Things you must know:

Definition of average velocity
Definition of momentum The Momentum Principle

Other physical quantities:

$$\gamma \equiv \frac{1}{\sqrt{1-\left(\frac{|\vec{v}|}{c}\right)^2}}$$

$$\vec{F}_{grav} = -G\frac{m_1 m_2}{|\vec{r}|^2}\hat{r}$$

$\left|\vec{F}_{grav}\right| \approx mg$ near Earth's surface

$$\vec{F}_{elec} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

$\left|\vec{F}_{spring}\right| = k_s s$ opposite to the stretch

$\hat{f} = \langle \cos\theta_x, \cos\theta_y, \cos\theta_z \rangle$ unit vector from angles

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N $\cdot$ m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N $\cdot$ m^2/C^2
Proton charge	e	1.6×10^{-19} C
Avogadro's number	N_A	6.02×10^{23} atoms/mol

milli	m	1×10^{-3}	kilo	K	1×10^3
micro	μ	1×10^{-6}	mega	M	1×10^6
nano	n	1×10^{-9}	giga	G	1×10^9
pico	p	1×10^{-12}	tera	T	1×10^{12}

Problem 1
A hockey puck slides across an ice rink. Consider the origin to be at the center of the rink; the plane of the rink is the xz plane. At time $t = 0.0$ s a hockey puck is observed to be at location $\langle -7, 0, -6 \rangle$ m. At time $t = 0.4$ s the puck is observed at location $\langle 7, 0, 4 \rangle$ m.

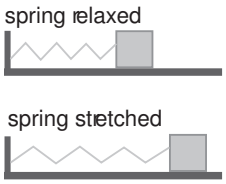
(a) What is the average velocity of the hockey puck during this time interval? Show all work.

(b) What is the magnitude of the average velocity? Show all work.

(c) What is the unit vector in the direction of the velocity? Show all work.

Problem 2
An electron initially has momentum $\langle 2.7 \times 10^{-24}, 0, 0 \rangle$ kg $\cdot$ m/s. At time $t = 0$, a constant force $\vec{F}$ is applied to the electron for 1×10^{-11} seconds. At time $t = 1 \times 10^{-11}$ seconds the momentum of the electron is $\langle 2.7 \times 10^{-24}, 0, -1.6 \times 10^{-24} \rangle$ kg $\cdot$ m/s. Calculate the force $\vec{F}$. Show your work.

Problem 3
A 60 gram block is attached to a horizontal spring, of stiffness 13 N/m, which is attached at one end to a wall. The block rests on a slippery surface, so friction is negligible. When the spring is relaxed, its length is 0.6 m. You pull horizontally on the block, stretching the spring so its length is now 0.75 m. You make sure the block is at rest, then you release it, moving your hand away. Make the approximation that the force on the block by the spring is constant during the next 0.02 seconds. What is the magnitude of the change in the momentum of the block during this time interval?



Problem 4
At a time t = 0 a star of mass 4×10^{30} kg has velocity $\langle 7 \times 10^4, 6 \times 10^4, -8 \times 10^4 \rangle$ m/s and is located at $\langle 2.00 \times 10^{12}, -5.00 \times 10^{12}, 4.00 \times 10^{12} \rangle$ m relative to the center of a cluster of stars. There is only one nearby star that exerts a significant force on the first star. The mass of the second star is 3×10^{30} kg, its velocity is $\langle 2 \times 10^4, -1 \times 10^4, 9 \times 10^4 \rangle$ m/s, and it is located at $\langle 2.03 \times 10^{12}, -4.94 \times 10^{12}, 3.95 \times 10^{12} \rangle$ m relative to the center of the cluster of stars.

(a) At t = 1×10^5 s, what is the approximate momentum of the first star?

(b) Discuss briefly some ways in which your result is approximate, not exact.

(c) At = 1×10^5 s, what is the approximate position of the first star?

(d) Discuss briefly some ways in which your result is approximate, not exact.

Problem 5
(a) Young's modulus for copper is $1.2 \times 10^{11} \ \dfrac{\text{N}}{\text{m}^2}$. A thin copper rod is suspended vertically. The rod is 1.4 m long, with a cross section 1.5 mm by 1.2 mm (1.5×10^{-3} m by 1.2×10^{-3} m). When you apply a force of 260 N to the rod, how much does the rod stretch? Show your calculation!

(b) The radius of a copper atom is 1.15×10^{-10} m. In copper, what is the stiffness of the interatomic bond, modeled as a spring? Show your calculation!

Problem 6

A metal has a density ρ (in kg/m^3) and an atomic (molar) mass of M (in kg/mol). Which of the following expressions gives the average length of the interatomic bond in the metal? ($N_A = 6 \times 10^{23}$ in the expressions below.)

A. $\left(\frac{M}{\rho}\right)^{1/3}$ B. $\left(\frac{N_A \rho}{M}\right)^{1/3}$ C. $\left(\frac{M}{N_A \rho}\right)^{1/3}$

D. $(N_A \rho M)^{1/3}$ E. $\left(\frac{M}{N_A \rho}\right)$