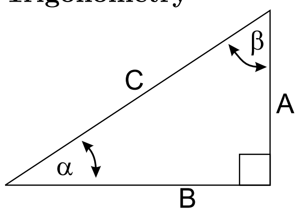
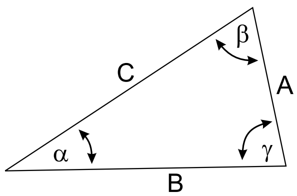
Quadratic Formula
$ax^2 + bx + c = 0,$
$x = [-b \pm \sqrt{b^2 - 4ac}]/(2a)$
Geometry
Circle: circumference=$2\pi R$, area=πR^2
Sphere: area=$4\pi R^2$, volume=$4\pi R^3/3$
Trigonometry



$$\sin\alpha = \frac{A}{C}, \quad \cos\alpha = \frac{B}{C}$$
$$\tan\alpha = \frac{A}{B}$$



$$\frac{\sin\alpha}{A} = \frac{\sin\beta}{B} = \frac{\sin\gamma}{C}$$
$$A^2 + B^2 - 2AB\cos\gamma = C^2$$

Polar Coordinates
$x = r\cos\theta, \quad y = r\sin\theta$
$r = \sqrt{x^2 + y^2}, \quad \tan\theta = y/x$
SI Units and Constants

quantity	unit	abbreviation
Mass m	kilograms	kg
Distance x	meters	m
Time t	seconds	s
Force F	Newtons	N=kg m/s^2
Energy E	Joules	J=N m
Power P	Watts	W=J/s
Temperature T	°C, °K or °F	$T_{\circ F} = 32 + (9/5)T_{\circ C}$
Pressure P	Pascals	Pa=N/m^2

1 cal=4.1868 J, 1 hp=745.7 W
$g = 9.81$ m/s^2, G=6.67×10^{-11} Nm^2/kg^2
0°C=273.15°K, $N_A = 6.023 \times 10^{23}$
$R = 8.31$ J/(mol°K), $k_B = R/N_A = 1.38 \times 10^{-23}$ J/°K
$\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4)
$v_{\rm sound} = 331\sqrt{T/273}$ m/s
H_20: $c_{\rm ice,liq.,steam}$=$\{0.5, 1.0, 0.48\}$ cal/g°C
$L_{F,V}$=$\{80, 540\}$ cal/g, $\rho = 1.0$ g/cm^3.

1-d motion, constant a
$x = (1/2)(v_0 + v_f)t$
$v_f = v_0 + at$
$x = v_0 t + (1/2)at^2$
$x = v_f t - (1/2)at^2$
$(1/2)v_f^2 - (1/2)v_0^2 = ax$
Momentum, Force and Impulse
$p = mv, \ F = ma = \Delta p/\Delta t$
$I = F\Delta t = \Delta p$
Friction: $F_{\rm fric} = \mu N$
Spring: $F = -kx$

Work, Energy and Power
$W = Fx\cos\theta, KE = (1/2)mv^2, \ P = \Delta E/\Delta t = Fv$
Spring: $PE = (1/2)kx^2$
Rotational Motion
$v = \omega r = 2\pi r/T, \quad \omega = \Delta\theta/\Delta t = 2\pi f = 2\pi/T, f = 1/T$
$\alpha = (\omega_f - \omega_0)/t = \frac{a}{r}$
$L = I\omega = mvr\sin\theta$, ($\theta$= angle between v and r)
$KE = (1/2)I\omega^2 = L^2/(2I)$
$\tau = rF\sin\theta, \ I\alpha = \tau, \ I_{\rm point} = mR^2$
$I_{\rm cyl.shell} = MR^2, \ I_{\rm sphere} = (2/5)MR^2$
$I_{\rm solid\ cyl.} = (1/2)MR^2, \ I_{\rm sph.\ shell} = (2/3)MR^2$
$a = v^2/r = \omega v = \omega^2 r$
Gravity and circular orbits
$PE = -G\frac{Mm}{r}, \ \Delta PE = mgh$(small h)
$$F = G\frac{Mm}{r^2}, \quad \frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$
Gases, liquids and solids
$P = F/A, \ PV = NRT, \ \Delta P = \rho gh$
$\langle(1/2)mv^2\rangle = (3/2)k_BT$
$F_{\rm bouyant} = \rho_{\rm displaced\ liq.}V_{\rm displaced\ liq.}g$
Stress $= F/A$, Strain $= \Delta L/L$, $Y =$ Stress/Strain
$\frac{\Delta L}{L} = \frac{F/A}{Y}, \frac{\Delta V}{V} = \frac{-\Delta P}{B}, Y = 3B$
Bernoulli: $P_a + \frac{1}{2}\rho_a v_a^2 + \rho_a g h_a = P_b + \frac{1}{2}\rho_b v_b^2 + \rho_b g h_b$
Heat
$\Delta L/L = \alpha\Delta T, \ \Delta V/V = 3\alpha\Delta T$
$Q = mC_v\Delta T + mL$(if phase trans.)
Conduction and Radiation
$P = kA(T_b - T_a)/\Delta x = A(T_b - T_a)/R,$
$R \equiv \Delta x/k, \ P = e\sigma AT^4$
Thermodynamics
$\Delta U = Q + W, \quad W = -P\Delta V$, ideal gas: $\Delta U = nC_V\Delta T$
Adiabatic exp: pV^γ =const, $TV^{\gamma-1}$ =const
$\gamma = C_p/C_V$=5/3 (monotonic), =7/5 (diatomic)
$Q = T\Delta S, \ \Delta S > 0$
Engines: $W = |Q_H| - |Q_L|$
$\epsilon = W/Q_H < (T_H - T_L)/T_H < 1$
Refrigerators and heat pumps: $W = |Q_H| - |Q_L|$
$\epsilon = Q_L/W < T_L/(T_H - T_L)$
Simple Harmonic Motion and Waves
$f = 1/T, \omega = 2\pi f$
$x(t) = A\cos(\omega t - \phi), \ v = -\omega A\sin(\omega t - \phi)$
$a = -\omega^2 A\cos(\omega t - \phi)$
Spring: $\omega = \sqrt{k/m}$
Pendulum: $T = 2\pi\sqrt{L/g}$
Waves: $y(x,t) = A\sin[2\pi(ft - x/\lambda + \delta)], \ v = f\lambda$
$I = {\rm const}A^2f^2, \ I_2/I_1 = R_1^2/R_2^2$
Standing waves: $\lambda_n = 2L/n$
Strings: $v = \sqrt{T/\mu}$
Solid/Liquid: $v = \sqrt{B/\rho}$
Sound: $I = {\rm Power}/A = I_0 10^{\beta/10}, \ I_0 \equiv 10^{-12}$ W/m^2
Decibels: $\beta = 10\log_{10}(I/I_0)$
Beat freq.=$|f_1 - f_2|$
Doppler: $f_{\rm obs} = f_{\rm source}(V_{\rm sound} \pm v_{\rm obs})/(V_{\rm sound} \pm v_{\rm source})$
Pipes: same at both ends: $L = \lambda/2, \lambda, 3\lambda/2$
Pipes: open at only one end: $L = \lambda/4, 3\lambda/4, 5\lambda/4\cdots$

$\boxed{\textit{2 pt}}$ From dimensional analysis, mark these formulas as either 'valid' or 'invalid'. Assume that x has dimensions of distance, v has dimensions of velocity, t has dimensions of time, g has dimensions of acceleration and m has dimensions of mass.

▷ $m(x + vt)/(1 + gt) = mgt^2/2$
1. **A**◯ valid **B**◯ invalid

▷ $vt/x = 7/2$
2. **A**◯ valid **B**◯ invalid

$\boxed{\textit{4 pt}}$ A student hurls a baseball directly upward with an initial speed of 40 m/s. Later, the student catches the baseball at the same position from which it was released. For the following statements, displacements are measured relative to the release point and the upward direction is positive.

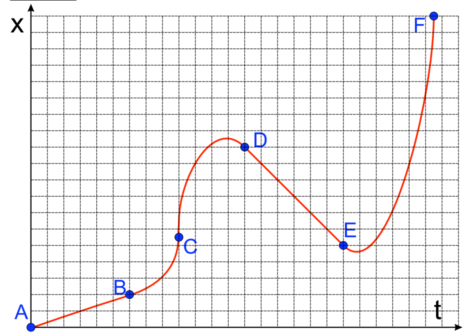
▷ At its highest point, the baseball has zero acceleration.
3. **A**◯ True **B**◯ False

▷ At its highest point, the baseball has zero velocity.
4. **A**◯ True **B**◯ False

▷ During the entire flight, the velocity of the baseball is positive or zero.
5. **A**◯ True **B**◯ False

▷ During the entire flight, the displacement of the baseball is positive or zero.
6. **A**◯ True **B**◯ False

$\boxed{\textit{4 pt}}$ Consider the plot of position vs. time below.

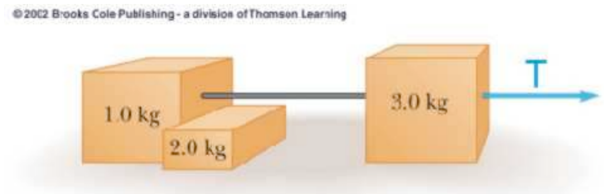


▷ The acceleration is negative in region ____.
7. **A**◯ AB **B**◯ CD **C**◯ DE **D**◯ EF

▷ The velocity is uniform and positive in region ____.
8. **A**◯ AB **B**◯ CD **C**◯ DE **D**◯ EF

▷ The acceleration is positive in region ____.
9. **A**◯ AB **B**◯ CD **C**◯ DE **D**◯ EF

▷ The velocity is uniform and negative in region ____.
10. **A**◯ AB **B**◯ CD **C**◯ DE **D**◯ EF



1 pt

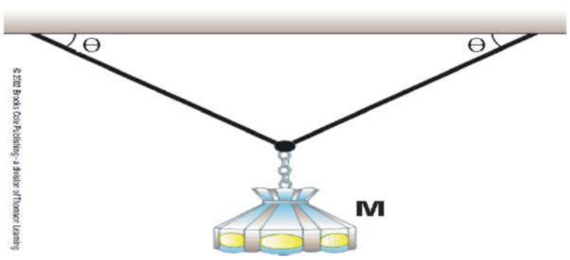
Assume that the three blocks in the figure move together on a frictionless surface and that a T=35 N force acts as shown on the 3.0-kg block. What is the tension in the cord connecting the 3.0-kg and the 1.0-kg blocks? *(in* `N`*)*

11.A◯ 9.50 **B**◯ 10.73 **C**◯ 12.13 **D**◯ 13.71
E◯ 15.49 **F**◯ 17.50 **G**◯ 19.77 **H**◯ 22.35

---

1 pt A ball is pushed down a hill with an initial velocity of 2.1 m/s. It accelerates down hill with a uniform acceleration of 2.2 m/s^2. The ball reaches the bottom of the hill in 11 seconds. What is its speed when it reaches the bottom of the hill? *(in* `m/s`*)*

12.A◯ 16.1 **B**◯ 18.2 **C**◯ 20.6 **D**◯ 23.3
E◯ 26.3 **F**◯ 29.7 **G**◯ 33.6 **H**◯ 37.9



1 pt

A lamp is hung as shown where the angle of the support wires is θ=45 degrees. If the maximum tension either wire can handle is 45 lbs, what is the maximum weight of a lamp that can be supported? (in lbs)

13.A◯ 40.7 **B**◯ 50.9 **C**◯ 63.6 **D**◯ 79.5
E◯ 99.4 **F**◯ 124.3 **G**◯ 155.4 **H**◯ 194.2

---

1 pt Nolan Ryan throws a rock horizontally from the roof of a tall building with an initial speed of 35 m/s. The rock travels a horizontal distance of 68 m before it hits the ground. From what height (above the ground) was the ball released? *(in* `m`*)*

14. **A**◯ 5.92 **B**◯ 7.87 **C**◯ 10.47 **D**◯ 13.92
E◯ 18.51 **F**◯ 24.62 **G**◯ 32.75 **H**◯ 43.56

1 pt After landing, a jet airplane comes to rest uniformly (the acceleration is constant) in 9.1 seconds. The landing speed of the aircraft is 188 km/hour. How far, in m, does the aircraft roll?

15. **A**◯ 173.7 **B**◯ 203.2 **C**◯ 237.8 **D**◯ 278.2
E◯ 325.5 **F**◯ 380.9 **G**◯ 445.6 **H**◯ 521.4

1 pt Just as the star ship Enterprise enters the Klingon sector, a Klingon ship is sighted. The Enterprise immediately accelerates in the same direction with a constant acceleration equal to 0.11 light-years/s^2. The Enterprise leaves the sector 73 seconds later with a velocity of 36.5 light-years/s. What distance did the Enterprise travel through the sector? (In light-years)

16. **A**◯ 1341 **B**◯ 1783 **C**◯ 2371 **D**◯ 3154
E◯ 4195 **F**◯ 5579 **G**◯ 7420 **H**◯ 9869

1 pt A pick-up truck carries a heavy crate in the back. The coefficient of static friction between the crate and the bed of the truck is 0.23. What is the maximum acceleration the truck can undergo without the crate sliding? *(in* `m/s^2`*)*

17. **A**◯ 1.81 **B**◯ 2.26 **C**◯ 2.82 **D**◯ 3.53
E◯ 4.41 **F**◯ 5.51 **G**◯ 6.89 **H**◯ 8.61

| *1 pt* | Goodyear Tire and Rubber Company wants to measure the coefficient of friction for a new miracle rubber compound by sliding a block down an inclined plane, where the surface of the block is coated with the new compound. If the block slides at constant velocity down the plane when the plane is inclined at an angle of 49 degrees, what is the kinetic coefficient of friction?

18. **A**◯ 0.45 **B**◯ 0.52 **C**◯ 0.61 **D**◯ 0.72
E◯ 0.84 **F**◯ 0.98 **G**◯ 1.15 **H**◯ 1.35

| *1 pt* | An airplane is on course to move due east (relative to the earth) despite a wind of 45 m/s which is blowing from the north. The plane is observed to have a ground speed of 143.1 m/s. What would the speed of the plane be if there were no wind? (in m/s)

19. **A**◯ 93.7 **B**◯ 109.6 **C**◯ 128.2 **D**◯ 150.0
E◯ 175.5 **F**◯ 205.3 **G**◯ 240.2 **H**◯ 281.1

| *1 pt* | A rocket, starting from rest, experiences a uniform acceleration of 15.5 m/s^2. What is its speed at the point where its displacement from its original location is 950 m? *(in* `m/s`*)*

20. **A**◯ 171.6 **B**◯ 248.8 **C**◯ 360.8
D◯ 523.2 **E**◯ 758.6 **F**◯ 1100.0
G◯ 1595.0 **H**◯ 2312.7