# *The physics GRE*

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# Resources on the web

- General information and Physics Test Practice Book:
- http://www.ets.org
- http://www.ets.org/Media/Tests/GRE/pdf/Physics.pdf
- OSU Prep. course:
- http://www.physics.ohio-state.edu/undergrad/ugs_gre.php

# Dates

## Subject Test Dates

- **Not all test centers are open on all test dates. Download the Test Center List (PDF) for testing locations.**
- Be sure to check the score report mailing date when selecting a test date.

**2008-09 Test Dates**

| TEST DATES | | 10/18/08 | 11/08/08 | 04/04/09 |
|---|---|---|---|---|
| **U.S. and Puerto Rico**<br><br>Registration Receipt Dates at ETS | Supplementary Test Center[1] and Monday Administration[2] | 08/29/08 | 09/19/08 | 02/13/09 |
| | Regular Registration | 09/12/08 | 10/03/08 | 02/27/09 |
| | Late Registration[3] | 09/19/08 | 10/10/08 | 03/06/09 |
| | | | | |
| **Other Locations, Including U.S. Territories**<br><br>Registration Receipt Dates at ETS | Supplementary Test Center[1] and Monday Administration[2] | 08/22/08 | 09/12/08 | 02/06/09 |
| | Regular Registration | 09/05/08 | 09/26/08 | 02/20/09 |
| | Late Registration[3] | 09/12/08 | 10/03/08 | 02/27/09 |
| **APPROXIMATE SCORE REPORT MAILING DATE** | | 11/26/08 | 12/19/08 | 05/15/09 |

[1]No supplementary test centers will be established for the November or April test dates.

[2]Monday test dates will be October 20, 2008, November 10, 2008, and April 6, 2009.

[3]Late registration is available for online registration only for a fee of $25. Late registration closes one week after the regular registration deadline.

# Content of the exam
## *Format*

- 100 questions in 170 minutes.
- Multiple choice A-E.
- Pencil + brain. *No calculators.*
- Most numerical constants provided.
- *No equations provided.*

TABLE OF INFORMATION

| | |
|---|---|
| Rest mass of the electron | $m_e = 9.11 \times 10^{-31}$ kilogram $= 9.11 \times 10^{-28}$ gram |
| Magnitude of the electron charge | $e = 1.60 \times 10^{-19}$ coulomb $= 4.80 \times 10^{-10}$ statcoulomb (esu) |
| Avogadro's number | $N_A = 6.02 \times 10^{23}$ per mole |
| Universal gas constant | $R = 8.31$ joules/(mole · K) |
| Boltzmann's constant | $k = 1.38 \times 10^{-23}$ joule/K $= 1.38 \times 10^{-16}$ erg/K |
| Speed of light | $c = 3.00 \times 10^{8}$ m/s $= 3.00 \times 10^{10}$ cm/s |
| Planck's constant | $h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second |
| | $\hbar = h/2\pi$ |
| Vacuum permittivity | $\epsilon_0 = 8.85 \times 10^{-12}$ coulomb$^2$/(newton · meter$^2$) |
| Vacuum permeability | $\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter) |
| Universal gravitational constant | $G = 6.67 \times 10^{-11}$ meter$^3$/(kilogram · second$^2$) |
| Acceleration due to gravity | $g = 9.80$ m/s$^2$ $= 980$ cm/s$^2$ |
| 1 atmosphere pressure | 1 atm $= 1.0 \times 10^5$ newtons/meter$^2$ $= 1.0 \times 10^5$ pascals (Pa) |
| 1 angstrom | 1Å $= 1 \times 10^{-10}$ meter |

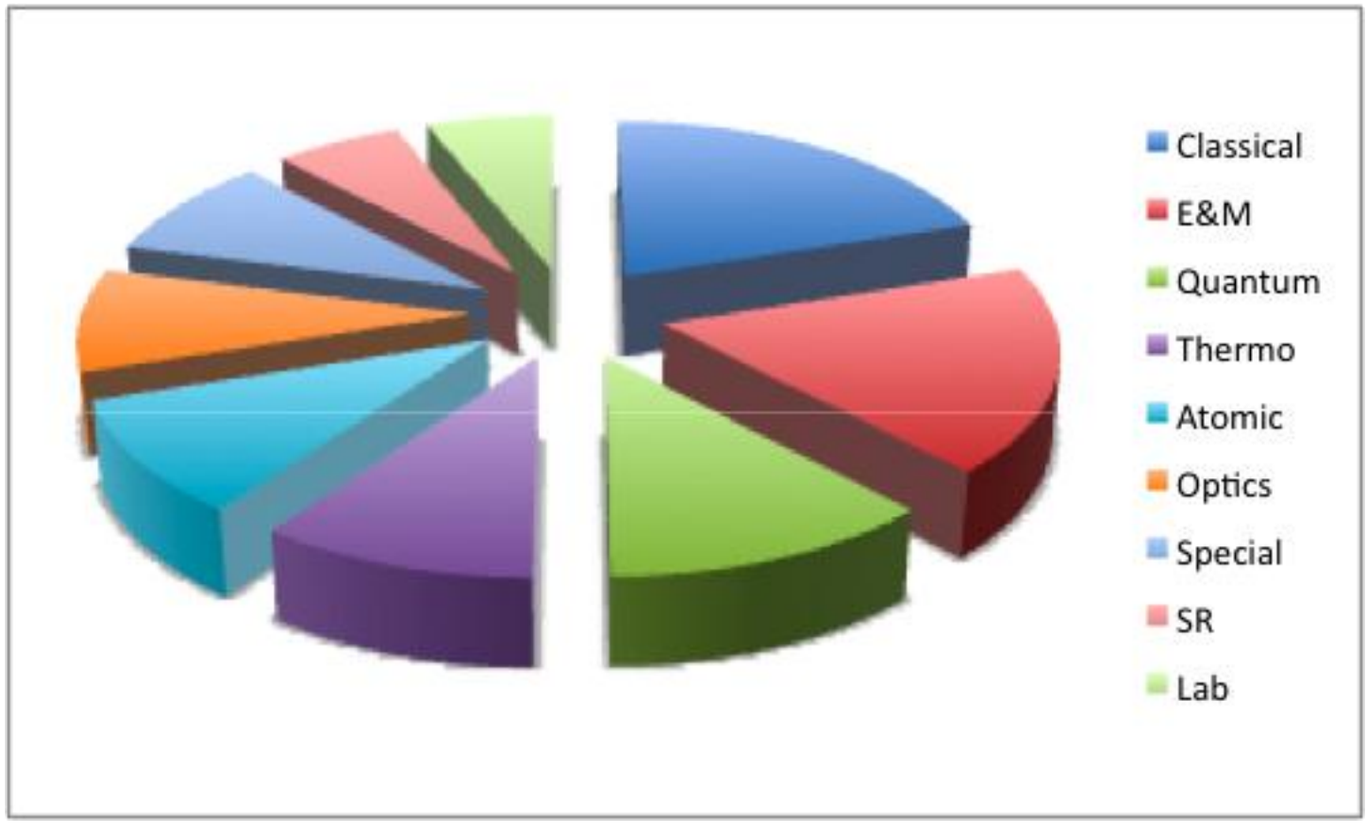
1 weber/m$^2$ = 1 tesla = $10^4$ gauss

Moments of inertia about center of mass

| | |
|---|---|
| Rod | $\frac{1}{12} M\ell^2$ |
| Disc | $\frac{1}{2} MR^2$ |
| Sphere | $\frac{2}{5} MR^2$ |

# Content of the exam
## *Topics covered on the exam*

20% Classical Mechanics
18% Electricity & magnetism
12% Quantum mechanics
10% Thermo+stat. mech.
10% Atomic physics
9% Optics and waves
9% Special topics
6% Special relativity
6% Laboratory methods




- Questions test mastery of material from a typical undergraduate curriculum.
- For the most part the exam draws from “Halliday and Resnick” level classical, E&M, Thermo, optics, and waves.
- Quantum and atomic physics typical of a 3rd semester modern physics course.

# Scoring the exam

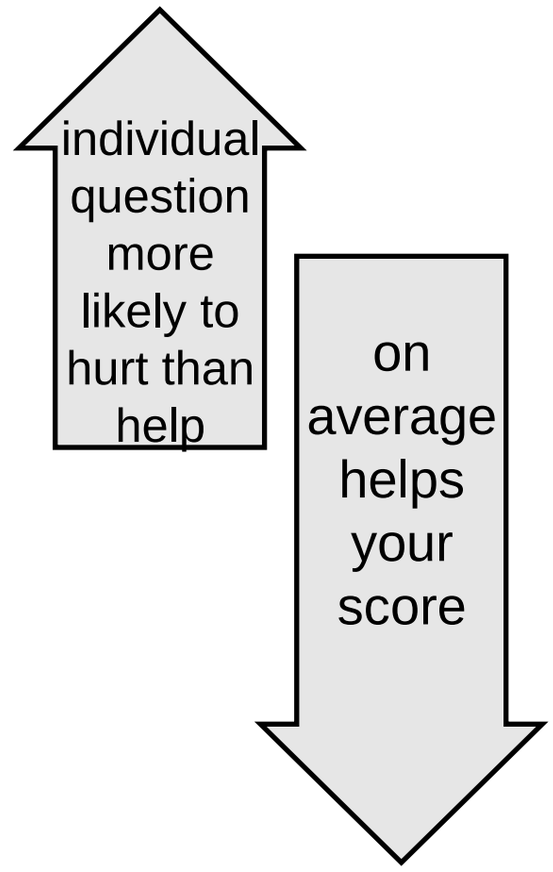
- The exam is scored in a two step process

- A *raw score* is computed as: $C - 1/4\ I$ where $C$ is the number of correct answers and $I$ is the number of incorrect answers. Un-answered $(U)$ questions earn 0 points.

- There are many combinations which earn the same raw score. For example:
  - $C = 52, I=8, U=40 : R= 50$
  - $C = 60, I=40, U=0: \ R= 50$
- The raw score is then converted to a *scaled score*. The scaling procedure is complicated and tries to account for “bad” questions and the relative difficulty of this year’s exam compared to previous years.

# Test taking strategy
## *To guess or not to guess?*

| Number of choices eliminated | P(correct) | P(incorrect) | Average points earned by guessing |
|---|---|---|---|
| 0 | 20% | 80% | 0.00 |
| 1 | 25% | 75% | 0.06 |
| 2 | 33% | 67% | 0.17 |
| 3 | 50% | 50% | 0.38 |
| 4 | 100% | 0% | 1.00 |



# Test taking strategy
## *Have a game plan*

•A good pace to work the exam might be:
-t=30 min,  n=25 questions
-t=60 min,  n=50 questions
-t=90 min,  n=75 questions
-t=120 min, n=100 questions
-This leaves 50 minutes to work problems you skipped, check work
•A “game plan” like this will prevent you from dwelling on difficult problems and not having time to answer “easy” problems later in the exam. *Remember: the easy problems and the difficult problems earn you the same number of points!*
•Work out a “book keeping” system before hand to mark problems you want to come back to. No time to invent this during the exam.

# Test taking strategy
## *Get a good night's sleep*

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*Occup Environ Med* 2000;57:649–655



# Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication

A M Williamson, Anne-Marie Feyer

# Test taking strategy
# *Get a good night's sleep*

*Table 5 Interpolated performance estimates as a function of time of day (hours since waking where average waking time was 0544) during the selected sleep deprivation time window*

| *Test* | *Measure* | *First sleep test session 0800 (2.27)* | *Start of analysed window 1900 (13.27)* | *Time of day (hours since waking)* | | | *0.1 BAC* |
|---|---|---|---|---|---|---|---|
| | | | | *1944 (14.00)* | *2344 (18.00)* | *2744/03 44 (22.00)* | |
| Reaction time | Speed (ms) | 494 | 495 | 497 | 521 | 540 | 566 |
| | Accuracy (misses) | 0.69 | 1.08 | 0.98 | 1.67 | 3.10 | 2.81 |
| Dual task | Speed (ms) | 618 | 617 | 627 | 709 | 775 | 792 |
| | Hand-eye coordination difficulty level | 48.84 | 48.31 | 49.11 | 46.62 | 33.37 | 23.69 |
| Tracking | Hand-eye coordination difficulty level | 44.07 | 49.52 | 47.66 | 40.83 | 36.70 | 23.39 |
| Mackworth | Speed (ms) | 1020 | 964 | 1010 | 1225 | 1511 | 1361 |
| | Accuracy (targets detected (n)) | 12.77 | 12.00 | 11.89 | 9.86 | 7.04 | 7.76 |
| | Accuracy (false alarms) | 2.15 | 1.28 | 1.48 | 2.85 | 4.24 | 4.48 |
| Symbol digit | Speed (ms) | 2289 | 2245 | 2282 | 2430 | 2577 | 2656 |
| | Speed (targets inspected (n)) | 38.49 | 40.05 | 39.30 | 36.90 | 34.30 | 32.74 |
| | Accuracy (correct (%)) | 98.05 | 98.32 | 98.29 | 98.37 | 97.41 | 94.52 |
| Grammatical reasoning | Speed (ms) | 4413 | 4054 | 4128 | 4255 | 4182 | 3945 |
| | Accuracy (correct (n)) | 21.62 | 23.59 | 23.13 | 22.76 | 22.46 | 20.05 |
| Memory and search | Speed (ms)—2 targets | 11988 | 11336 | 11620 | 12439 | 12581 | 12500 |
| | Speed (ms)—6 targets | 22423 | 20729 | 20787 | 21460 | 21101 | 19555 |
| | Accuracy (correct (n))—2 targets | 5.54 | 5.65 | 5.57 | 5.37 | 5.35 | 5.01 |
| | Accuracy (correct (n))—6 targets | 5.08 | 5.16 | 5.14 | 5.12 | 4.80 | 4.21 |
| Spatial memory | Length of recalled series | 5.25 | 5.15 | 5.14 | 4.87 | 4.27 | 3.73 |
| Tiredness | Rating | 19.87 | 38.74 | 40.52 | 58.62 | 75.47 | 44.83 |

Performance during the first test session of the sleep deprivation is included for comparison with the start of the selected window.

*22 hours w/o sleep*

*>0.08 BAC = legally drunk*

1. CLASSICAL MECHANICS (such as kinematics, Newton's laws, work and energy, oscillatory motion, rotational motion about a fixed axis, dynamics of systems of particles, central forces and celestial mechanics, three-dimensional particle dynamics, Lagrangian and Hamiltonian formalism, noninertial reference frames, elementary topics in fluid dynamics)

20%

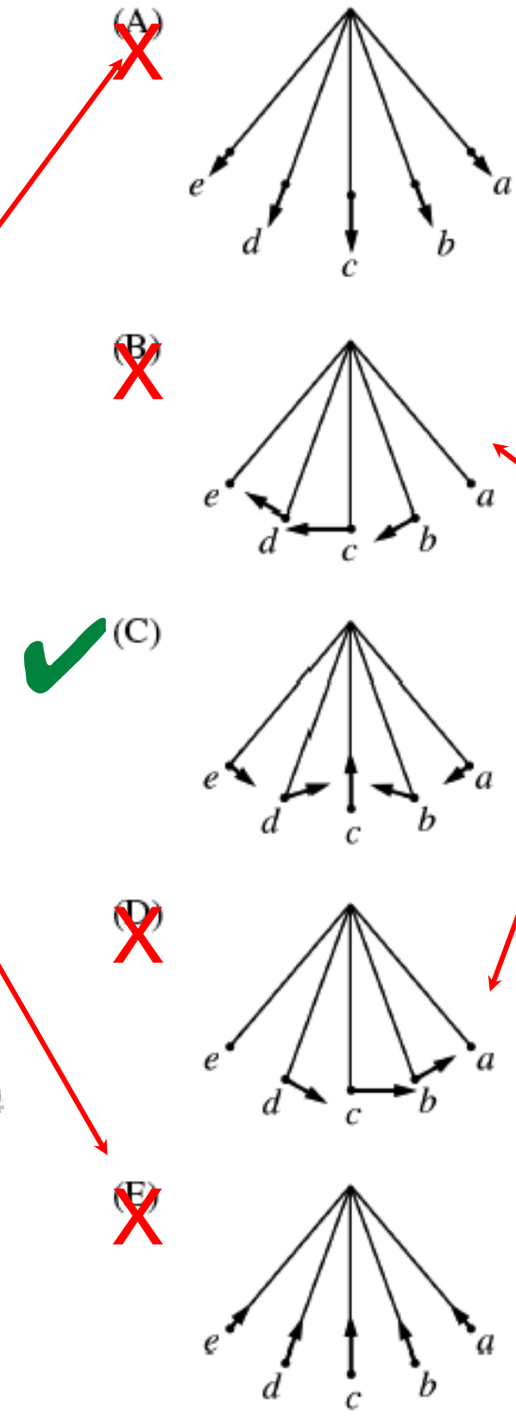
# *Problem solving*

## Sample classical mechanics problem

Centripetal component must be zero at end points

Need centripetal component at midpoint

1. Which of the following best illustrates the acceleration of a pendulum bob at points *a* through *e* ?




54% answered correctly

# *Problem solving*
# Practice calculating for speed and accuracy

2. The coefficient of static friction between a small coin and the surface of a turntable is 0.30. The turntable rotates at 33.3 revolutions per minute. What is the maximum distance from the center of the turntable at which the coin will not slide?

(A) 0.024 m
(B) 0.048 m
(C) 0.121 m
(D) 0.242 m
(E) 0.484 m

*required accuracy x2*

*static frictional force*

*centripetal acceleration*

$$\mu mg = m\frac{v^2}{r}$$

$$\mu mg = m\frac{\omega^2 r^2}{r}$$

$$r = \frac{\mu g}{\omega^2}$$

$$\omega = \frac{33.3 \text{ rev}}{\text{min}} \frac{2\pi \text{ rad}}{\text{rev}} \frac{1 \text{ min}}{60 \text{ s}}$$

$$r = \frac{0.3\ 9.8\ 60^2}{(2\pi)^2\ 33.3^2}$$

$$r \simeq \frac{3\ 36\ 100}{4\ 10\ 3^2\ 100}$$

$$r \simeq \frac{12}{4\ 10}$$

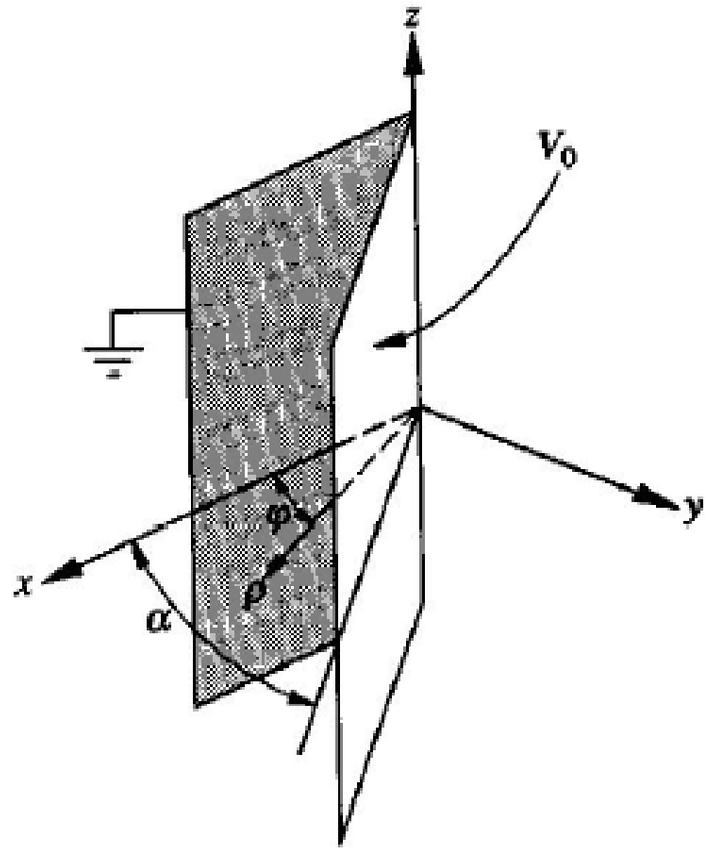
$$r \simeq \frac{1}{4}$$

30% answered correctly

# *Problem solving*

## Sample electricity and magnetism problem

2. ELECTROMAGNETISM (such as electrostatics, currents and DC circuits, magnetic fields in free space, Lorentz force, induction, Maxwell's equations and their applications, electromagnetic waves, AC circuits, magnetic and electric fields in matter) 18%




Don't need to solve to get to the correct answer. Check boundary conditions.

These don't satisfy boundary conditions

12. Two large conducting plates form a wedge of angle $\alpha$ as shown in the diagram above. The plates are insulated from each other; one has a potential $V_0$ and the other is grounded. Assuming that the plates are large enough so that the potential difference between them is independent of the cylindrical coordinates $z$ and $\rho$, the potential anywhere between the plates as a function of the angle $\varphi$ is

(A) $\frac{V_0}{\alpha}$ ✗

(B) $\frac{V_0\varphi}{\alpha}$ ✔

(C) $\frac{V_0\alpha}{\varphi}$ ✗

(D) $\frac{V_0\varphi^2}{\alpha}$ ✗

(E) $\frac{V_0\alpha}{\varphi^2}$ ✗

56% answered correctly

# *Problem solving*

Two answers make no sense. Guess among remaining three?

3. For blue light, a transparent material has a relative permittivity (dielectric constant) of 2.1 and a relative permeability of 1.0. If the speed of light in a vacuum is $c$, the phase velocity of blue light in an unbounded medium of this material is

(A) $\sqrt{3.1}\,c$

(B) $\sqrt{2.1}\,c$

(C) $\frac{c}{\sqrt{1.1}}$

(D) $\frac{c}{\sqrt{2.1}}$ ✔ correct

(E) $\frac{c}{\sqrt{3.1}}$

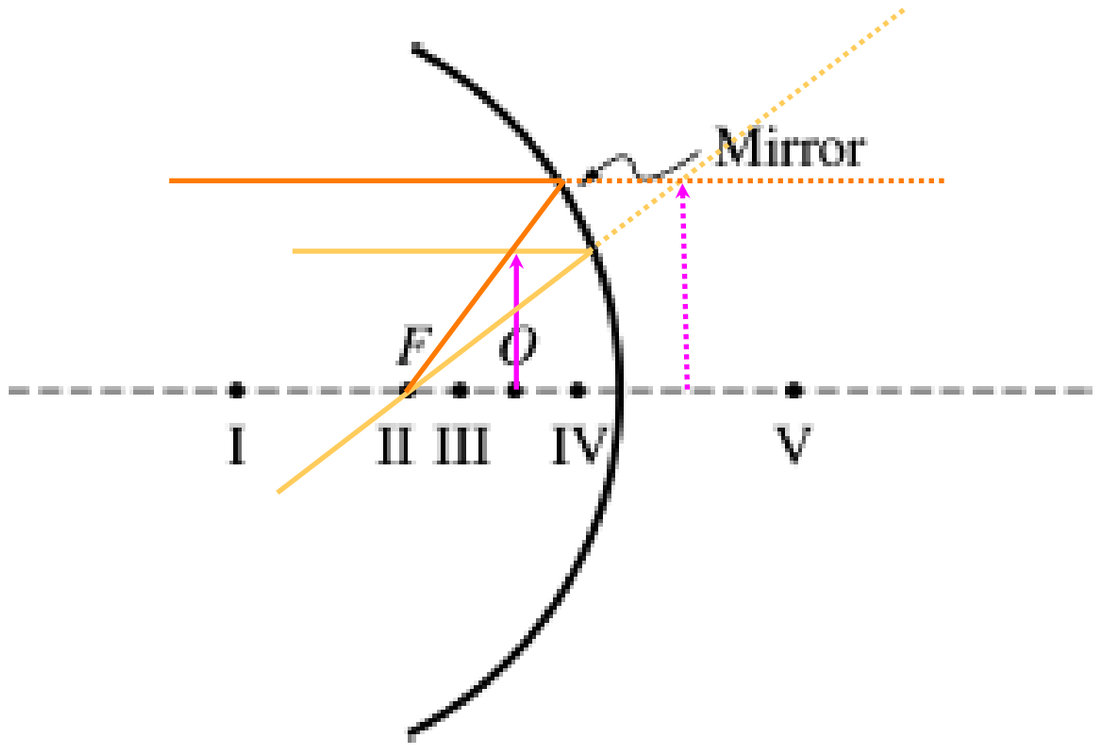
These two are non-sense!

These two seem to involve ε±μ which makes no sense in terms of units

55% answered correctly

3. OPTICS AND WAVE PHENOMENA (such as wave properties, superposition, interference, diffraction, geometrical optics, polarization, Doppler effect) 9%

# Problem solving
# Sample optics problem

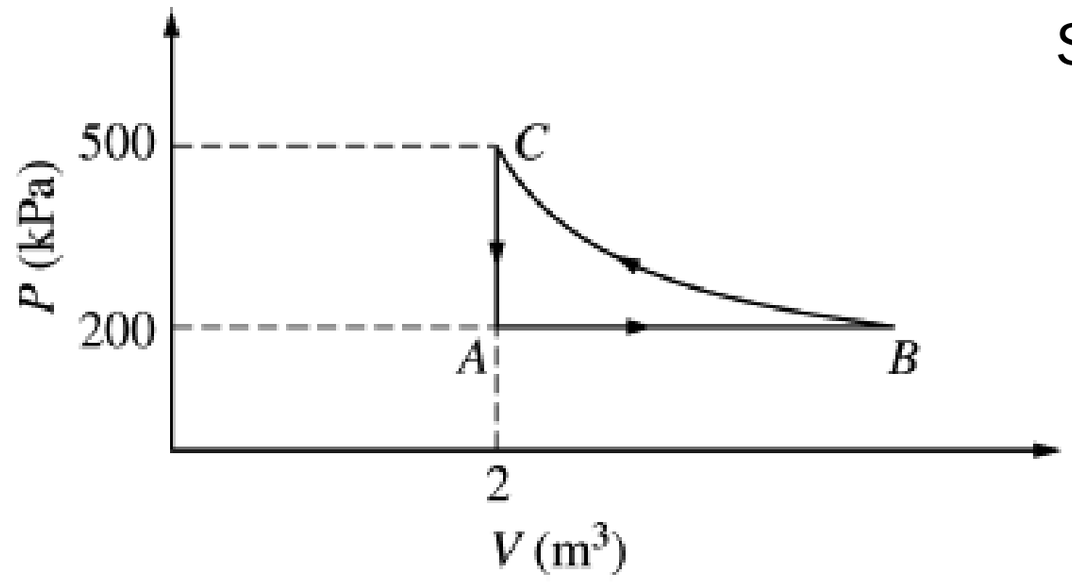



12. A spherical, concave mirror is shown in the figure above. The focal point $F$ and the location of the object $O$ are indicated. At what point will the image be located?

(A) I
(B) II
(C) III
(D) IV
(E) V

40% answered correctly

4. THERMODYNAMICS AND STATISTICAL MECHANICS (such as the laws of thermodynamics, thermodynamic processes, equations of state, ideal gases, kinetic theory, ensembles, statistical concepts and calculation of thermodynamic quantities, thermal expansion and heat transfer) 10%




37. A constant amount of an ideal gas undergoes the cyclic process $ABCA$ in the $PV$ diagram shown above. The path $BC$ is isothermal. The work done by the gas during one complete cycle, beginning and ending at $A$, is most nearly

(A) 600 kJ
(B) 300 kJ
(C) 0
(D) –300 kJ
(E) –600 kJ

# Sample problem

## *Thermodynamics and statistical physics*

Since BC is isothermal: $P_B V_B = P_C V_C$

$$V_B = \frac{P_C V_C}{P_B}$$

$$V_B = \frac{500 \cdot 2}{200}$$

$$V_B = 5$$

Work done by gas is area under curve. The difference in the areas is roughly:

$$W \simeq -\frac{1}{2}(5-2)(500-200)$$

$$= -450 \text{ kJ}$$

Choose (D) since triangle overestimates area under actual curve.

36% answered correctly

5. QUANTUM MECHANICS (such as fundamental concepts, solutions of the Schrödinger equation (including square wells, harmonic oscillators, and hydrogenic atoms), spin, angular momentum, wave function symmetry, elementary perturbation theory) 12%

# Sample problem
# *Quantum mechanics*

94. The raising and lowering operators for the quantum harmonic oscillator satisfy

$$a^\dagger \,|\, n\rangle = \sqrt{n+1}\,|\, n+1\rangle, \quad a|\, n\rangle = \sqrt{n}\,|\, n-1\rangle$$

for energy eigenstates $|\, n\rangle$ with energy $E_n$. Which of the following gives the first-order shift in the $n = 2$ energy level due to the perturbation

$$\Delta H = V(a + a^\dagger)^2,$$

where $V$ is a constant?

(A) 0
(B) $V$
(C) $\sqrt{2}V$
(D) $2\sqrt{2}V$
(E) $5V$

$$\begin{aligned}
(a+a^\dagger)^2 &= a^2 + aa^\dagger + a^\dagger a + a^{\dagger 2} \\
\langle 2|\frac{\Delta H}{V}|2\rangle &= \langle 2|a^2|2\rangle + \langle 2|aa^\dagger|2\rangle + \langle 2|a^\dagger a|2\rangle + \langle 2|a^{\dagger 2}|2\rangle \\
&= 0 + \langle 2|a\sqrt{3}|3\rangle + \langle 2|a^\dagger\sqrt{2}|1\rangle + 0 \\
&= 3\langle 2|2\rangle + 2\langle 2|2\rangle \\
&= 5
\end{aligned}$$

29% answered correctly

6. ATOMIC PHYSICS (such as properties of electrons, Bohr model, energy quantization, atomic structure, atomic spectra, selection rules, black-body radiation, x-rays, atoms in electric and magnetic fields) 10%

# Sample problem
## *Atomic physics*

21. In the hydrogen spectrum, the ratio of the wavelengths for Lyman-$\alpha$ radiation ($n = 2$ to $n = 1$) to Balmer-$\alpha$ radiation ($n = 3$ to $n = 2$) is

(A) 5/48
(B) 5/27
(C) 1/3
(D) 3
(E) 27/5

$$\Delta E = E_0(\frac{1}{n_2^2} - \frac{1}{n_1^2})$$

$$\Delta E_L = E_0(\frac{1}{1^2} - \frac{1}{2^2})$$

$$\Delta E_B = E_0(\frac{1}{2^2} - \frac{1}{3^2})$$

$$\frac{\lambda_L}{\lambda_B} = \frac{E_B}{E_L}$$

$$= \frac{\frac{1}{4} - \frac{1}{9}}{\frac{1}{1} - \frac{1}{4}}$$

$$= \frac{9 - 4}{9 \cdot 4 - 9}$$

$$= \frac{5}{27}$$

60% answered correctly

# Remaining topics

| | |
|---|---|
| 7. SPECIAL RELATIVITY (such as introductory concepts, time dilation, length contraction, simultaneity, energy and momentum, four-vectors and Lorentz transformation, velocity addition) | 6% |
| 8. LABORATORY METHODS (such as data and error analysis, electronics, instrumentation, radiation detection, counting statistics, interaction of charged particles with matter, lasers and optical interferometers, dimensional analysis, fundamental applications of probability and statistics) | 6% |
| 9. SPECIALIZED TOPICS: Nuclear and Particle physics (e.g., nuclear properties, radioactive decay, fission and fusion, reactions, fundamental properties of elementary particles), Condensed Matter (e.g., crystal structure, x-ray diffraction, thermal properties, electron theory of metals, semiconductors, superconductors), Miscellaneous (e.g., astrophysics, mathematical methods, computer applications) | 9% |

# Preparation will improve your GRE score

- Know what material to study
- Practice working numerical problems efficiently
- Practice your test taking strategy
- *Good Luck!*