Part 1

Multiple Choice: (instead of Problem 0)

1. [3 pts] If I tell you that \( \hbar c = 1.97 \times 10^{-11} \text{ MeV-cm} \) is a true statement, then \( \hbar \) is? (the speed of light, \( c \), is \( 3 \times 10^8 \text{ km/s} \); note that you shouldn’t need a calculator here — the units and orders of magnitude should tell you which is correct).

(a) \( 6.6 \times 10^{-22} \text{ MeVs} \)  
(b) \( 1.5 \times 10^{+21} \text{ MeVs} \)  
(c) \( 6.6 \times 10^{-22} \text{ MeVs} \)  
(d) \( 1.5 \times 10^{+21} \text{ MeVs} \)

2. [5 pts] I measured the diameter of a hockey puck to be \( D = (7.50 \pm 0.06) \text{ cm} \). Knowing that \( C = \pi D \), how should I quote the value of the circumference, \( C \)? *Hint: \( \pi \) is a number with no uncertainty that multiplies \( D \).*

(a) \( 23.5 \pm 0.1 \text{ cm} \)  
(b) \( 23.5 \pm 0.2 \text{ cm} \)  
(c) \( 23.5 \pm 0.3 \text{ cm} \)  
(d) \( 23.530529 \text{ cm} \)

3. [5 pts] Consider the following plot of an object’s displacement versus time and decide which answer is true:

(a) The velocity is always in the \( +\hat{z} \) direction.  
(b) The average speed from \( t=1 \) to \( t=2 \) is greater than the instantaneous speed at \( t=2 \).  
(c) The acceleration curve would look like:  
(d) The velocity curve would look like:

![Plot of Object's Displacement](image)

4. [5 pts] You attach a 0.5 kg mass to a spring on Pluto (where the acceleration due to gravity is \( 0.54 \text{ m/s}^2 \)) and see that it fell 0.2 cm when released. What is the spring constant?

(a) 0.054 N/cm  
(b) 1.35 N/cm  
(c) 5.4 N/cm  
(d) 24.5 N/cm

Or you can do the following problem:

Problem "0" (instead of multiple choice) Relative motion: Trevor Linden is streaking up the ice at \(+60^\circ\) to the horizontal \( \hat{z} \)-axis with a speed of 4 \( \text{ m/s} \). At the same time, defenseman Chris Pronger is skating backwards trying to stop his attack. Linden’s velocity relative to Pronger’s is \( +1.0 \text{ m/s in the forward } \hat{y} \)-direction.

(a) [14 pts] What is Pronger’s speed and direction relative someone stationary on the ice?

\[
\mathbf{v}_{L/E} = 4\cos 60^\circ \hat{x} + 4\sin 60^\circ \hat{y} \\
\mathbf{v}_{L/P} = 1 \hat{\mathbf{y}} \\
\mathbf{v}_{P/E} = \mathbf{v}_{L/E} + \mathbf{v}_{L/P} \\
\mathbf{v}_{P/E} = 4\cos 60^\circ \hat{x} + (4\sin 60^\circ - 1)\hat{y} \\
|\mathbf{v}_{P/E}| = \sqrt{(4\cos 60)^2 + (4\sin 60 - 1)^2} \\
= 3.17 \text{ m/s} \\
\theta = \tan^{-1} \left( \frac{4\sin 60 - 1}{4\cos 60} \right) = 50.9^\circ \\
\text{Ans: } \mathbf{v}_P = 3.17 \text{ m/s } 51^\circ \text{ above horizontal}
\]

(b) [4 pts] Sketch a *rough* diagram of the three relative velocities which shows the angle of Pronger’s velocity relative to the ice (the only thing that matters here is that you demonstrate you understand the angle you calculated above).

![Rough Diagram of Velocities](image)
Problem 1  1D motion: Chris Chelios sees Steve Yzerman open for a pass ahead of him, and from his goal line passes the puck with a constant velocity \( \vec{u}_{\text{puck}} = 23.1 \, \text{m/s} \). At the same time, Yzerman starts from rest and takes off from his blue line \((x_{o,yzerman} = +19.5 \, \text{m} \) in front of Chelios) at constant acceleration in the \(+\hat{x}\) direction. Assume that the ice is a frictionless surface.

(a) [12 pts] If Yzerman is too fast, the puck won’t reach him until after he passes the other team’s blue line \((34.7 \, \text{m} \) in front of Chelios), which would make him offside. What should Yzerman’s acceleration be in order to have both him and the puck reach the other team’s blue line at the same time?

\[
\text{Yzerman reaches blue line in same time if (} x_o = 19.5, \quad v_o = 0 \text{)} \rightarrow \quad x_{\text{Yzerman}}(t=1.5) = 34.7 = 19.5 + \frac{1}{2} a_{\text{Yzerman}} (1.5)^2
\]

or \( a = \frac{2(34.7-19.5)}{2.25} = 13.5 \, \text{m/s}^2 \ \hat{x} \)

Ans: \( \vec{a} = 13.5 \, \text{m/s}^2 \ \hat{x} \)

(b) [6 pts] Use this acceleration to calculate what Yzerman’s speed would be when he reaches the other blue line and gets the pass.

\[
\vec{v}(t) = \vec{v}_o + \vec{a} t
\]

\[
= 13.5 (1.5)
\]

\[
= 20.3 \, \text{m/s}
\]

Ans: \( |\vec{v}| = 20 \, \text{m/s} \)
Problem 2  Free-fall and projectile motion: You’re standing on the SkyPod deck of the CN Tower (351 m above the ground) and, in careless disregard for human life, drop a penny. Neglect air resistance and wind currents in this problem.

(a) [6 pts] What is the speed of the penny when it lands?

\[ v_f^2 = v_i^2 + 2a(y-y_i) \]
\[ v_f^2 = -2(9.8)(-351-0) \]
\[ v_f = \sqrt{196(351)} \]
\[ = 82.9 \text{ m/s} \]

Ans: \[ |v_f| = 82.9 \text{ m/s} \]

(b) [6 pts] How long after you dropped the penny would it hit the ground?

\[ y(t) = -351 = 0 + 0 - \frac{1}{2}(9.8)t^2 \]
\[ t = \sqrt{\frac{2(351)}{9.8}} \]
\[ = 8.46 \text{ s} \]

Ans: \[ t = 8.46 \text{ s} \]

(c) [6 pts] If you instead threw it horizontally at 50 km/hr, how far from the Tower would it land?

\[ v_{0,x} = 50 \text{ km/hr} = \frac{50(10^3 \text{ m})}{3600 \text{ s}} = 13.9 \text{ m/s} \]

goes horizontal for as long as it’s in the air (8.46s)

\[ x(t=8.46) = v_{0,x}t \]
\[ = 13.9(8.46) \]
\[ = 118 \text{ m} \]

Ans: dist = 118 m
Problem 3 \textit{Newton’s Laws and motion:} Alexander Ovechkin takes a slap shot from the blue line aiming for the open spot just below the top of the net. The 0.16 kg puck is initially at rest on the ice and one can neglect air resistance in this problem.

(a) [8 pts] If Ovechkin’s stick applies a constant force of 285 N at an angle of 6° above the horizontal to the puck, what is the acceleration, \( \ddot{a} \), of the puck while it is in contact with his stick?

\[
\Sigma F_x = m\ddot{a}_x \Rightarrow \ddot{a}_x = \frac{285 \cos 6^\circ}{0.16} = 1771 \text{ m/s}^2
\]

\[
\Sigma F_y = m\ddot{a}_y \Rightarrow \ddot{a}_y = \frac{285 \sin 6^\circ}{0.16} - g = 176.4 \text{ m/s}^2
\]

(no normal force since \( 285 \sin 6^\circ > mg \) & puck leaves surface when struck)

\[
|\ddot{a}| = \sqrt{(1771)^2 + (176)^2}
\]

\[
= 1780 \text{ m/s}^2
\]

\[
\theta = \tan^{-1}\left( \frac{176}{1771} \right) = 5.7^\circ
\]

Ans: \( \ddot{a} = 1780 \text{ m/s}^2 \) \ 5.7° above surface

(b) [8 pts] If his stick made contact with the puck for a total of 0.025 s during the slap shot, what would be the puck’s velocity when it left his stick?

\[
\overrightarrow{v} = \ddot{a} \cdot t
\]

\[
= (1781)(0.025) \ 5.7^\circ \text{ above surf}
\]

\[
= 44.5 \text{ m/s same dir as } \ddot{a}
\]

Ans: \( \overrightarrow{v} = 44.5 \text{ m/s} \) \ 5.7° above surface

(c) [5 pts] What would be the \( x \)-position of the puck when it leaves his stick?

\[
x(t=0.025) = \frac{1}{2}a_x t^2
\]

\[
= \frac{1}{2}(1771)(0.025)^2
\]

\[
= 0.55 \text{ m}
\]

Ans: \( \frac{x}{x} = 0.55 \text{ m} \) \( \overrightarrow{x} \)
Problem 4  *Newton's Laws and friction*: I took my nephews skating one day. Mel, who weighs 180 N, grabbed a rope I had slung over my shoulder and Dario (who weighs 110 N) in turn held onto a rope tied around Mel’s waist so that we made a little “train”. Because I’m taller than Mel, the angle of the rope between us was 30° above the horizontal. The idealized situation is shown below where we assume the ropes are weightless. We will not, however, be treating the ice as a frictionless surface this time.

![Diagram](image)

(a) [5 pts] Turn the above figure into a free-body diagram by drawing and clearly labelling all of the forces acting on my nephews. The absolute lengths of your arrows aren’t going to be graded, but if two forces are equal and opposite, your diagram must reflect that. Include components of any forces not along along an axis, and ensure that the directions of your arrows are correct. (Grading here will not be as pedantic as MasteringPhysics was!).

(b) [8 pts] If the coefficient of static friction between Dario’s skates and the ice is 0.10, what is the magnitude of the tension that is needed in the rope between him and Mel before he’ll start moving?

\[
\Sigma F_y = 0 \Rightarrow n_D - W_D = 0 \quad \text{so} \quad f_{s,D} \leq \mu_s n_D \quad \mu_s = 0.1 \\
\Rightarrow n = 110 N \\
\text{or} \quad f_{s,D}^{\text{max}} = 11 N
\]

\[
\Sigma F_x > 0 \Rightarrow T - f_{s,D}^{\text{max}} > 0 \quad \text{(anything above zero & he’ll start moving)} \Rightarrow T > 11 N
\]

Ans: \(T \geq 11 N \text{ will start moving Dario}\)

(c) [12 pts] If Mel has the same \(\mu_s\) as Dario, what would be the magnitude of the force, \(|\vec{F}|\), that I need to apply in order to start moving the train?

\[
\Sigma F_y = 0 \Rightarrow n_m + F_{\sin 30} - W_m = 0 \\
\Rightarrow n_m = 180 - F_{\sin 30} \\
\text{so} \quad f_{s,m}^{\text{max}} = 18 - (0.1)F_{\sin 30}
\]

\[
\Sigma F_x > 0 \Rightarrow F_{\cos 30} - T - f_{s,m}^{\text{max}} > 0 \\
F_{\cos 30} - 11 - (18 - 0.1F_{\sin 30}) > 0 \\
F(\cos 30 + 0.1\sin 30) \geq 29 \\
F \geq \frac{29}{0.916} \quad \text{Ans:} \quad |\vec{F}| \geq 31.6 N \text{ will start moving the train}
\]

\[F \geq 31.6 N\]