

USEFUL INFORMATION

Rest mass of the electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Magnitude of the electron charge	$e = 1.60 \times 10^{-19} \text{ C}$
Avogadro's number	$N_A = 6.02 \times 10^{23}$
Universal gas constant	$R = 8.31 \text{ J}/(\text{mol} \cdot \text{K})$
Boltzmann's constant	$k_B = 1.38 \times 10^{-23} \text{ J/K}$
Speed of light	$c = 3.00 \times 10^8 \text{ m/s}$
Planck's constant	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
Reduced Planck's constant	$\hbar = h/2\pi$
Vacuum permittivity	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$
Vacuum permeability	$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$
Universal gravitational constant	$G = 6.67 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2)$
Acceleration due to gravity	$g = 9.80 \text{ m/s}^2$
1 atmosphere pressure	$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2 = 1.0 \times 10^5 \text{ Pa}$
1 angstrom	$1 \text{ \AA} = 1 \times 10^{-10} \text{ m} = 0.1 \text{ nm}$

Prefixes for Powers of 10

10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P

Rotational inertia about center of mass

Rod (rotation about axis perpendicular to axis of symmetry)	$\frac{1}{12}MR^2$
Disc (rotation about symmetry axis)	$\frac{1}{2}MR^2$
Sphere	$\frac{2}{5}MR^2$

Physics

Time Allowed: 2 hours

Instructions: Each question in this exam is followed by five suggested answers. Select the one that is best for each question. For your convenience, the questions have been categorized to fall into four areas so you may judiciously spend your time. Attempt all questions. All questions carry equal weight.

Please note that a few questions in each section are provided as a sample. The actual test will have many more questions.

Math Methods

1. Which of the following functions is a solution to the differential equation:

$$\frac{d^2y}{dx^2} + \frac{dy}{dx} - 6y = 0$$

- A. $\exp(-2x)$
 - B. $\exp(3x)$
 - C. $\exp(2x) + \exp(-3x)$**
 - D. $\exp(-2x) + \exp(3x)$
 - E. $C_1 \exp(3x) + C_2$, where C_1 and C_2 are constants
2. Consider the four vectors $(1, 2, 3)$, $(1, 0, 0)$, $(0, 1, 0)$, $(0, 0, 1)$. These vectors are
 - A. orthogonal
 - B. singular
 - C. unitary
 - D. linearly independent
 - E. linearly dependent**

Mechanics

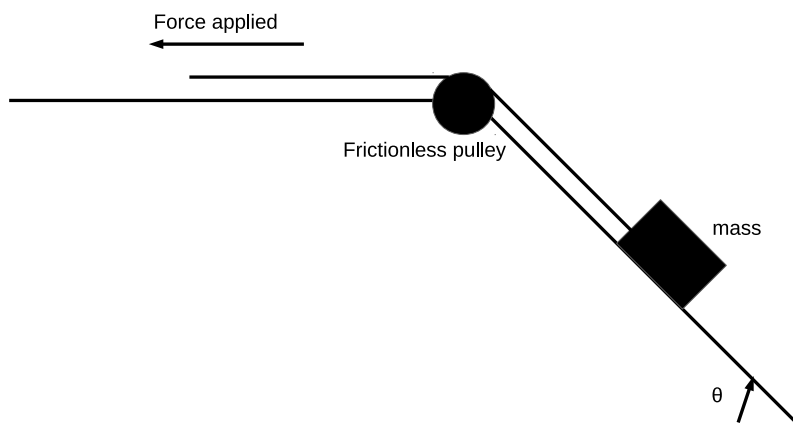
3. A particle is moving such that its position is

$$\vec{r} = R \cos(\omega t) \hat{x} + R \sin(\omega t) \hat{y}.$$

The particle's acceleration is directed along

- A. $\cos(\omega t)\hat{x} - \sin(\omega t)\hat{y}$
- B. $-\cos(\omega t)\hat{x} - \sin(\omega t)\hat{y}$
- C. \hat{z}
- D. $-\cos(\omega t)\hat{x} + \sin(\omega t)\hat{y}$
- E. $\hat{x} + \hat{y} + \hat{z}$

4. A block with a mass of 1kg is pulled up an incline at constant velocity where the surface is inclined at an angle of 45° as shown in the Figure below. The coefficient of kinetic friction between the block and the surface is 0.5 . Determine the magnitude of the applied force. Take the acceleration due to gravity as 10 m/s^2 . You may assume that the pulley is massless and frictionless.



- A. $15/\sqrt{2}\text{ N}$
- B. $15\sqrt{2}\text{ N}$
- C. $30/\sqrt{2}\text{ N}$
- D. 30 N
- E. None of the above

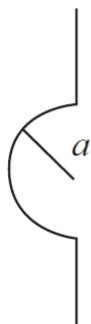
Electromagnetism

5. What is the speed of light in a medium with a permeability of $2\mu_o$ and a permittivity of $3\epsilon_o$?

- A. c
- B. $\frac{c}{\sqrt{3}}$
- C. $\frac{c}{2}$
- D. $\frac{c}{\sqrt{6}}$
- E. $\frac{c}{6}$

6. A wire consists of a half circle whose ends extend perpendicular to the circle as shown in the figure below. If current I flows downward through the wire, what is the magnitude of the magnetic field at the center of the circle?

- A. $\frac{\mu_0 I}{4a^2}$
- B. $\frac{\mu_0 I}{4a}$**
- C. $\frac{\mu_0 I}{a}$
- D. 0
- E. $\frac{\mu_0 I}{4\pi a}$



Thermodynamics, Relativity and Quantum Physics

7. Consider two operators \hat{X} and \hat{Q} defined in the x -basis as:

$$\hat{X}g(x) = xg(x)$$

$$\hat{Q}g(x) = \left(-i\hbar\frac{d}{dx} + f(x)\right)g(x),$$

where $f(x)$ and $g(x)$ are any arbitrary functions of x . What is $[\hat{X}, \hat{Q}]g(x)$?

8. A stick of length L moves past you at speed v . There is a time interval between the front end coinciding with you and the back end coinciding with you. What is the time interval in the stick's frame? Speed of light is denoted by c .

- A. $\frac{L}{\gamma v}$
- B. $\frac{\gamma L}{v}$
- C. $\frac{L}{v}$**
- D. $\frac{vL}{c^2}$
- E. $\frac{L}{c}$

9. Take a glass of water initially at room temperature and place it inside a freezer maintained at -10°C . The water eventually freezes. Choose the best option.
- A. The entropy of water reduces.**
 - B. The entropy of the water increases.
 - C. The entropy of water is constant during this process.
 - D. One cannot define a reasonable entropy function for water.
 - E. The change in entropy of water depends on the detailed geometry of the freezer.