PHYSICS CONCEPTS

NEWTONIAN MECHANICS

KINEMATICS

1. Distance is the total length that an object in motion covers. Displacement is a vector quantity that indicates the change in position that an object moves in a particular direction. Average speed is the distance covered per unit time. Average velocity is the displacement divided by the time interval.
2. Acceleration occurs whenever there is a change of speed or direction of motion.
3. Free fall problems can be solved like other acceleration problems by substituting 'a' for 'g' = 9.8 m/s^2. The sign of 'g' is (+) or (-) depending on the choice of up or down as the positive direction. It is OK to use 'g' = 10 m/s^2 in the multiple-choice section of the exam.
4. A ball rolled off a horizontal table will take the same amount of time to hit the ground as another dropped from the same height.
5. Projectile motion:
a. horizontal and vertical components are independent,
b. the horizontal component of the velocity remains constant, the vertical component has constant acceleration 'g',
c. only the vertical component of the velocity at the maximum height is zero,
d. for projectiles fired at an angle you may assign negative signs to all vectors going down.

FORCES

6. For free-body-diagrams draw only the forces acting on the object in question.
7. Newton's First Law: for objects at rest or moving at constant velocity the net force is zero.
8. For Newton's Second Law: a net unbalanced force produces acceleration.
9. The normal force and the gravitational force are not an action-reaction pair.
10. Static friction exists between two surfaces when motion is impending; kinetic friction occurs when two surfaces are in relative motion. In either case, the friction forces are proportional to the normal force.
11. For inclined planes, the minimum coefficient of static friction $\mu_s = \tan\theta$

WORK, ENERGY AND MOMENTUM

12. Work and energy are scalar quantities.
13. Work is equal to the product of the displacement and the component of the force in the direction of the displacement.
14. For an object traveling in circular motion, the centripetal force never does work.
15. Mechanical energy is the sum of all kinetic and potential energies.
16. Work-Energy Theorem: the net work is equal to the change in kinetic energy.
17. Conservation of mechanical energy under the action of a dissipative force includes the work due to frictional forces (non-conservative forces).
18. Power is the time rate of change of work or energy, but it can also be calculated using force x speed.

19. The impulse is the product of the average force and the time interval through which it acts. Impulse is equal to the change in momentum.
20. Momentum is conserved in all collision systems. Kinetic energy is conserved only in elastic collisions.
21. Objects stick together in perfectly inelastic collisions.

CIRCULAR MOTION AND GRAVITATION

22. Uniform circular motion refers to motion in a circle where the speed is constant and only the direction changes. The change in direction produced by a central force is called centripetal acceleration.
23. The centripetal force is not a special kind of force; therefore never label a force on a free-body-diagram as 'centripetal'. The centripetal force is provided by the component of the force that is directed towards the center of the circular path e.g. friction, tension, gravity, normal, etc.
24. The gravitational force is directly proportional to the product of the masses and inversely proportional to the square of the distance between them.

OSCILLATIONS

25. Simple harmonic motion is periodic motion in which the restoring force is proportional to the displacement.
26. The maximum displacement of an object from its equilibrium position is the amplitude.
27. At the maximum displacement the object experiences the maximum acceleration and maximum elastic potential energy.
28. At the equilibrium position the object experiences zero acceleration, maximum velocity and maximum kinetic energy.
29. The period of a pendulum depends on its length and the value of 'g' at that particular location.
30. The period of a mass-spring system depends on the mass and the spring constant 'k'.

FLUID MECHANICS AND THERMAL PHYSICS

FLUID MECHANICS

31. Absolute pressure is equal to the gauge pressure plus the atmospheric pressure.
32. Fluid pressure is independent of the shape or area of the container.
33. Archimedes' Principle: An object that is completely or partly submerged in fluid experiences an upward force (buoyant force) equal to the weight of the fluid displaced.
34. An object will float (sink) in a fluid if the density of the object is less (greater) than the density of the fluid.
35. The submerged fraction of an object is the ratio of the submerged volume to the total volume or the ratio of the density of the object to the density of the fluid.
36. Pascal's Principle: An external pressure applied to a confined fluid is transmitted throughout the fluid.
37. Bernoulli's Equation: The net work done on a fluid is equal to the changes in kinetic and potential energy of the fluid in terms of quantities per volume.

THERMAL ENERGY AND THERMODYNAMICS

38. Thermal energy represents the total internal energy of an object, the sum of its molecular kinetic and potential energies.
39. Kinetic theory relates the average kinetic energy of the molecules in a gas to the temperature of the gas in Kelvins.
40. First Law of Thermodynamics: $\Delta U = W + Q$
Where W is the work done ON the system.
41. Thermodynamic Processes:
- Adiabatic process: $Q = 0$
- Isovolumetric (isochoric) process: $W = 0$
- Isothermal process: $\Delta U = 0$
- Isobaric process: $\Delta U = W + Q$

42. On a PV diagram, if the cycle is clockwise the system is a heat engine and the net work is negative. If the cycle is counterclockwise the system is a refrigerator and the net work is positive.
42. Carnot cycles involve only isothermal and adiabatic processes. To determine the efficiency use the Kelvin temperatures of the reservoirs.
44. Second Law of Thermodynamics:
- Heat flows naturally from an object at higher temperature to one of lower temperature.
- All natural systems tend toward a state of higher disorder (entropy).

ELECTRICITY AND MAGNETISM

ELECTRICITY

45. Coulomb's Law: the force of attraction or repulsion between two point charges is directly proportional to the product of the two charges and inversely proportional to the square of the separation between the charges.
46. Use the sign of the charges to determine the direction of the forces and Coulomb's Law to determine their magnitudes.
47. Electric forces and electric fields are vectors, electric potentials are scalars.
48. Electric fields point in the direction of the force on a positive test charge.
49. The electric field inside a closed conductor is zero. Outside the conductor the electric field is not zero and the electric field lines are drawn perpendicular to the surface.
50. Electric field lines are perpendicular to equipotential lines.
51. Electric fields between two parallel plates are uniform in strength except at the edges.
52. The electric potential energy increases as a positive charge is moved against the electric field, and it decreases as a negative charge is moved against the same field.
53. The energy gained by a charged particle that is accelerated through a potential difference can be expressed in electronvolts (eV). (1 eV = 1.6×10^{-19} J)
54. The electric potential (V) is equal to the work per unit charge.
55. No work is done in moving a charged object along an equipotential line.
56. Capacitance is the ratio of charge to the potential for a given conductor.
57. The capacitance for a parallel-plate capacitor depends on the surface area of each plate, the plate separation and the permittivity or dielectric constant.

58. A source of electromotive force (*emf*) is a device that converts chemical, mechanical, or other forms of energy into electric energy.
59. Resistance depends on the kind of material (resistivity), the length, cross-sectional area, and temperature. Resistance is proportional to length and inversely proportional to cross-sectional area.
60. All resistors in parallel have equal voltage. Adding a resistor in parallel decreases the total resistance of a circuit.
61. All resistors in series have equal current. Adding a resistor in series increases the total resistance of a circuit.
62. Voltmeters have a high resistance (to keep from drawing current) and are wired in parallel (because voltage is the same in parallel). Ammeters have a low resistance (to keep from reducing the current) and are wired in series (because current is the same in series).
63. Kirchhoff's First Rule: The sum of all the currents entering a junction point equals the sum of all the currents leaving the junction point. This rule is based on the conservation of electric charge.
64. Kirchhoff's Second Rule: The algebraic sum of all the gains and losses of potential around any closed path must equal zero. This rule is based on the law of conservation of energy.
65. All capacitors in parallel have equal voltage. The total charge is equal to the sum of the charges and the effective capacitance is the sum of the individual capacitances.
66. All capacitors in series have equal charge. The potential difference across the battery is equal to the sum of the drops across each capacitor.
67. For circuits that contain capacitors and resistors:
- A capacitor that is empty allows the flow of current such as a wire.
- A capacitor that is full acts like a broken wire.

MAGNETISM

68. Magnetic fields point from the north to the south outside the magnet.
69. A particle entering a magnetic field between two plates will follow a circular path.
The magnetic force provides the centripetal force.
70. Magnetic force on a charged particle is at its maximum when the field and velocity vectors are at right angles. The force is at a minimum (0) when the field and velocity vectors are parallel or antiparallel.
71. Right hand rules are for positive charges, for negative charges the direction is the opposite of the one found with the right hand rule.
72. Moving electric charges (current) creates magnetic field (Oersted), but a *changing* magnetic field creates an electric current (Faraday).
73. Relative motion between a conductor and a magnetic field induces an *emf* in the conductor.
74. The direction of the induced *emf* depends upon the direction of motion of the conductor with respect to the field.
75. The magnitude of the *emf* is directly proportional to the rate at which the conductor cuts magnetic flux lines.
76. According to Lenz's law, the induced current must be in a direction that opposes the change that produced it.

WAVES AND OPTICS

WAVES AND SOUND

77. Transverse wave particles vibrate perpendicular to the wave direction and longitudinal wave particles vibrate parallel to the direction of the wave propagation.
78. Sound waves are mechanical longitudinal waves. Light waves are electromagnetic transverse waves.
79. The speed of a wave depends only on the properties of the medium.
80. The energy of a wave is directly proportional to the square of the amplitude.
81. The intensity of sound is inversely proportional to the distance.
82. Superposition Principle: When two or more waves exist simultaneously in the same medium, the resultant amplitude at any point is the algebraic sum of the amplitudes of each wave.
83. The harmonics produced in open pipes are similar to those produced in strings. The fundamental occurs when the length of the pipe (or string) equals 1/2 λ.
84. The fundamental on a closed pipe occurs when the length of the pipe equals 1/4 λ. Only the odd harmonics are possible for a closed pipe.
85. Whenever two waves exist simultaneously in the same medium and they are nearly at the same frequency, beats are set up.
86. Doppler effect is the apparent change in frequency of a source of sound when there is relative motion of the source and the listener.

GEOMETRICAL AND PHYSICAL OPTICS

87. The wave behavior of light is proven by diffraction, interference and the polarization of light.
88. The particle behavior of light is proven by the photoelectric effect.
89. The electromagnetic spectrum (radio, microwaves, infrared, visible, ultraviolet, x-ray and gamma rays) is listed from lowest frequency to highest (longer to smaller wavelength).
90. The range of wavelengths for visible light goes from 400 nm for violet to 700 nm for red.
91. All angles in reflection and refraction are measured with respect to the normal.
92. At the critical angle a wave will be refracted to 90 degrees.
93. Total internal reflection occurs at angles greater than the critical angle.
94. Light rays bend away from the normal as they enter a lower index of refraction medium while the frequency remains constant.
95. Light bends toward the normal and has a shorter wavelength when it enters a higher index of refraction medium while the frequency remains constant.
96. In Young's double-slit experiment interference and diffraction account for the production of bright and dark fringes.
97. Single slit diffraction produces a much wider central maximum than double slit.
98. Waves in phase undergo constructive interference; waves out of phase (1/2 λ) will undergo destructive interference.
99. When light reflects from a medium with higher index of refraction than that of the medium in which it is traveling, a 180˚ phase change (1/2 λ) occurs.
100. For a single optical device, real images are always inverted and virtual images are always upright.

101. Concave mirrors are converging and convex mirrors are diverging. Concave lenses are diverging and convex lenses are converging.
102. Convex mirrors and concave lenses produce only small virtual images.

ATOMIC AND NUCLEAR PHYSICS

103. The kinetic energy of the ejected electrons is the energy of the incident radiation minus the work function of the surface.
104. Increasing light frequency increases the kinetic energy of the emitted photoelectrons.
105. Increasing light intensity increases the number of emitted photoelectrons but not their kinetic energy.
106. Below a certain frequency, called the threshold frequency no electrons are emitted no matter how intense the light beam.
107. Stopping potential is the voltage needed to stop the emission of electrons and it is equal to the maximum kinetic energy per unit charge.
108. De Broglie proposed that all objects have wavelengths related to their momentum.
19. The lowest energy state of an atom is called the ground state.
110. Emission spectra are photons leaving the atom as electrons come down energy levels. Absorption spectra are photons being absorbed as electrons move up energy levels from the ground state.
111. Alpha particles are the same as helium nuclei: 2 protons, 2 neutrons. Beta particles are electrons, and gamma "particles" are photons.
112. The mass of a nucleus is always less than the sum of the masses of the nucleons. This mass defect is converted into binding energy. ($E=mc^2$) One amu of mass is equal to 931 MeV of energy.
113. Nuclear fusion is a reaction in which two nuclei are combined to form a large nucleus. Fusion is the source of energy in stars.
114. Nuclear fission is a reaction in which a nucleus is split.

CLASSIC EXPERIMENTS

J.J. Thomson
Experimentally measured the charge to mass ratio of cathode rays.
Ernest Rutherford
The scattering of alpha particles by a thin sheet of gold foil. This experiment demonstrated that atoms consist of mostly empty space with a very dense core, the nucleus.
Neils Bohr
Bohr's planetary model of the atom correctly describes the spectra of hydrogen.
R.A. Millikan
Millikan's oil drop experiment confirmed that the fundamental electric charge is quantized.
Hertz and Einstein
The photoelectric effect was first observed by Hertz and later explained by Einstein. Einstein obtained a Nobel Prize for the mathematical description of the photoelectric effect.

A.H. Compton
The scattering of x-rays photons provided the final confirmation of the validity of Planck's quantum hypothesis that electromagnetic radiation came in discrete massless packets (photons) with energy proportional to frequency.
Davisson-Germer
Their experiment of the diffraction of electrons demonstrated the wave nature of the electron, confirming the earlier hypothesis of de Broglie.

GRAPHICAL ANALYSIS

Valuable information can be obtained by analyzing graphs.

A. Most common slopes:
1. The slope of a position-time graph gives the velocity.
2. The slope of a velocity-time graph gives the acceleration.
3. The slope of a force-elongation graph gives the spring constant.
4. For Ohmic materials the slope of a voltage-current graph gives the resistance.
5. The slope of a charge-voltage graph for a capacitor is its capacitance.
6. The slope of a sine incident angle-sine refracted angle graph gives the index of refraction.
7. The slope of a kinetic energy maximum-frequency graph gives Planck's constant.

B. Most common areas under the curve:
8. The area under the curve of a velocity-time graph gives the displacement.
9. The area under the curve of an acceleration-time graph gives the change in velocity.
10. The area under the curve of a force-time graph gives the impulse (change in momentum).
11. The area under the curve of a force-distance graph gives the work done.
12. The area under the curve of a pressure-volume graph gives the work done by the gas.
13. The area under a charge-voltage graph is the work required to charge the capacitor i.e. energy stored.

C. Most common intercepts:
14. For two resistors in parallel, the intercepts of the $1/R_1 - 1/R_2$ graph give the effective resistance.
15. For mirrors or lenses, the intercepts of the $1/d_0 - 1/d_i$ graph give the focal length.
16. The x-intercept of a kinetic energy maximum-frequency graph gives the threshold frequency.
17. The y-intercept of a kinetic energy maximum-frequency graph gives the work function.

BASE AND DERIVED UNITS

MEASUREMENT	UNIT	SYMBOL	EXPRESSED IN BASE UNITS	EXPRESSED IN OTHER SI UNITS
Acceleration		m/s^2	m/s^2	
Capacitance	Farad	F	$A^2.s^4/kg.m^2$	C/V
Current	Ampere	A		C/s
Electric charge	Coulomb	C	A.s	
Electric field		N/C	$kg.m/C.s^2$	V/m
Electric resistance	Ohm	Ω	$kg.m^2/A^2.s^3$	V/A
Energy, work	Joule	J	$kg.m^2/s^2$	N.m
Emf, voltage	Volt	V	$kg.m^2/A.s^3$	
Force	Newton	N	$kg.m/s^2$	
Frequency	Hertz	Hz	s^{-1}	
Magnetic field	Tesla	T	$kg/A.s^2$	N.s/C.m or Wb/m^2
Magnetic flux	Weber	Wb	$kg.m^2/A.s^2$	V.s
Pressure	Pascal	Pa	kg/ms^2	N/m^2
Potential difference	Volt	V	$kg.m^2/A.s^3$	W/A or J/C
Power	Watt	W	$Kg.m^2/s^3$	J/s

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Special thanks to Bill Pappas