Intro Physics Semester I **Name:**

Homework 7: Energy: One or two or no full answer questions will be marked. There will also be a mark for completeness. Homeworks are due usually the day after the chapter they are for is finished. Solutions will be posted soon thereafter. The solutions are intended to be (but not necessarily are) super-perfect and often go beyond a fully correct answer.

Answer Table

Name:

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	31.	O	O	O	O	O
2.	O	O	O	O	O	32.	O	O	O	O	O
3.	O	O	O	O	O	33.	O	O	O	O	O
4.	O	O	O	O	O	34.	O	O	O	O	O
5.	O	O	O	O	O	35.	O	O	O	O	O
6.	O	O	O	O	O	36.	O	O	O	O	O
7.	O	O	O	O	O	37.	O	O	O	O	O
8.	O	O	O	O	O	38.	O	O	O	O	O
9.	O	O	O	O	O	39.	O	O	O	O	O
10.	O	O	O	O	O	40.	O	O	O	O	O
11.	O	O	O	O	O	41.	O	O	O	O	O
12.	O	O	O	O	O	42.	O	O	O	O	O
13.	O	O	O	O	O	43.	O	O	O	O	O
14.	O	O	O	O	O	44.	O	O	O	O	O
15.	O	O	O	O	O	45.	O	O	O	O	O
16.	O	O	O	O	O	46.	O	O	O	O	O
17.	O	O	O	O	O	47.	O	O	O	O	O
18.	O	O	O	O	O	48.	O	O	O	O	O
19.	O	O	O	O	O	49.	O	O	O	O	O
20.	O	O	O	O	O	50.	O	O	O	O	O
21.	O	O	O	O	O	51.	O	O	O	O	O
22.	O	O	O	O	O	52.	O	O	O	O	O
23.	O	O	O	O	O	53.	O	O	O	O	O
24.	O	O	O	O	O	54.	O	O	O	O	O
25.	O	O	O	O	O	55.	O	O	O	O	O
26.	O	O	O	O	O	56.	O	O	O	O	O
27.	O	O	O	O	O	57.	O	O	O	O	O
28.	O	O	O	O	O	58.	O	O	O	O	O
29.	O	O	O	O	O	59.	O	O	O	O	O
30.	O	O	O	O	O	60.	O	O	O	O	O

1. Five special forces in physics are:

   a) gravitational force, normal force, tension, friction force, and the linear force (the Hooke's law force).
   b) gravitational force, normal force, tension, friction force, and left force (the Captain Hooke's law force).
   c) gravitational force, normal force, tension, friction force, and right force.
   d) gravitational force, normal force, tension, friction force, and air force.
   e) gravitational force, normal force, tension, friction force, and **the Force**.

2. In one dimension, the linear force formula is:

   a) $F = -kx^2$. b) $F = kx$. c) $F = -kx$. d) $F = kx^2$. e) $F = k/x^2$.

3. If you double the force constant of a simple harmonic oscillator, the period changes by a factor of:

   a) $1/2$. b) $\sqrt{2}$. c) 2. d) $1/\sqrt{2}$. e) $2/3$.

4. "Let's play *Jeopardy*! For $100, the answer is: Admitting that all short definitions of it are inadequate, one can suggest that it is the conserved essence of structure and transformability. 'Converved' means that the quantity that is neither created nor destroyed. In this case, all forms of the quantity must be summed to have conservation in general though in special cases conservation may hold for a subset of forms. 'Essence of structure' means that the quantity is a general measure of structure, but it does not describe details of structure. 'Structure' is used here in a very general sense to mean the ordering of objects, particles, fields, and motions. 'Essence of transformability' means that the quantity can be transformed into different forms of itself and that all changes in the amounts of the forms result in changes in structure. If you have some of the quantity, transformations are possible. Knowing which ones occur requires more detailed information."

   What is ____________, Alex?

   a) force b) momentum c) angular momentum d) potential e) energy

5. "Let's play *Jeopardy*! For $100, the answer is: A useful, but incomplete definition, is the quantified capacity for change."

   What is ____________, Alex?

   a) momentum b) force c) potential d) energy e) aspiration

6. "Let's play *Jeopardy*! For $100, the answer is: It has been described as that property of something that enables that something to do work."

   What is ____________, Alex?

   a) inevitability b) noise c) tension d) gravity e) energy

7. The principle of conservation of energy is that energy is never:

   a) adequately defined. b) destroyed, but can be created. c) created or destroyed.
   d) created, but can be destroyed. e) destroyed.

8. The total energy of a closed system (i.e., a system which nothing enters or leaves) is:

   a) conserved. b) annihilated. c) created. d) combusted. e) eviscerated.

9. The physical dimensions of energy are:

   a) $\mathrm{ML^2/T^2}$. b) $\mathrm{ML/T^2}$. c) $\mathrm{ML^2}$. d) $\mathrm{ML^2/T}$. e) $\mathrm{M/T^2}$.

10. The standard SI unit of energy and of work is the:

    a) joule (J). b) newton (N). c) kelvin (K). d) bassingthorp (B).
    e) trufflehunter (T).

11. That one has enough energy for a certain job or transformation that requires energy E is a ______________ condition, but **NOT** a ______________ condition for the job or transformation.

    a) necessary; sufficient b) sufficient; necessary c) inevitable; necessarily so
    d) harmonious; ceremonious e) forbidden; given

12. "Let's play *Jeopardy*! For \$100, the answer is: Because of its protean nature, energy is very much like this thing in everyday human life which, however, unlike energy is not conserved."

    What is/are ____________, Alex?

    a) furs b) assignats c) shells d) gold e) money

13. "Let's play *Jeopardy*! For \$100, the answer is: In physics, it is a macroscopic process of energy transfer."

    What is ____________, Alex?

    a) energy b) work c) force d) weight e) sloth

14. The differential work formula is:

    a) $dW = \vec{F}\,d\vec{s}$. b) $dW = \vec{F}\cdot d\vec{s}$. c) $dW = \vec{F}/d\vec{s}$. d) $dW = F\,ds$. e) $dW = \vec{F}\times d\vec{s}$.

15. A constant force $\vec{F}$ acts on a body while that body moves a distance $\Delta\vec{r}$. The work W done on the body by the force is given by:

    a) $W = \vec{F}/\Delta\vec{r}$. b) $W = \vec{F}$. c) $W = \vec{F}\cdot\Delta\vec{r}$. d) $W = \vec{F}\cdot\vec{F}\cdot\Delta\vec{r}$. e) $W = \vec{F}\cdot\Delta\vec{r}\cdot\Delta\vec{r}$.

16. How much work is done by a lifter lifting a 100 kg load straight upward 10 m without acceleration?

    a) 9800 J. b) 100 J. c) 1000 J. d) 10 J. e) 980 J.

17. A person holds 10 kg grouse at 2.0 m above the ground for 30 s. How much macroscopic net work is done by the person on the grouse?

    a) 600 J. b) 20 J. c) 300 J. d) 60 J. e) 0 J.

18. Kinetic energy is:

    a) the energy of **POSITION** with formula $KE = mgy$. b) the energy of **MOTION** with formula $KE = mgy$. c) the energy of **MOTION** with formula $KE = (1/2)mv^2$. d) the energy of **POSITION** with formula $KE = (1/2)mv^2$. e) heat energy.

19. The work-kinetic-energy theorem is:

    a) $KE = \frac{1}{2}mv^2$. b) $\Delta E = W_{\text{non}}$. c) $\Delta KE = W$. d) $\Delta KE = \frac{1}{2}W$.
    e) $\Delta KE = \frac{1}{2}mv^2$.

20. A moving object has initial $KE = 100$ J and is subjected to a friction force of magnitude 2 N and no other forces. How far does the object go before coming to a stop?

    a) 100 m. b) 2 m. c) 1000 m. d) 50 m. e) 0 m.

21. We will now the derive the work-kinetic energy theorem in little-bitty steps. Recall the work-kinetic-energy theorem is

    $$W = \Delta KE\ ,$$

    where W is the work done by the net external force acting on a body and ΔKE is the change in the body's center-of-mass kinetic energy.

    a) Write down the differential definition of work.

    b) Write down the integral definition of work with unspecified endpoints.

    c) Write down the formula for the work between points $\vec{A}$ and $\vec{B}$ done by net external force on a body and make use of Newton's 2nd law to rewrite this formula in terms of the body's center-of-mass acceleration.

    d) Prove that

    $$\vec{a}\cdot\vec{v} = \frac{1}{2}\frac{dv^2}{dt}\ .$$

    e) Given that $d\vec{s} = \vec{v}\,dt$, now prove the work-kinetic-energy theorem

22. You are pushing a 60 kg block across a frictionless surface—which is no mean feat in itself.

a) You exert 100 N of force in the direction of motion and push the block for 30 m. How much work have you done on the block? Show how you got your answer.

b) Assuming you start the block from **REST** and no other forces do work, what is the final kinetic energy and speed of the block? Show how you got your answer.

23. Power in physics is the rate per unit time of energy transferred or transformed. This is a general definition independent of the where the energy is coming from and where it is going too. If work is the energy transfer process, the differential work formula $dW = \vec{F} \cdot d\vec{s}$ leads immediately to the power formula for work:

$$P = \frac{dW}{dt} = \vec{F} \cdot \frac{d\vec{s}}{dt} = \vec{F} \cdot \vec{v} \ ,$$

where $\vec{v}$ is velocity (i.e., center-of-mass velocity) of the displaced system. The MKS unit of work is the joule per second (J/s) which has its own name: the familear watt with symbol (W).

Now that we've preambled, there is a frictionless block of ice of 50 kg on an incline of 30°. A worker pushes the block straight up the incline at a **CONSTANT** velocity of 3.0 m/s.

a) What is the power output (i.e., rate of work done) by the worker?

b) What is the power output by gravity?

c) What is the power output by the normal force? Why?

Equation Sheet for Introductory Physics Calculus-Based

This equation sheet is intended for students writing tests or reviewing material. Therefore it is neither intended to be complete nor completely explicit. There are fewer symbols than variables, and so some symbols must be used for different things: context must distinguish.

The equations are mnemonic. Students are expected to understand how to interpret and use them.

1 Constants

$$
\begin{aligned}
c &= 2.99792458 \times 10^8\,\mathrm{m/s} \approx 2.998 \times 10^8\,\mathrm{m/s} \approx 3 \times 10^8\,\mathrm{m/s} \approx 1\,\mathrm{lyr/yr} \approx 1\,\mathrm{ft/ns} \qquad \text{exact by definition} \\
e &= 1.602176487(40) \times 10^{-19}\,\mathrm{C} \\
G &= 6.67428(67) \times 10^{-11}\,\mathrm{N\,m^2/kg^2} \qquad \text{(2006, CODATA)} \\
g &= 9.8\,\mathrm{m/s^2} \qquad \text{fiducial value} \\
k &= \frac{1}{4\pi\varepsilon_0} = 8.987551787\ldots \times 10^9 \approx 8.99 \times 10^9 \approx 10^{10}\,\mathrm{N\,m^2/C^2}\text{exact by definition} \\
k_{\mathrm{Boltzmann}} &= 1.3806504(24) \times 10^{-23}\,\mathrm{J/K} = 0.8617343(15) \times 10^{-4}\,\mathrm{eV/K} \approx 10^{-4}\,\mathrm{eV/K} \\
m_e &= 9.10938215(45) \times 10^{-31}\,\mathrm{kg} = 0.510998910(13)\,\mathrm{MeV} \\
m_p &= 1.672621637(83) \times 10^{-27}\,\mathrm{kg} = 938.272013(23),\mathrm{MeV} \\
\varepsilon_0 &= \frac{1}{\mu_0 c^2} = 8.8541878176\ldots \times 10^{-12}\,\mathrm{C^2/(N\,m^2)} \approx 10^{-11} \qquad \text{vacuum permittivity (exact by definition)} \\
\mu_0 &= 4\pi \times 10^{-7}\,\mathrm{N/A^2} \qquad \text{exact by definition}
\end{aligned}
$$

2 Geometrical Formulae

$$C_{\mathrm{cir}} = 2\pi r \qquad A_{\mathrm{cir}} = \pi r^2 \qquad A_{\mathrm{sph}} = 4\pi r^2 \qquad V_{\mathrm{sph}} = \frac{4}{3}\pi r^3$$

$$\Omega_{\mathrm{sphere}} = 4\pi \qquad d\Omega = \sin\theta\, d\theta\, d\phi$$

3 Trigonometry Formulae

$$\frac{x}{r} = \cos\theta \qquad \frac{y}{r} = \sin\theta \qquad \frac{y}{x} = \tan\theta = \frac{\sin\theta}{\cos\theta} \qquad \cos^2\theta + \sin^2\theta = 1$$

$$\csc\theta = \frac{1}{\sin\theta} \qquad \sec\theta = \frac{1}{\cos\theta} \qquad \cot\theta = \frac{1}{\tan\theta}$$

$$c^2 = a^2 + b^2 \qquad c = \sqrt{a^2 + b^2 - 2ab\cos\theta_c} \qquad \frac{\sin\theta_a}{a} = \frac{\sin\theta_b}{b} = \frac{\sin\theta_c}{c}$$

$$f(\theta) = f(\theta + 360^\circ)$$

$$\sin(\theta + 180^\circ) = -\sin(\theta) \qquad \cos(\theta + 180^\circ) = -\cos(\theta) \qquad \tan(\theta + 180^\circ) = \tan(\theta)$$

$$\sin(-\theta) = -\sin(\theta) \qquad \cos(-\theta) = \cos(\theta) \qquad \tan(-\theta) = -\tan(\theta)$$

$$\sin(\theta + 90^\circ) = \cos(\theta) \qquad \cos(\theta + 90^\circ) = -\sin(\theta) \qquad \tan(\theta + 90^\circ) = -\tan(\theta)$$

$$\sin(180^\circ - \theta) = \sin(\theta) \qquad \cos(180^\circ - \theta) = -\cos(\theta) \qquad \tan(180^\circ - \theta) = -\tan(\theta)$$

$$\sin(90^\circ - \theta) = \cos(\theta) \qquad \cos(90^\circ - \theta) = \sin(\theta) \qquad \tan(90^\circ - \theta) = \frac{1}{\tan(\theta)} = \cot(\theta)$$

$$\sin(a + b) = \sin(a)\cos(b) + \cos(a)\sin(b) \qquad \cos(a + b) = \cos(a)\cos(b) - \sin(a)\sin(b)$$

$$\sin(2a) = 2\sin(a)\cos(a) \qquad \cos(2a) = \cos^2(a) - \sin^2(a)$$

$$\sin(a)\sin(b) = \frac{1}{2}\left[\cos(a - b) - \cos(a + b)\right] \qquad \cos(a)\cos(b) = \frac{1}{2}\left[\cos(a - b) + \cos(a + b)\right]$$

$$\sin(a)\cos(b) = \frac{1}{2}\left[\sin(a - b) + \sin(a + b)\right]$$

$$\sin^2\theta = \frac{1}{2}[1 - \cos(2\theta)] \qquad \cos^2\theta = \frac{1}{2}[1 + \cos(2\theta)] \qquad \sin(a)\cos(a) = \frac{1}{2}\sin(2a)$$

$$\cos(x) - \cos(y) = -2\sin\left(\frac{x + y}{2}\right)\sin\left(\frac{x - y}{2}\right)$$

$$\cos(x) + \cos(y) = 2\cos\left(\frac{x + y}{2}\right)\cos\left(\frac{x - y}{2}\right)$$

$$\sin(x) + \sin(y) = 2\sin\left(\frac{x + y}{2}\right)\cos\left(\frac{x - y}{2}\right)$$

4 Approximation Formulae

$$\frac{\Delta f}{\Delta x} \approx \frac{df}{dx} \qquad \frac{1}{1 - x} \approx 1 + x \; : \; (x << 1)$$

$$\sin\theta \approx \theta \qquad \tan\theta \approx \theta \qquad \cos\theta \approx 1 - \frac{1}{2}\theta^2 \qquad \text{all for } \theta << 1$$

5 Quadratic Formula

$$\text{If} \qquad 0 = ax^2 + bx + c\,, \qquad \text{then} \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = -\frac{b}{2a} \pm \sqrt{\left(\frac{b}{2a}\right)^2 - \frac{c}{a}}$$

6 Vector Formulae

$$a = |\vec{a}| = \sqrt{a_x^2 + a_y^2} \qquad \theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) + \pi? \qquad \vec{a} + \vec{b} = (a_x + b_x, a_y + b_y)$$

$$a = |\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2} \qquad \phi = \tan^{-1}\left(\frac{a_y}{a_x}\right) + \pi? \qquad \theta = \cos^{-1}\left(\frac{a_z}{a}\right)$$

$$\vec{a} + \vec{b} = (a_x + b_x, a_y + b_y, a_z + b_z)$$

$$\vec{a} \cdot \vec{b} = ab\cos\theta = a_x b_x + a_y b_y + a_z b_z$$

$$\vec{c} = \vec{a} \times \vec{b} = ab\sin(\theta)\hat{c} = (a_y b_z - b_y a_z, a_z b_x - b_z a_x, a_x b_y - b_x a_y)$$

7 Differentiation and Integration Formulae

$$\frac{d(x^p)}{dx} = px^{p-1} \quad \text{except for } p = 0; \qquad \frac{d(x^0)}{dx} = 0 \qquad \frac{d(\ln|x|)}{dx} = \frac{1}{x}$$

Taylor's series

$$\begin{aligned} f(x) &= \sum_{n=0}^{\infty} \frac{(x - x_0)^n}{n!} f^{(n)}(x_0) \\ &= f(x_0) + (x - x_0) f^{(1)}(x_0) + \frac{(x - x_0)^2}{2!} f^{(2)}(x_0) + \frac{(x - x_0)^3}{3!} f^{(3)}(x_0) + \ldots \end{aligned}$$

$$\int_a^b f(x)\,dx = F(x)|_a^b = F(b) - F(a) \quad \text{where} \quad \frac{dF(x)}{dx} = f(x)$$

$$\int x^n\,dx = \frac{x^{n+1}}{n+1} \quad \text{except for } n = -1; \qquad \int \frac{1}{x}\,dx = \ln|x|$$

8 One-Dimensional Kinematics

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} \qquad v = \frac{dx}{dt} \qquad a_{\text{avg}} = \frac{\Delta v}{\Delta t} \qquad a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

$$v = at + v_0 \qquad x = \frac{1}{2}at^2 + v_0 t + x_0 \qquad v^2 = v_0^2 + 2a(x - x_0)$$

$$x = \frac{1}{2}(v_0 + v)t + x_0 \qquad x = -\frac{1}{2}at^2 + vt + x_0 \qquad g = 9.8\,\text{m/s}^2$$

$$x_{\text{rel}} = x_2 - x_1 \qquad v_{\text{rel}} = v_2 - v_1 \qquad a_{\text{rel}} = a_2 - a_1$$

$$x' = x - v_{\text{frame}} t \qquad v' = v - v_{\text{frame}} \qquad a' = a$$

9 Two- and Three-Dimensional Kinematics: General

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{r}}{\Delta t} \qquad \vec{v} = \frac{d\vec{r}}{dt} \qquad \vec{a}_{\text{avg}} = \frac{\Delta \vec{v}}{\Delta t} \qquad \vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$$

10 Projectile Motion

$$x = v_{x,0} t \qquad y = -\frac{1}{2} g t^2 + v_{y,0} t + y_0 \qquad v_{x,0} = v_0 \cos\theta \qquad v_{y,0} = v_0 \sin\theta$$

$$t = \frac{x}{v_{x,0}} = \frac{x}{v_0 \cos\theta} \qquad y = y_0 + x \tan\theta - \frac{x^2 g}{2 v_0^2 \cos^2\theta}$$

$$x_{\text{for } y \text{ max}} = \frac{v_0^2 \sin\theta \cos\theta}{g} \qquad y_{\max} = y_0 + \frac{v_0^2 \sin^2\theta}{2g}$$

$$x(y = y_0) = \frac{2 v_0^2 \sin\theta \cos\theta}{g} = \frac{v_0^2 \sin(2\theta)}{g} \qquad \theta_{\text{for max}} = \frac{\pi}{4} \qquad x_{\max}(y = y_0) = \frac{v_0^2}{g}$$

$$x(\theta = 0) = \pm v_0 \sqrt{\frac{2(y_0 - y)}{g}} \qquad t(\theta = 0) = \sqrt{\frac{2(y_0 - y)}{g}}$$

11 Relative Motion

$$\vec{r} = \vec{r}_2 - \vec{r}_1 \qquad \vec{v} = \vec{v}_2 - \vec{v}_1 \qquad \vec{a} = \vec{a}_2 - \vec{a}_1$$

12 Polar Coordinate Motion and Uniform Circular Motion

$$\omega = \frac{d\theta}{dt} \qquad \alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\vec{r} = r\hat{r} \qquad \vec{v} = \frac{d\vec{r}}{dt} = \frac{dr}{dt}\hat{r} + r\omega\hat{\theta} \qquad \vec{a} = \frac{d^2\vec{r}}{dt^2} = \left(\frac{d^2 r}{dt^2} - r\omega^2\right)\hat{r} + \left(r\alpha + 2\frac{dr}{dt}\omega\right)\hat{\theta}$$

$$\vec{v} = r\omega\hat{\theta} \qquad v = r\omega \qquad a_{\tan} = r\alpha$$

$$\vec{a}_{\text{centripetal}} = -\frac{v^2}{r}\hat{r} = -r\omega^2\hat{r} \qquad a_{\text{centripetal}} = \frac{v^2}{r} = r\omega^2 = v\omega$$

13 **Very Basic Newtonian Physics**

$$\vec{r}_{\rm cm} = \frac{\sum_i m_i \vec{r}_i}{m_{\rm total}} = \frac{\sum_{\rm sub} m_{\rm sub} \vec{r}_{\rm cm\ sub}}{m_{\rm total}} \qquad \vec{v}_{\rm cm} = \frac{\sum_i m_i \vec{v}_i}{m_{\rm total}} \qquad \vec{a}_{\rm cm} = \frac{\sum_i m_i \vec{a}_i}{m_{\rm total}}$$

$$\vec{r}_{\rm cm} = \frac{\int_V \rho(\vec{r})\vec{r}\, dV}{m_{\rm total}}$$

$$\vec{F}_{\rm net} = m\vec{a} \qquad \vec{F}_{21} = -\vec{F}_{12} \qquad F_g = mg \qquad g = 9.8\,{\rm m/s^2}$$

$$\vec{F}_{\rm normal} = -\vec{F}_{\rm applied} \qquad F_{\rm linear} = -kx$$

$$f_{\rm normal} = \frac{T}{r} \qquad T = T_0 - F_{\rm parallel}(s) \qquad T = T_0$$

$$F_{\rm f\ static} = \min(F_{\rm applied}, F_{\rm f\ static\ max}) \qquad F_{\rm f\ static\ max} = \mu_{\rm static} F_{\rm N} \qquad F_{\rm f\ kinetic} = \mu_{\rm kinetic} F_{\rm N}$$

$$v_{\rm tangential} = r\omega = r\frac{d\theta}{dt} \qquad a_{\rm tangential} = r\alpha = r\frac{d\omega}{dt} = r\frac{d^2\theta}{dt^2}$$

$$\vec{a}_{\rm centripetal} = -\frac{v^2}{r}\hat{r} \qquad \vec{F}_{\rm centripetal} = -m\frac{v^2}{r}\hat{r}$$

$$F_{\rm drag,lin} = bv \qquad v_{\rm T} = \frac{mg}{b} \qquad \tau = \frac{v_{\rm T}}{g} = \frac{m}{b} \qquad v = v_{\rm T}(1 - e^{-t/\tau})$$

$$F_{\rm drag,quad} = bv^2 = \frac{1}{2}C\rho A v^2 \qquad v_{\rm T} = \sqrt{\frac{mg}{b}}$$

14 **Energy and Work**

$$dW = \vec{F}\cdot d\vec{s} \qquad W = \int \vec{F}\cdot d\vec{s} \qquad KE = \frac{1}{2}mv^2 \qquad E_{\rm mechanical} = KE + PE$$

$$P_{\rm avg} = \frac{\Delta W}{\Delta t} \qquad P = \frac{dW}{dt} \qquad P = \vec{F}\cdot\vec{v}$$

$$\Delta KE = W_{\rm net} \quad \Delta PE_{\text{of a conservative force}} = -W_{\text{by a conservative force}} \quad \Delta E = W_{\rm nonconservative}$$

$$F = -\frac{dPE}{dx} \qquad \vec{F} = -\nabla PE \qquad PE = \frac{1}{2}kx^2 \qquad PE = mgy$$