^8 \text{ m/s}$	g	$= 9.80 \text{ m/s}^2$
N_A	$= 6.023 \times 10^{23} \text{ molecules/mole}$	1 cal	$= 4.187 \text{ J}$
1 mm	$= 10^{-3} \text{ m}$	1 cm	$= 10^{-2} \text{ m}$
1 km	$= 10^3 \text{ m}$	1 hr	$= 3600 \text{ s}$
1 foot (ft)	$= 0.3048 \text{ m}$	1 mile	$= 5280 \text{ ft}$
1 kg	$= 10^3 \text{ gm}$	1 liter	$= 10^{-3} \text{ m}^3$
1 day	$= 8.64 \times 10^4 \text{ s}$	1 yr	$= 365.242 \text{ days}$
P_o	$= 1.00 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$	1 Pa	$= 1 \text{ N} / \text{m}^2$

Useful Formulae

$A \text{ (circle)} = \pi R^2 = \pi D^2/4, \quad 2R = D$	$V \text{ (sphere)} = 4\pi R^3/3$
$A \text{ (rectangle)} = L H$	$V \text{ (cylinder)} = h A = \pi h D^2/4$
$\sin \theta = \text{opposite/hypotenuse}$	$\cos \theta = \text{adjacent/hypotenuse}$
$\tan \theta = \text{opposite/adjacent}$	$r^2 = x^2 + y^2$

Useful Formulae (continued)

$$\Sigma \vec{F} = m\vec{a}$$

$$E = \text{KE} + \text{PE}$$

$$\text{KE} = \frac{1}{2}mv^2$$

$$\text{PE}_g = mgy$$

$$\omega = \omega_o + \alpha(t - t_o) = \Delta\theta/\Delta t$$

$$g = G M/r^2$$

$$v_{\text{orb}} = \sqrt{GM/r}$$

$$\tau = F d = I \alpha$$

$$\text{KE}_r = \frac{1}{2}I\omega^2$$

$$P = \rho k_B T / (\mu m_H) = N k_B T$$

$$\rho = m/V = \mu m_H N = \overline{m} N = \mu m_H n N_A / V$$

$$T_F = \frac{9}{5}T_C + 32$$

$$W = -P \Delta V$$

$$U = \frac{3}{2}nRT$$

$$v_{\text{rms}} = \sqrt{3k_B T/m}$$

$$e = 1 - |Q_C|/|Q_H| = 1 - T_C/T_H$$

$$\Delta S = Q/T$$

$$\vec{F}_g = \vec{w} = m\vec{g}$$

$$E = m c^2$$

$$p = m v$$

$$\text{PE}_s = \frac{1}{2}kx^2$$

$$1 \text{ rev} = 2\pi \text{ radians} = 360^\circ$$

$$r = R + h$$

$$T = 2\pi r/v_{\text{orb}}$$

$$L = I\omega$$

$$P = F/A$$

$$PV = nRT$$

$$P = P_o + \rho gh$$

$$T_C = T - 273.15$$

$$\Delta U = Q + W$$

$$n = (\# \text{ molecules}) / N_A$$

$$E = F + TS$$

$$Q = m c \Delta T$$

$$Q = mL$$

Final (A) – 9 December 2024

Part A: Hard Multiple Choice (20 points total, 2 points each). Circle the best answer.

1. Convert 12,800 ft/hour to SI units.

- a) 0.447 m/s b) 1.08 m/s c) 90.0 m/s d) 214 cm/s e) 980 cm/s

2. A 27.2 kg ball is hit from rest with a force of 664 N and travels in a straight line path at constant acceleration for 22.6 s. What is the acceleration of this ball?

- a) 6.64 m/s² b) 24.4 m/s² c) 276 m/s² d) 6.23 km/s² e) 170 km/s²

3. A wheel rotates at a constant angular speed. It makes four complete revolutions in 4.48 seconds, what is its angular speed?

- a) 9.46×10^4 rad/s b) 5.61 rad/s c) 3.93 rad/s
d) 1.57 rad/s e) 360°/min

4. A 24.6 grams of liquid releases 2440 J of heat when it completely freezes. What is the latent heat of fusion for this unknown substance?

- a) 4.19×10^3 J/kg b) 8.88×10^3 J/kg c) 9.92×10^4 J/kg
d) 2.12×10^5 J/kg e) 6.52×10^5 J/kg

5. At what temperature (in °C) is absolute zero (*i.e.*, 0 K)?

- a) zero b) -459.67 c) -273.15 d) 303.45 e) 233.15

6. Helium gas ($m = 4m_p$) is in a 3.70 liter container. If the root-mean-square of the helium atoms is 1.60 km/s, what is the temperature of this helium?

- a) 414 K b) 370 K c) 224 K d) 32.6°C e) -122°C

7. Sea water has a density of 1025 kg/m^3 . What is the pressure at a depth of 1.68 km below the surface of the ocean?

- a) 4.67×10^4 Pa b) 1.33×10^5 Pa c) 8.55×10^5 Pa
d) 24.2 atm e) 168 atm

8. A total of 2.34 moles of helium gas in a 3.70 liter container has an internal energy of 1.08×10^4 J. What is the temperature of the helium gas?

- a) 414K b) 370 K c) 224 K d) 32.6°C e) -122°C

9. An ideal gas resides in a volume of 3.70 liters at a pressure of 5.66 atm and temperature of 330 K. How many moles of gas are in this container?

- a) 4.39×10^{-2} mol b) 0.774 mol c) 12.3 mol
d) 141 mol e) 1180 mol

10. The total energy of a gas in an isolated system is 7890 J and the Helmholtz free energy is 5240 J. What is the temperature of this gas if it has an entropy of 2.66 J/K?

- a) 52.6 K b) 265 K c) 402 K d) 698 K e) 996 K

Part B: Easy Multiple Choice (20 points total, 1 point each). Circle the best answer.

11. Which of the following is a basic unit of mass?

- a) mm b) kg c) lb d) s e) N

12. Which of the following parameters is a vector?

- a) mass b) displacement c) speed d) time e) volume

13. The theory of general relativity is a theory because:

- a) Einstein said so
- b) its model was the simplest
- c) its equations are known by all scientists
- d) it has been validated through repeated experiments
- e) none of the above

14. Whose principle deals with buoyancy?

- a) Pascal
- b) Einstein
- c) Newton
- d) Poiseuille
- e) Archimedes

15. What would happen to a rocket whose total energy is exactly zero?

- a) It would sit on the launch pad forever.
- b) The rocket would be traveling at the speed of light by the time it reached orbit.
- c) The rocket's initial velocity is the escape velocity.
- d) The rocket would break apart.
- e) None of these are true.

16. The energy associated with the microscopic components of a system (*i.e.*, atoms and molecules) is called

- a) moment of inertia
- b) heat
- c) internal energy
- d) entropy
- e) inertia

17. Linear acceleration is to angular acceleration as mass is to

- a) weight
- b) moment of inertia
- c) angular speed
- d) force
- e) torque

18. Which of the following results from Kepler's 2nd law of planetary motion?

- a) Planets move faster when they are closer to the Sun.
- b) Mass bends space-time.
- c) Inertia is a measure of the resistance that matter has to changes in motion.
- d) A Carnot engine cannot exist in nature since friction is always present.
- e) $T^2 = a^3$.

19. Which of the following must be true for a mass to have steady state motion?

- a) Turbulence must be present.
- b) The moment of inertia must be smoothly changing during the motion.
- c) All forces acting on the object sum to zero.
- d) Acceleration must be constant and non-zero.
- e) Linear momentum is not conserved.

20. Which of the following properties do **not** describe an ideal fluid?

- a) The fluid is laminar.
- b) The fluid is steady.
- c) The fluid is isothermal.
- d) The fluid is incompressible.
- e) The fluid is non-viscous.

21. Entropy is sometimes defined as the measure of a system's

- a) heat
- b) potential energy
- c) disorder
- d) temperature
- e) angular momentum

22. Who developed the probabilistic description of the Second Law of Thermodynamics?

- a) Carnot b) Kepler c) Newton d) Boltzmann e) Boyle

23. Which parameter tells you the number of molecules per mole?

- a) Universal Gas Constant b) Boltzmann's constant c) Planck's constant
d) Avogadro's Number e) Specific Gravity

24. The area of physics that describes the motion of heat in a probabilistic formalism is called

- a) fluid mechanics b) classical mechanics c) quantum mechanics
d) statistical mechanics e) none of these

25. If heat does not enter or leave the system, a process is called

- a) isobaric b) isochoric c) isothermal
d) adiabatic e) isometric

26. A body in hydrostatic equilibrium has the following characteristic:

- a) A body absorbs and emits energy at the same rate.
b) A body is in local thermodynamic equilibrium.
c) A body is at the same temperature as its surroundings.
d) The entropy of a body remains constant.
e) The internal pressure of a gaseous layer is balanced by the weight on top.

27. The number of independent means by which a gas can possess energy is called

- a) convective overshooting b) opacity c) nucleosynthesis
d) calorimetry e) degrees of freedom

28. Which of the following is the state variable that describes the energy associated with changes of state?

- a) entropy b) enthalpy c) heat d) photon e) hydrostatic

29. Which of the following corresponds to the Second Law of Thermodynamics?

- a) All external forces are very small with respect to the force of the collision.
- b) This law indicates the direction in which time progresses.
- c) This law corresponds to the conservation of energy involving heat.
- d) When collisions occur, they must be elastic according to this law.
- e) Planets orbit the Sun in elliptical paths.

30. What is your professor's last name for this course?

- a) Einstein b) Newton c) Luttermoser d) Pascal e) Stupid
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Part C: Problems (20 points total, 10 points each).

31. A 12.8 kg block is connected to a spring with a spring constant of 892 N/m. It oscillates back and forth on a frictionless horizontal plane. The total energy of this block-spring during the oscillation is 92.6 J. (a) What is the distance of the maximum extension of the block (in cm)? (b) What is the maximum velocity of this block? (**Show all work!!!**)

32. A satellite is orbiting an extra-solar planet at an altitude of 2.56×10^5 km above the surface of this planet. The orbit is circular in shape. The radius of the planet is 7.88×10^4 km. (a) If this satellite experiences an acceleration due to gravity of 27.6 m/s^2 , what is the mass of this planet? (b) What is the orbital velocity of this satellite (in km/s)? (c) What is the orbital period of this satellite in days? (**Show all work!!! Don't forget to do the unit conversions.**)

33. A cylindrical container has a diameter of 12.8 cm and a height of 26.2 cm. This cylinder is completely filled with 8.96×10^{21} molecules of molecular hydrogen, H_2 , exerting a pressure of 0.248 atm on the walls of the cylinder. (a) How many moles of molecular hydrogen are in this container? (b) What is the volume of this container (in liters)? (c) What is the temperature of this molecular hydrogen in $^{\circ}\text{C}$? (*Hint:* Assume the gas is ideal. Refer the ‘Useful Constants’ sheet for needed parameters. **Show all work!!!**)

34. A gas is compressed at a constant pressure of 1.18 atm from 15.2 liters to 2.60 liters. In the process, 120 J of heat is lost from the container as the temperature drops from 312 K to 252 K. (a) What is the work done on the gas? (b) What is the change of the internal energy? (c) What is the change in entropy for this gas? (*Hint:* Note that the temperature in the entropy equation is the average temperature of the gas, $(T_h + T_c)/2$. **Show all work and don't forget to convert units!**)

Extra Credit Problem (10 points, 5 points each — do this only if you have time).

35. An object is moving in a straight line path at a constant velocity of 23.8 m/s . If it has a linear momentum of 86.2 kg m/s , calculate its kinetic energy. (**Show all work!**)
36. In the atmosphere of the red giant star Arcturus, the temperature of the gas is 3066 K and the gas pressure is 14.48 Pa . (a) What is the number density of the gas particles? (b) What is the mass density of this gas if the mean molecular weight of the gas is 0.9202 ? (**Show all work!**)