

Revision

GRE · GRE Subject Test · GRE Physics

Apply the course version boundaries in notes.md; HSK tasks are transferable language practice, not a claimed HSK 3.0 mock.

gre physics · mixed-revision · 1

A reversible engine runs between 500 K and 200 K and absorbs 600 J. Find maximum work and rejected heat.

Worked answer

Carnot efficiency 0.6 gives work 360 J and rejected heat 240 J.

gre physics · mixed-revision · 2

An infinite well has levels $E_n = n^2 E_1$. Find the photon energy for $4 \rightarrow 2$.

Worked answer

$(16 - 4)E_1 = 12E_1$; emitted energy is positive.

gre physics · mixed-revision · 3

For isotropic emission, source distance increases by factor 3. What happens to flux and luminosity?

Worked answer

Flux becomes one ninth; intrinsic luminosity remains unchanged.

gre physics · mixed-revision · 4

A 1 kg cart at (6,0) m/s sticks to a 2 kg cart at (0,3) m/s. Find common velocity and kinetic-energy loss.

Worked answer

Momentum (6,6), final velocity (2,2) m/s. Initial $K = 18 + 9 = 27$ J; final $K = 12$ J, so loss 15 J.

gre physics • mixed-revision • 5

Spring B has four times spring A's stiffness. Compare stored energies first at equal force, then at equal extension.

Worked answer

At equal force $U_B/U_A=1/4$; at equal extension it is 4. State the fixed quantity before using U .

gre physics • mixed-revision • 6

A rolling solid sphere has total kinetic energy 14 J. How much is rotational? Compare terminal speeds of identical-shape quadratic-drag balls with mass ratio 16, neglecting buoyancy.

Worked answer

Rotational fraction $2/7$ gives 4 J. Terminal-speed ratio $\sqrt{16}=4$.

gre physics • mixed-revision • 7

A uniform rod of length 2 m is pivoted at one end at angle 30° from vertical. With $g=10 \text{ m/s}^2$, find angular-acceleration magnitude.

Worked answer

$3g \sin\theta/(2L)=30 \cdot 0.5/4=3.75 \text{ rad/s}^2$, using end-pivot inertia.

gre physics • mixed-revision • 8

A 6 kg table mass connects to a 2 kg hanging mass over an ideal pulley; $g=10 \text{ m/s}^2$. Find acceleration and tension.

Worked answer

$a=20/8=2.5 \text{ m/s}^2$ and $T=6 \cdot 2.5=15 \text{ N}$, below hanging weight 20 N.

gre physics • mixed-revision • 9

A level aircraft moves at 90 m/s and releases a load. With no drag and $g=10 \text{ m/s}^2$, find ground velocity, aircraft-relative velocity and vertical drop after 5 s.

Worked answer

Ground velocity $(90, -50) \text{ m/s}$; relative velocity $(0, -50) \text{ m/s}$; drop $\frac{1}{2} \cdot 10 \cdot 25=125 \text{ m}$.

gre physics • mixed-revision • 10

A centred charge $+5Q$ lies inside a spherical conducting shell of net $-2Q$ and outer radius b . Find induced surface charges and material potential, zero at infinity.

Worked answer

Inner surface $-5Q$; outer $+3Q$; $V=3Q/(4\pi\epsilon_0 b)$, constant in the material.

gre physics • mixed-revision • 11

Two attractive forces on an electron have magnitudes 5 N and 12 N at right angles. Find their resultant magnitude; explain why potential would be added differently.

Worked answer

Force magnitude $\sqrt{25+144}=13$ N. Potential is a scalar sum, whereas force is a vector sum.

gre physics • mixed-revision • 12

A sinusoidal current has peak 4 A in a $5\ \Omega$ resistor. Find rms current and average power.

Worked answer

$I_{\text{rms}}=4/\sqrt{2}=2\sqrt{2}$ A; $P=I_{\text{rms}}^2 R=8 \cdot 5=40$ W.

gre physics • mixed-revision • 13

A 200-turn coil of area 0.01 m^2 has perpendicular field decrease from 0.08 to 0.02 T in 0.30 s. Find average emf magnitude and state the Lenz condition.

Worked answer

Magnitude $=200 \cdot 0.01 \cdot 0.06/0.30=0.4$ V. Induced current opposes the decrease in original flux.

gre physics • mixed-revision • 14

A $-x$ travelling wave has electric field along $+z$. Find magnetic and Poynting directions.

Worked answer

B is $+y$, since $(-x) \times z = +y$. $E \times B = z \times y = -x$, matching propagation.

gre physics • mixed-revision • 15

A nonmagnetic lossless material has $\epsilon_r=36$. Find v/c . At a zero-interior-B boundary, which exterior magnetic component is constrained to zero?

Worked answer

$v/c=1/6$. The component normal to the surface is zero; tangential field may remain.

gre physics • mixed-revision • 16

A 600 Hz moving source approaches a fixed reflecting wall at 20 m/s in still air of speed 320 m/s. Find the echo frequency heard at the source.

Worked answer

$600 \cdot 340/300=680$ Hz; multiply the moving-source and moving-observer factors.

gre physics • mixed-revision • 17

An ideal both-open pipe has fundamental 90 Hz. Give the first three allowed frequencies after one end is closed; does 90 Hz remain?

Worked answer

45,135,225 Hz. The old 90 Hz is twice the new fundamental, an absent even harmonic.

gre physics • mixed-revision • 18

A relaxed-view telescope has 100 cm lens separation and 20 cm eyepiece focal length. Find objective focal length and magnification magnitude.

Worked answer

Objective 80 cm; magnification 4.

gre physics • mixed-revision • 19

Evacuating a 4.5 cm Michelson gas cell gives 60 fringes at 450 nm. Find n before evacuation.

Worked answer

$n-1=60 \cdot 450 \times 10^{-9}/0.09=0.0003$, so $n=1.0003$.

gre physics • mixed-revision • 20

For $f(x)=1+2\cos x+4\cos(3x)$, identify a_0 , a_1 , a_3 and all b_n under the standard Fourier convention.

Worked answer

$a_0=2$, $a_1=2$, $a_3=4$; all $b_n=0$. The mean is 1.

gre physics • mixed-revision • 21

Two equal coherent waves have individual intensity I_0 and phase difference $2\pi/3$. Find combined intensity. Compare the incoherent average.

Worked answer

Coherent intensity $2I_0(1-1/2)=I_0$; incoherent average $2I_0$.

gre physics • mixed-revision • 22

A clockwise triangular P–V cycle has pressure span 6000 Pa and volume span 0.004 m³. Find net work and heat.

Worked answer

Work = $\frac{1}{2} \cdot 6000 \cdot 0.004 = 12$ J; net entering heat is also 12 J.

gre physics • mixed-revision • 23

A Carnot refrigerator absorbs 1800 J at 240 K and rejects heat at 300 K. Find COP, work input and rejected heat.

Worked answer

COP = $240/60 = 4$; work 450 J; rejected heat 2250 J.

gre physics • mixed-revision • 24

A speed-count density has trapezoid area $3av_0$, $N=180$ and $v_0=5$ m/s. Find a and explain its units.

Worked answer

$a=12$ particles per unit speed; integrating the density over speed gives a particle count.

gre physics • mixed-revision • 25

Two levels have ground degeneracy 1, excited degeneracy 4 and gap $kBT \ln 4$. Find probabilities of the excited level and one specified excited state.

Worked answer

Each level has total weight 1, so excited level probability $1/2$; one excited state has probability $1/8$.

gre physics • mixed-revision • 26

For $N=250$ independent detector trials and $p=0.20$, find mean, variance and standard deviation.

Worked answer

Mean 50; variance 40; standard deviation $\sqrt{40} \approx 6.32$.

gre physics • mixed-revision • 27

A kinetic-energy estimate has independent mass uncertainty 8% and speed uncertainty 3%. Find approximate fractional standard uncertainty. Explain why dimensional analysis alone cannot determine a coefficient.

Worked answer

$\sqrt{8^2 + 6^2} \% = 10\%$. A dimensionless coefficient does not affect unit powers, so it is undetermined by dimensions.

gre physics • mixed-revision • 28

A particle moves at $0.8c$. Find γ and kinetic energy as a fraction of rest energy. For a longitudinal wavelength ratio 5, find recession speed.

Worked answer

$\gamma = 5/3$ and $K/(mc^2) = 2/3$. $\beta = (25-1)/(25+1) = 12/13$.

gre physics • mixed-revision • 29

A particle has total energy 17 GeV and $pc = 15$ GeV. Find rest energy and explain why $E - pc$ is not the answer.

Worked answer

Rest energy $\sqrt{289 - 225} = 8$ GeV. The invariant is quadratic; direct subtraction would give 2 GeV incorrectly.

gre physics • mixed-revision • 30

A two-body one-electron model has nuclear mass $4m_e$. Find μ/m_e . A photon has energy 5 eV and work function is 3 eV: find stopping magnitude.

Worked answer

Reduced-mass ratio $4/5$; maximum electron energy 2 eV, stopping magnitude 2 V.

gre physics • mixed-revision • 31

Franck–Hertz current features are spaced by 6 V. Find the excitation energy and corresponding single-photon wavelength using $hc=1240 \text{ eV} \cdot \text{nm}$.

Worked answer

Energy 6 eV; wavelength $1240/6 \approx 206.7 \text{ nm}$. Repeated features can reflect repeated losses of this same energy.

gre physics • mixed-revision • 32

A step has $k_2=5k_1$. Find reflection/transmission probabilities and verify their sum.

Worked answer

$r=-2/3$ gives $R=4/9$; $T=5 \cdot (1/3)^2=5/9$; sum one.

gre physics • mixed-revision • 33

Count spin-zero isotropic oscillator states for $N=5$, and compute $\sigma_y \sigma_x$.

Worked answer

Degeneracy $6 \cdot 7/2=21$; $\sigma_y \sigma_x = -i\sigma_z$.

gre physics • mixed-revision • 34

Compare B/A for $(A,B)=(5,30 \text{ MeV})$ and $(15,120 \text{ MeV})$. Is total binding alone the correct comparison?

Worked answer

Values 6 and 8 MeV per nucleon. Total binding alone confounds different nucleon counts.

gre physics • mixed-revision • 35

Classify neutrino, kaon and neutron as lepton/meson/baryon in the ordinary constituent model. Explain the sign of R_H for one-carrier holes.

Worked answer

Neutrino lepton, kaon meson, neutron baryon. Hole charge $+e$ gives positive R_H under $R_H = 1/(nq)$.

gre physics • mixed-revision • 36

Identical satellites have circular orbit-radius ratio 16 around the same dominant mass. Compare angular momentum and period ratios.

Worked answer

Angular momentum ratio $\sqrt{16}=4$; period ratio $16^{3/2}=64$.

gre physics • mixed-revision • 37

A central-force particle conserves $p\theta$. Radius changes from 4 m to 2 m. Compare angular speeds. For a 1 m pendulum with $g=10$, give the linear angular frequency and the approximation needed.

Worked answer

Angular speed quadruples because $mr^2\dot{\theta}$ is fixed. The pendulum has $\omega = \sqrt{10}$ rad/s only for small angles in radians.

gre physics • mixed-revision • 38

For $L = 2(\dot{x}^2 + \dot{y}^2)/2 - 3x^2$, identify cyclic coordinates, a conserved momentum and the x equation.

Worked answer

y is cyclic and $p_y = 2\dot{y}$ is conserved. Euler–Lagrange gives $2\ddot{x} + 6x = 0$; x is not cyclic.

gre physics • mixed-revision • 39

At $r = (3, 0, 0)$, $\Omega = (0, 0, 2)$, $m = 1$ and $v' = (0, 0, 0)$, find apparent forces for constant rotation and the real force required to stay fixed.

Worked answer

Centrifugal $= (12, 0, 0)$ N; Coriolis $=$ Euler $= 0$. Real force $= (-12, 0, 0)$ N, inward.

gre physics • mixed-revision • 40

An 8 kg passenger accelerates upward at 1.5 m/s^2 with $g=10$. Then evaluate Coriolis direction for Ω along $+z$ and relative motion along $-x$.

Worked answer

Scale force $8(10+1.5)=92 \text{ N}$. $z \times (-x) = -y$, so Coriolis is along $+y$.

gre physics • mixed-revision • 41

An ideal horizontal incompressible flow speeds up from 2 to 5 m/s with density 800. Find pressure drop. If a laminar tube radius halves at fixed Δp , compare Q .

Worked answer

Ideal pressure drop $= 800(25-4)/2 = 8400 \text{ Pa}$. At fixed Δp , laminar Q becomes $1/16$; this is distinct from fixed- Q continuity.

gre physics • mixed-revision • 42

A liquid has density 900 and viscosity $0.003 \text{ Pa} \cdot \text{s}$; mean pipe speed is 0.1 m/s and diameter 0.01 m . Find Re and explain why a steady uniform pipe can still have a pressure drop.

Worked answer

$Re = 900 \cdot 0.1 \cdot 0.01 / 0.003 = 300$. Viscous momentum transfer can dissipate energy at unchanged mean speed; loss-free Bernoulli alone misses it.

gre physics • mixed-revision • 43

A capacitor stays connected to an ideal battery while a dielectric of $\epsilon_r=6$ completely fills its gap. Compare free charge, E and stored energy with the vacuum case. Contrast the isolated fixed- Q case.

Worked answer

At fixed V : free charge and U are six times larger; $E=V/d$ is unchanged. At fixed Q : E , V and U are one sixth. The connected source exchanges energy.

gre physics • mixed-revision • 44

For a uniform linear dielectric with $\epsilon_r=2$ and free plate density σ , find P/σ . A long solenoid has $nI=250 \text{ A/m}$ and $\chi_m=0.2$. Find H , M and B/μ_0 .

Worked answer

$P=(\epsilon_r-1)\sigma/\epsilon_r=\sigma/2$. $H=250$ A/m, $M=50$ A/m and $B/\mu_0=300$ A/m under the long-solenoid linear-response assumptions.

gre physics • mixed-revision • 45

An RC discharge has $\tau=3$ s and initial voltage 10 V. Find voltage at 6 s and the time to halve. An RL circuit has $L=0.3$ H and $R=6$ Ω ; find its time constant.

Worked answer

Voltage= $10e^{(-2)}=1.353$ V; half-time= $3 \ln 2=2.079$ s. RL $\tau=L/R=0.05$ s.

gre physics • mixed-revision • 46

In series RLC, $R=10$ Ω , $L=0.1$ H, $C=0.001$ F, $V_{\text{rms}}=20$ V and $\omega=200$ rad/s. Find X , impedance magnitude, current, phase direction and mean power.

Worked answer

$X=20-5=15$ Ω ; $|Z|=\sqrt{325}=18.028$ Ω ; $I_{\text{rms}}=1.1094$ A. Current lags voltage. $P=400 \cdot 10/325=12.308$ W. This is off resonance; $\omega_0=100$ rad/s.

gre physics • mixed-revision • 47

A linear beam of intensity 64 W/m² passes ideal analyser axes at 45° and then 75° relative to its initial direction. Find the two outputs. What would a circular input of the same intensity transmit through one analyser?

Worked answer

Outputs $64 \cos^2 45^\circ=32$ and $32 \cos^2 30^\circ=24$ W/m²; the second relative angle is 30°, not 75°. Circular input gives 32 W/m² through one ideal analyser.

gre physics • mixed-revision • 48

At a fixed point $E_x=5 \cos \omega t$ and $E_y=5 \cos \omega t$. Classify the field. For ideal incidence from $n_1=1.2$ into $n_2=1.6$ find θ_B and the complementary refracted angle.

Worked answer

The field is linear at 45°, not circular: the components have equal phase. $\theta_B=\text{atan}(4/3)=53.13^\circ$; refracted angle 36.87°.

gre physics • mixed-revision • 49

Two equal finite slits have $\lambda=400$ nm, $L=2$ m, $a=0.20$ mm and $d=1.0$ mm. Find fringe spacing, central-envelope width, first missing orders and nominal centres inside the central envelope.

Worked answer

Spacing 0.8 mm, width 8 mm, missing ± 5 and nine nominal centres -4 through $+4$. Boundary orders ± 5 are dark.

gre physics • mixed-revision • 50

For a uniform far-field single slit, calculate I/I_c at $\beta=\pi/3$. If slit width triples while λ and L remain fixed, compare small-angle central widths.

Worked answer

$(\sin(\pi/3)/(\pi/3))^2=27/(4\pi^2)\approx 0.6839$. Central width becomes one third. Amplitude and intensity ratios are different.

gre physics • mixed-revision • 51

A diverging lens has $f=-20$ cm and a real object 60 cm away. Find signed image distance and magnification. Contrast a concave mirror $f=20$ cm with the same object distance.

Worked answer

Lens $s'=-15$ cm and $M=+1/4$, virtual upright reduced. Concave mirror $s'=30$ cm and $M=-1/2$, real inverted in front.

gre physics • mixed-revision • 52

A converging lens at $x=0$ has $f=10$ cm and real object $x=-30$ cm. A second $f=10$ cm lens is at $x=10$ cm, before the first predicted image. Find its signed object distance and final image coordinate.

Worked answer

First predicted image $x=15$ cm. At the second lens incoming rays converge toward a point 5 cm beyond it, so $s_2=-5$ cm. $1/s_2'=1/10+1/5=3/10$, giving $s_2'=10/3$ cm and final $x=40/3$ cm. $M_1=-1/2$, $M_2=+2/3$ and total $-1/3$.

gre physics • mixed-revision • 53

Two parallel heat paths have resistances 0.5 and 1.5 K/W between 50°C and 20°C. Find each rate, total rate and equivalent resistance.

Worked answer

Rates 60 W and 20 W; total 80 W; equivalent $R=30/80=0.375$ K/W. They share the temperature difference rather than the heat rate.

gre physics • mixed-revision • 54

Ice already at its melting point has mass 0.04 kg and specified latent heat 3×10^5 J/kg. It receives 9000 J with no losses. Find melted mass and explain why $mc\Delta T$ is insufficient.

Worked answer

Melted mass $= Q/\ell = 0.03$ kg; 0.01 kg ice remains. Temperature stays at the melting point during this ideal phase conversion; latent energy is not a temperature rise.

gre physics • mixed-revision • 55

A two-state fixed spectrum has energies 0 and Δ with $\Delta/(kBT) = \ln 4$. Calculate U/Δ , $\text{Var}(E)/\Delta^2$ and C/kB .

Worked answer

$p_{\text{exc}} = 1/5$, so $U/\Delta = 1/5$, variance $= 1/5 - 1/25 = 4/25$; $C/kB = 4(\ln 4)^2/25 \approx 0.307490$. Differentiate at fixed Δ .

gre physics • mixed-revision • 56

A canonical two-level model has a unique ground state. Describe U , S and C at low temperature and at arbitrarily high temperature; then shift both levels by fixed ε .

Worked answer

Low T: $U \rightarrow 0$, $S \rightarrow 0$, $C \rightarrow 0$ for energies 0, Δ . High T: $U \rightarrow \Delta/2$, $S \rightarrow kB \ln 2$, $C \rightarrow 0$. Offset ε shifts U/F by ε but leaves S , variance and C unchanged.

gre physics • mixed-revision • 57

At $(\varepsilon - \mu)/(kBT) = \ln 9$, compute single-state Fermi, Bose and Maxwell–Boltzmann means. Count two identical bosons in four complete states and two identical fermions in the same states.

Worked answer

Fermi $1/10$, Bose $1/8$, dilute approximation $1/9$. Bosonic patterns choose $(5,2)=10$; fermionic choose $(4,2)=6$.

gre physics • mixed-revision • 58

An oscillator has fixed spacing ε and $\varepsilon/(kBT)=\ln 4$. Find thermal energy above zero point divided by ε and C/kB . State the classical high-T and frozen low-T heat-capacity limits.

Worked answer

Energy/ $\varepsilon=1/3$; $C/kB=4(\ln 4)^2/9 \approx 0.854139$. High T $C \rightarrow kB$; low T $C \rightarrow 0$. The fixed zero-point $\varepsilon/2$ does not change these derivatives.

gre physics • mixed-revision • 59

A normalised well state in $0 < x < 5$ nm receives weak γx with $\gamma = 0.012$ eV/nm. Find its first-order shift. Explain what changes if the perturbation is $\gamma(x - 2.5$ nm).

Worked answer

The first shift is $\gamma L/2 = 0.03$ eV. The centred odd perturbation has zero first-order diagonal expectation; off-diagonal mixing and higher-order shifts can remain.

gre physics • mixed-revision • 60

Within a two-state exact degeneracy, a perturbation is $\varepsilon[[3, -1], [-1, 3]]$, $\varepsilon > 0$. Find first-order shifts and the symmetric/antisymmetric combinations.

Worked answer

Symmetric $(1,1)/\sqrt{2}$ gives 2ε ; antisymmetric $(1,-1)/\sqrt{2}$ gives 4ε . The two diagonal entries 3ε are not the first-order energy shifts.

gre physics • mixed-revision • 61

Two electrons can access four spatial orbitals with two spin states each. Count complete-state occupations for two electrons. Which spin sector can put both in one spatial orbital?

Worked answer

Eight complete states give choose $(8,2)=28$ patterns. Same-orbital double occupation needs antisymmetric spin, the singlet.

gre physics • mixed-revision • 62

For distinct orthonormal orbitals a, b , classify the exchange symmetry of $\Psi_{-} + \chi_{-}$ triplet and $\Psi_{-} - \chi_{-}$ singlet. Are either allowed two-electron total states?

Worked answer

Both products are symmetric overall: $(+)(+)$ and $(-)(-)$. Neither is allowed for two identical electrons. Allowed pairings are $\Psi_{-} +$ with singlet or $\Psi_{-} -$ with triplet.

gre physics • mixed-revision • 63

A finite-well ground root is $\rho=2$, $z=1.02986653$. Find E/V_0 and κa . Why should the well-edge amplitude not be set to zero?

Worked answer

$E/V_0 = z^2/4 - 1 \approx -0.734844$; $\kappa a \approx 1.714461$. Finite boundaries match the nonzero oscillatory interior to decaying tails; zero-edge conditions belong to infinite walls.

gre physics • mixed-revision • 64

For a one-electron $Z=2$ ion at $n=4$, find approximate bound energy and spatial degeneracy. For $l=3, m_l=-2$, give L magnitude and L_z .

Worked answer

$E \approx -13.6 \cdot 4/16 = -3.4$ eV; spatial degeneracy 16. $L = \sqrt{12}\hbar$ and $L_z = -2\hbar$. Spin/fine structure and reduced mass have been excluded.

gre physics • mixed-revision • 65

An electron in the uncoupled magnetic regime has $m_l=-1, m_s=+1/2$. Find its linear shift. A weak LS-coupled $L=1, S=1/2, J=3/2, m_J=-3/2$ level is instead placed in 0.5 T: find its shift using $\mu_B = 5.788 \times 10^{-5}$ eV/T.

Worked answer

Uncoupled shift is zero. In the other regime $g_J = 4/3$, so $g_J m_J = -2$ and the shift is -5.788×10^{-5} eV. Regime-specific labels cannot be interchanged.

gre physics • mixed-revision • 66

A degenerate opposite-parity pair has supplied real dipole matrix $[[0, d], [d, 0]]$, $d = 1.5$ e · nm. For $F = 2 \times 10^5$ V/m find the level shifts and splitting. What would a nondegenerate parity-state diagonal expectation alone predict at first order?

Worked answer

Shifts ± 0.0003 eV, separation 0.0006 eV. A nondegenerate parity-state expectation is zero at first order; it cannot describe the off-diagonal splitting in this degenerate model.

gre physics • mixed-revision • 67

For a 5000 K grey surface with $\varepsilon=0.4$, $A=3\times 10^{-5}$ m² and $T_{\text{env}}=1000$ K, find wavelength peak using $b=2.898\times 10^{-3}$ m · K and net power with $\sigma=5.670\times 10^{-8}$. State the wavelength-independent-emissivity assumption.

Worked answer

Peak 579.6 nm under the grey spectral model. Net power $0.4 \cdot 3\times 10^{-5} \cdot 5.670\times 10^{-8}(5000^4-1000^4)=424.5696$ W. Emissivity is independent of wavelength and the large surroundings fill the relevant view.

gre physics • mixed-revision • 68

A heavy-nucleus one-electron $Z=2$ ion emits $n=4\rightarrow 2$. Find photon energy/wavelength, $n=4$ Bohr radius, and ionisation energy from $n=4$, using 13.6 eV and 1240 eV · nm constants. Distinguish the Bohr $n\hbar$ from wave angular momentum.

Worked answer

Photon 10.2 eV; $\lambda\approx 121.5686$ nm; Bohr radius $8a_0$; $n=4$ ionisation 3.4 eV. Wave orbital $L=\sqrt{l(l+1)}\hbar$ with $l=0,\dots,3$; it is not fixed to $4\hbar$ for every $n=4$ orbital.