Student Worksheet for 1-D Kinematics

After you've worked through the sample problems in the videos, you can work out the problems below to practice doing this yourself. Answers are given on the last page.

Kinematic Equations:

$x_f - x_i = v_i t + ½\ at^2$ OR $d = v_i + ½\ at^2$

$v_f^2 = v_i^2 + 2a(x_f - x_i)$ OR $v_f^2 = v_i^2 + 2ad$

$x_f - x_i = ½\ (v_f + v_i)t$ OR $d= ½\ (v_f + v_i)t$

$v_f = v_i + at$ (Where: t=time, d=displacement, x=position, v=velocity, a=acceleration, i=initial, f= final)

Practice Problems:

1. A professional baseball pitcher is trying to get his fastball across home plate as fast as possible, and the plate is 60.5 feet away. If the ball leaves the pitcher's hand at 94 mph and maintains this speed across the plate, how long does it take the ball to cross the plate?

2. A runner warms up by walking 100 meters at 0.5 m/s, and then runs 100 meters at 9.3 m/s. What is the runner's average speed?

3. A motocross rider goes up a hill at 30 mph and then returns down the hill at 50 mph. What is the average speed for the trip?

4. A rocket accelerates at 9.6 kph per second. What is its acceleration in m/s^2?

5. A snowboarder is attempting to clear a gap after a jump, and it is known that he must be travelling at least 34 mph to clear the gap. If the distance from the start of hill to the jump is 42 yards long, what is the acceleration of the snowboarder if he starts from rest? Please express your answer in ft/s^2. (Hint: 1760 yards = 1 mile)

6. An aircraft landing on an aircraft carrier is assisted in landing on a short runway through the use of cables on the carrier and hooks on the aircraft. If the airplane is flying at a velocity of 322 ft/s and the aircraft stops in 1.25 seconds, find the acceleration of the aircraft and express the value in *g*'s. (Hint: 1 g in English units is 32.2 ft/s^2, so divide your acceleration answer by 32.2)

7. Find the acceleration of a rabbit that increases its speed constantly from 10 to 25 kph in 5 seconds, and then compare it to a bird who speeds up uniformly from rest to 20 kph in the same amount of time.

8. The maximum acceleration for an Amtrak train with passengers is 64 kph per second. If the distance between stops is 1.6 kilometers, what is the maximum speed attained by the train and how much time has passed in between stops?

9. At a construction site, a wrench strikes the ground with a speed of 24 m/s. From what height was it dropped, and how long did it fall?

10. A penny is dropped from a tall building in New York that is 234 feet tall. If air resistance is ignored, at what speed will the penny hit the ground?

11. A potato is launched vertically into the air and reaches a height of 33.7m in 2.17 seconds. What was the potato's initial speed? What will be the potato's maximum height?

12. A hammer is dropped from a roof with a height of 12 feet. It is hits the ground and remains in contact with the ground for 0.025 seconds before coming to rest. What is the average acceleration of the hammer during its contact with the ground? Assume the hammer does not bounce on contact with the ground.

13. A bouncy ball is bounced straight up, and has a vertical velocity of 10 m/s at height of 75m above the ground. How long will it take the bouncy ball to come back to the ground and at what speed does the ball hit the ground?

14. A pilot ejects from his aircraft and falls 60m from the ground without friction. When he opens his parachute, he decelerates at 2.5 m/s^2. The pilot hits the ground at a speed of 4 m/s. How long was the pilot in the air and at what height did he begin his fall?

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After you've worked through the sample problems in the videos, you can work out the problems below to practice doing this yourself. Answers are given on the last page.

Kinematic Equations:

$x_f - x_i = v_i t + \frac{1}{2} a t^2$ OR $d = v_i + \frac{1}{2} a t^2$

$v_f^2 = v_i^2 + 2a(x_f - x_i)$ OR $v_f^2 = v_i^2 + 2ad$

$x_f - x_i = \frac{1}{2}(v_f + v_i)t$ OR $d = \frac{1}{2}(v_f + v_i)t$

$v_f = v_i + at$ (Where: t=time, d=displacement, x=position, v=velocity, a=acceleration, i=initial, f= final)

Practice Problems:

1. A professional baseball pitcher is trying to get his fastball across home plate as fast as possible, and the plate is 60.5 feet away. If the ball leaves the pitcher's hand at 94 mph and maintains this speed across the plate, how long does it take the ball to cross the plate?

Given: $x_f = 60.5$ ft Find: t
$v_i = 94$ mph

Solution | This kinematic problem involves simply horizontal movement. Using our equations above, we can find out how long it takes. It should be noted that since our velocity is constant, a = 0 in the horizontal direction.

$x_f - x_i = v_i t + \frac{1}{2} a t^2$ (a = 0) lets convert velocity to ft/s $94 \frac{m}{hr} \cdot \frac{5280 ft}{m} \cdot \frac{1 hr}{60 m} \cdot \frac{1 m}{60 s}$ $V = 138$ ft/s

$t = \frac{x_f - x_i}{v_i}$ $t = \frac{60.5 - 0}{138}$ **t = 0.44 s**

2. A runner warms up by walking 100 meters at 0.5 m/s, and then runs 100 meters at 9.3 m/s. What is the runner's average speed?

Given: $x_1 = 100$ $v_1 = 0.5$ m/s Find: $V_{average}$
$x_2 = 100$ $v_2 = 9.3$ m/s

Solution | Our total distance is 200 meters, we need to first find out how much time is spent in each leg of the distance and divide 200 by that number. acceleration is zero for each leg

leg 1
$d = \frac{1}{2}(v_f + v_i)t$
$t = \frac{2(100)}{(0.5 + 0.5)}$ $t_1 = 200$ s

leg 2
$t = \frac{2(100)}{(9.3 + 9.3)}$ $t_2 = 11$ s

$V_{avg} = \frac{\text{total distance}}{\text{total time}}$

$V_{avg} = \frac{200}{(200 + 11)}$

$V_{avg} = 0.95$ m/s

3. A motocross rider goes up a hill at 30 mph and then returns down the hill at 50 mph. What is the average velocity for the trip?

Given: $V_1 = 30$mph Find: V_{avg}
$V_2 = 50$mph

Solution | Kinematic problem that can be found using simple arithmetic

$$V_{avg} = \frac{30mph + 50mph}{2} \quad V_{avg} = 40 \text{ mph}$$

4. A rocket accelerates at 9.6 kph per second. What is its acceleration in m/s²?

Given: $a = 9.6 \frac{Km}{hr \cdot s}$ Find: a in m/s^2

Solution | Using our conversion transfers and our knowledg of units, this problem can also be solved with algebra.

$$a = 9.6 \frac{Km}{hr \cdot s} \cdot \frac{1000m}{1 Km} \cdot \frac{1 hr}{60 m} \cdot \frac{1 m}{60 s} = 2.67 \frac{m}{s \cdot s} = 2.67 \frac{m}{s^2}$$

5. A snowboarder is attempting to clear a gap after a jump, and it is known that he must be travelling at least 34 mph to clear the gap. If the distance from the start of hill to the jump is 42 yards long, what is the acceleration of the snowboarder if he starts from rest? Please express your answer in ft/s². (Hint: 1760 yards = 1 mile)

Given: $V = 34$mph Find: a solution
$\delta = 42$ yards

We are not given time, so we need an equation without t and we should convert to feets and seconds to ensure unit transfer

$$V = 34 \frac{m}{hr} \cdot \frac{1760 \text{ yards}}{m} \cdot \frac{3 ft}{yard} \cdot \frac{1 hr}{60 m} \cdot \frac{1 m}{60 s} \quad V = 50 \text{ ft/s}$$

$X_f = 42$ yards × 3 feet
$X_f = 126$ feet

Now using
$V_f^2 = V_i^2 + 2a(X_f - X_i)$ we can get $a = \frac{V_f^2}{2X_f}$ $a = \frac{(50)^2}{2(126)}$ $a = 10 \text{ ft/s}^2$
where $V_i = 0$
$X_i = 0$

6. An aircraft landing on an aircraft carrier is assisted in landing on a short runway through the use of cables on the carrier and hooks on the aircraft. If the airplane is flying at a velocity of 322 ft/s and the aircraft stops in 1.25 seconds, find the acceleration of the aircraft and express the value in *g*'s. (Hint: 1 g in English units is 32.2 ft/s², so divide your acceleration answer by 32.2)

Given: $V_i = 322$ ft/s $V_f = 0$ Find: a
$t = 1.25$ s

Solution | Because we only have v & t and we dont know distance, our best bet is using $V_f = V_i + at$. Then after solving for a, we divide by gravities acceleration to get the # of g's

$V_f = V_i + at$ $0 = 322 + a(1.25)$ $a = \frac{-322}{1.25}$ $a = -258$ ft/s²

$g's = \frac{a}{-32.2}$ $g's = \frac{-258}{-32.2}$ **$g's = 8$** ← 8 times the accel. due to gravity

7. Find the acceleration of a rabbit that increases its speed constantly from 10 to 25 kph in 5 seconds, and then compare it to a bird who speeds up uniformly from rest to 20 kph in the same amount of time.

Given: $V_{1i} = 10$ kph $V_{2i} = 0$ $t = 5$ s find: a_1 a_2
$V_{1f} = 25$ kph $V_{2f} = 20$ kph

Solution | using $V_f = V_i + at$, we can find both a_1 and a_2. For convinience, lets convert time to hours

$t = 5s \cdot \frac{1m}{60s} \cdot \frac{1hr}{60m}$ $t = 0.0022$ hours

Rabbit

$25 = 10 + a(0.0022)$

$a_1 = \frac{25-10}{0.0022}$

$a_1 = 6818 \frac{km}{hr^2}$ or 0.53 m/s²

Bird

$20 = 0 + a(0.0022)$

$a_2 = \frac{20}{0.0022}$

$a_2 = 9091 \frac{km}{hr^2}$ or 0.7 m/s²

8. The maximum acceleration for an Amtrak train with passengers is 64 kph per second. If the distance between stops is 1.6 kilometers, what is the maximum speed attained by the train and how much time has passed in between stops?

Given: $a = -64 \frac{K}{hr \cdot s}$, $d = 1.6$ km Find: V_{max} and t

First, unit conversion: $a = -64 \frac{km}{hr \cdot s} \cdot \frac{1000m}{1 km} \cdot \frac{1 hr}{60 min} \cdot \frac{1 min}{60 s}$ $a = -18 \, m/s^2$ ← negative because we are slowing down

$d = 1600$ m

Now we find V using $V_f^2 = V_i^2 + 2ad$ where $V_f = 0$ so $V_i = \sqrt{-2ad}$

$V_i = \sqrt{-2(-18)(1600)}$ $V_i = 240 \, m/s$

Now we find t using $V_f = V_i + at$ ($V_f = 0$), $t = \frac{-V_i}{a}$ → $t = \frac{-240}{-18}$ $t = 13.33$ s

9. At a construction site, a wrench strikes the ground with a speed of 24 m/s. From what height was it dropped, and how long did it fall?

Given: $V_i = 0$, $V_f = 24$ m/s Find: d and t

Because we are dropping something, $a = -9.81 \, m/s^2$, which will help us find d and then t.

$V_f^2 = V_i^2 + 2ad$ ($V_i = 0$)

$d = \frac{V_f^2}{2a}$

$d = \frac{(24)^2}{2(9.81)}$ $d = 29$ meters

now we have d, a, & V, lets get t

$d = \frac{1}{2}(V_f + V_i)t$ so $t = \frac{2d}{V_f + V_i}$

$t = \frac{2(29)}{24 + 0}$ $t = 2.4$ s

10. A penny is dropped from a tall building in New York that is 234 feet tall. If air resistance is ignored, at what speed will the penny hit the ground?

Given: $d = 234$ ft, $a = -32.2 \, ft/s^2$ Find: V

using $V_f^2 = V_i^2 + 2ad$ where $V_i = 0$ (dropped = started from rest) we can find V_f

$V_f = \sqrt{2ad}$

$V_f = \sqrt{2(32.2)(234)}$ $V_f = 123 \, ft/s$

11. A potato is launched vertically into the air and reaches a height of 33.7m in 2.17 seconds. What was the potato's initial speed? What will be the potato's maximum height?

Given: $a = -9.81 m/s^2$ $d = 33.7m$ $t = 2.17s$ Find: V_i and y_{max}

First, lets answer the easy part and find our initial velocity since we know t, d, and a

$d = V_i t + \frac{1}{2}at^2$

$V_i = \frac{d - \frac{1}{2}at^2}{t}$

$V_i = \frac{(33.7) - \frac{1}{2}(-9.81)(2.17)^2}{2.17}$

$V_i = 26 m/s$

Now we need max height, and we know max height is where the potato no longer has any any velocity so our $V_f = 0$ we can use $V_f^2 = V_i^2 + 2ad$ and solve for d

$V_f^2 - V_i^2 = 2ad \Rightarrow d = \frac{V_f^2 - V_i^2}{2a}$

$d = \frac{(0)^2 - (26)^2}{2(-9.81)}$

$d = 34.5$ meters

12. A hammer is dropped from a roof with a height of 12 feet. It is hits the ground and remains in contact with the ground for 0.025 seconds before coming to rest. What is the average acceleration of the hammer during its contact with the ground? Assume the hammer does not bounce on contact with the ground.

Given: $a_1 = -32.2 ft/s^2$ $t_2 = 0.025s$ $d = 12 ft.$ Find: a_2

$V_{1i} = 0 ft/s$

This is a 2 step problem, we need the velocity right before impact so we can then solve for the acceleration.

$V_f^2 = V_i^2 + 2a_1 d$

$V_f^2 = 0 + 2(-32.2)(12)$

$V_f = -\sqrt{2(32.2)(12)}$

$V_f = -28 ft/s$

Now we have the velocity when the hammer hits the ground. Now using our time increment and knowing our new $V_i = -28 ft/s$ and we end at rest ($V_f = 0$) we can use $V_f = V_i + at$

$a = \frac{V_f - V_i}{t}$ $a = \frac{0 - (-28)}{0.025}$

$a = 1120 ft/s^2$

13. A bouncy ball is bounced straight up, and has a vertical velocity of 10 m/s at height of 75m above the ground. How long will it take the bouncy ball to come back to the ground and at what speed does the ball hit the ground?

Given: $V_i = 10$ m/s, $d = 75$ m, $a = -9.81$ m/s² Find: V_f and t

First we need to find the max height of the ball on its way up

$V_f^2 = V_i^2 + 2ad$

$d = \frac{V_f^2 - V_i^2}{2a}$

$d = \frac{0^2 - (10)^2}{2(-9.81)}$

$d = 5.1$ m

So our final distance is 75m + 5.1m = 80.1m

Now we use the same equation to find V_f

$V_f^2 = V_i^2 + 2ad$

$V_f = \sqrt{0^2 + 2(9.81)(80.1)}$

$V_f = 40$ m/s

Now we can find time

$V_f = V_i + at$

$t = \frac{V_f - V_i}{a}$

$t = \frac{40 - 0}{9.81}$

$t = 4.04$ s

14. A pilot ejects from his aircraft and falls 60m from the ground without friction. When he opens his parachute, he decelerates at 2.5 m/s². The pilot hits the ground at a speed of 4 m/s. How long was the pilot in the air and at what height did he begin his fall?

Given: $d_1 = 60$ m, $a_1 = 2.5$ m/s² Find: t and d for the trip

Three Part Problem, first lets find the time before the parachute is deployed. Assume $V_i = 0$ when he ejects from the plane

$d = V_i^{0} + \frac{1}{2}at^2$

$t = \sqrt{\frac{2d}{a}}$

$t = \sqrt{\frac{2(60)}{9.81}}$

$t = 3.5$ s

Now we need the velocity at this point of parachute deployment

$V_f = V_i + at$

$V_f = 0 + 9.81(3.5)$

$V_f = 34$ m/s

Now we can find the time taken to reach the ground using $V_i = 34$ m/s, $V_f = 4$ m/s, $a = 2.5$ m/s²

$V_f = V_i + at$

$t = \frac{V_f - V_i}{a}$

$t = \frac{4 - 34}{-2.5}$

$t = 12$ s

So our total time is

$t = 15.5$ s

Now we get distance

$d = V_i + \frac{1}{2}at^2$

$d = 34 + \frac{1}{2}(2.5)(15.5_s)$

$d = 53$ m

So we started from 53m + 60m

$d = 113$ m

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS			
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude,	$e = 1.60 \times 10^{-19}$ C
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$

UNIT SYMBOLS								
	meter,	m	kelvin,	K	watt,	W	degree Celsius,	°C
	kilogram,	kg	hertz,	Hz	coulomb,	C		
	second,	s	newton,	N	volt,	V		
	ampere,	A	joule,	J	ohm,	Ω		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.

II. Assume air resistance is negligible unless otherwise stated.

III. In all situations, positive work is defined as work done <u>on</u> a system.

IV. The direction of current is conventional current: the direction in which positive charge would drift.

V. Assume all batteries and meters are ideal unless otherwise stated.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS, EFFECTIVE 2015

MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x (x - x_0)$

$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$\left|\vec{F}_f\right| \le \mu \left|\vec{F}_n\right|$

$a_c = \frac{v^2}{r}$

$\vec{p} = m\vec{v}$

$\Delta\vec{p} = \vec{F}\,\Delta t$

$K = \frac{1}{2} m v^2$

$\Delta E = W = F_{\parallel} d = Fd\cos\theta$

$P = \frac{\Delta E}{\Delta t}$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$x = A\cos(2\pi f t)$

$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$\tau = r_{\perp} F = rF\sin\theta$

$L = I\omega$

$\Delta L = \tau\,\Delta t$

$K = \frac{1}{2} I \omega^2$

$\left|\vec{F}_s\right| = k\left|\vec{x}\right|$

$U_s = \frac{1}{2} k x^2$

$\rho = \frac{m}{V}$

a = acceleration
A = amplitude
d = distance
E = energy
f = frequency
F = force
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
V = volume
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
ρ = density
τ = torque
ω = angular speed

$\Delta U_g = mg\,\Delta y$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$\left|\vec{F}_g\right| = G\frac{m_1 m_2}{r^2}$

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

$U_G = -\frac{G m_1 m_2}{r}$

ELECTRICITY

$\left|\vec{F}_E\right| = k\left|\frac{q_1 q_2}{r^2}\right|$

$I = \frac{\Delta q}{\Delta t}$

$R = \frac{\rho \ell}{A}$

$I = \frac{\Delta V}{R}$

$P = I\,\Delta V$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

A = area
F = force
I = current
ℓ = length
P = power
q = charge
R = resistance
r = separation
t = time
V = electric potential
ρ = resistivity

WAVES

$\lambda = \frac{v}{f}$

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2} bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

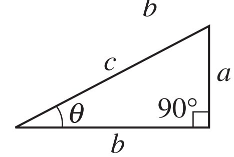
Rectangular solid
$V = \ell w h$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r \ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$



ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, $1\text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Universal gas constant, $R = 8.31$ J/(mol•K)	Acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}\text{ kg} = 931\ \text{MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s} = 4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25}\ \text{J}\cdot\text{m} = 1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^{5}\ \text{N/m}^2 = 1.0 \times 10^{5}\ \text{Pa}$

UNIT SYMBOLS								
meter,	m	mole,	mol	watt,	W	farad,	F
kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
second,	s	newton,	N	volt,	V	degree Celsius,	°C
ampere,	A	pascal,	Pa	ohm,	Ω	electron volt,	eV
kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. In all situations, positive work is defined as work done on a system.
III. The direction of current is conventional current: the direction in which positive charge would drift.
IV. Assume all batteries and meters are ideal unless otherwise stated.
V. Assume edge effects for the electric field of a parallel plate capacitor unless otherwise stated.
VI. For any isolated electrically charged object, the electric potential is defined as zero at infinite distance from the charged object.

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$|\vec{F}_f| \le \mu |\vec{F}_n|$

$a_c = \frac{v^2}{r}$

$\vec{p} = m\vec{v}$

$\Delta\vec{p} = \vec{F}\,\Delta t$

$K = \frac{1}{2}mv^2$

$\Delta E = W = F_{\parallel}d = Fd\cos\theta$

$P = \frac{\Delta E}{\Delta t}$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$x = A\cos(\omega t) = A\cos(2\pi f t)$

$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$

$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$\tau = r_{\perp}F = rF\sin\theta$

$L = I\omega$

$\Delta L = \tau\,\Delta t$

$K = \frac{1}{2}I\omega^2$

$|\vec{F}_s| = k|\vec{x}|$

a = acceleration
A = amplitude
d = distance
E = energy
F = force
f = frequency
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed

$U_s = \frac{1}{2}kx^2$

$\Delta U_g = mg\,\Delta y$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$|\vec{F}_g| = G\frac{m_1 m_2}{r^2}$

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

$U_G = -\frac{Gm_1 m_2}{r}$

ELECTRICITY AND MAGNETISM

$|\vec{F}_E| = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2}$

$\vec{E} = \frac{\vec{F}_E}{q}$

$|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$

$\Delta U_E = q\Delta V$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$|\vec{E}| = \left|\frac{\Delta V}{\Delta r}\right|$

$\Delta V = \frac{Q}{C}$

$C = \kappa\varepsilon_0\frac{A}{d}$

$E = \frac{Q}{\varepsilon_0 A}$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$

$I = \frac{\Delta Q}{\Delta t}$

$R = \frac{\rho\ell}{A}$

$P = I\,\Delta V$

$I = \frac{\Delta V}{R}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = separation
t = time
U = potential (stored) energy
V = electric potential
v = speed
κ = dielectric constant
ρ = resistivity
θ = angle
Φ = flux

$\vec{F}_M = q\vec{v} \times \vec{B}$

$|\vec{F}_M| = |q\vec{v}||\sin\theta||\vec{B}|$

$\vec{F}_M = I\vec{\ell} \times \vec{B}$

$|\vec{F}_M| = |I\vec{\ell}||\sin\theta||\vec{B}|$

$\Phi_B = \vec{B} \bullet \vec{A}$

$\Phi_B = |\vec{B}|\cos\theta|\vec{A}|$

$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t}$

$\mathcal{E} = B\ell v$

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

FLUID MECHANICS AND THERMAL PHYSICS

$$\rho = \frac{m}{V}$$

$$P = \frac{F}{A}$$

$$P = P_0 + \rho g h$$

$$F_b = \rho V g$$

$$A_1 v_1 = A_2 v_2$$

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

$$\frac{Q}{\Delta t} = \frac{kA\,\Delta T}{L}$$

$$PV = nRT = Nk_BT$$

$$K = \frac{3}{2}k_BT$$

$$W = -P\,\Delta V$$

$$\Delta U = Q + W$$

A = area
F = force
h = depth
k = thermal conductivity
K = kinetic energy
L = thickness
m = mass
n = number of moles
N = number of molecules
P = pressure
Q = energy transferred to a system by heating
T = temperature
t = time
U = internal energy
V = volume
v = speed
W = work done on a system
y = height
ρ = density

MODERN PHYSICS

$$E = hf$$

$$K_{max} = hf - \phi$$

$$\lambda = \frac{h}{p}$$

$$E = mc^2$$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

WAVES AND OPTICS

$$\lambda = \frac{v}{f}$$

$$n = \frac{c}{v}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$$

$$|M| = \left|\frac{h_i}{h_o}\right| = \left|\frac{s_i}{s_o}\right|$$

$$\Delta L = m\lambda$$

$$d\sin\theta = m\lambda$$

d = separation
f = frequency or focal length
h = height
L = distance
M = magnification
m = an integer
n = index of refraction
s = distance
v = speed
λ = wavelength
θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$$A = bh$$

Triangle
$$A = \frac{1}{2}bh$$

Circle
$$A = \pi r^2$$
$$C = 2\pi r$$

Rectangular solid
$$V = \ell wh$$

Cylinder
$$V = \pi r^2 \ell$$
$$S = 2\pi r\ell + 2\pi r^2$$

Sphere
$$V = \frac{4}{3}\pi r^3$$
$$S = 4\pi r^2$$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$$c^2 = a^2 + b^2$$
$$\sin\theta = \frac{a}{c}$$
$$\cos\theta = \frac{b}{c}$$
$$\tan\theta = \frac{a}{b}$$