

XF.17a

107

PHYS-107 (17) (Kaldon-37944)
 WMU - Fall 2004
 Final Exam - 200,000 points

Name _____ SOLUTION _____

CHECK-OUT: T1 T2

 Rev. 12/08/04 Wc.6

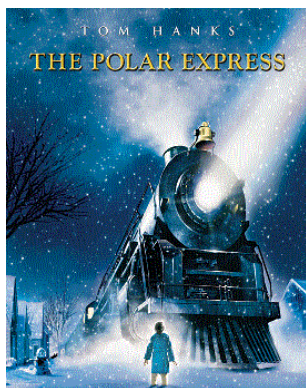
State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
 Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
 Short Answers Should Be Short! – Feel Free to Ask Any Questions

FINAL EXAM [FORM - A]

PHYS-107 (KALDON-17)

FALL 2004

WMU



The Polar Express vs. The Space Express

“Almost Over” (50,000 points) Multiple-Guess-Pick-The-Best-Answer-Fill-In-The-Bubbles

1.) In parts (a)-(d), select which Newton’s Law or Conservation Law best applies.

(a) Tom hits Harry and Harry hits Billy...
 A = Newton’s 1st B = Newton’s 2nd C = Newton’s 3rd
 D = Momentum E = Energy F = None of these A B C D E F

(b) Tom sits on Billy, so Billy can’t move...
A = Newton’s 1st B = Newton’s 2nd C = Newton’s 3rd
 D = Momentum E = Energy F = None of these A B C D E F

(c) This is conserved in all collisions...
 A = Newton’s 1st B = Newton’s 2nd C = Newton’s 3rd
D = Momentum E = Energy F = None of these A B C D E F

(d) A perpetual motion machine, if it could exist, would violate...
 A = Newton’s 1st B = Newton’s 2nd C = Newton’s 3rd
 D = Momentum E = Energy F = None of these A B C D E F

In parts (e)-(h), select which speed best represents the situation described.

(e) “Let me take my pet cheetah out for a run.”
 A = 1.0 m/s B = 7.0 m/s C = 30. m/s D = 300 m/s E = 344 m/s
 F = 1,000 m/s A B C D E F

(f) “I just had to run and catch the bus!”
 A = 1.0 m/s B = 7.0 m/s C = 30. m/s D = 300 m/s E = 344 m/s
 F = 1,000 m/s A B C D E F

(g) “By this time tomorrow I’ll be flying on a Northwest flight to Europe.”
 A = 1.0 m/s B = 7.0 m/s C = 30. m/s D = 300 m/s E = 344 m/s
 F = 1,000 m/s A B C D E F

(h) “Traveling faster than a speeding bullet – it’s SUPERMAN.”
 A = 1.0 m/s B = 7.0 m/s C = 30. m/s D = 300 m/s E = 344 m/s
F = 1,000 m/s A B C D E F

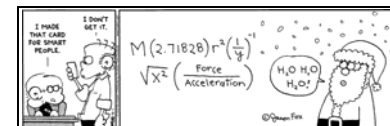
Use vector \vec{A} with an x-component $A_x = 22.0 \text{ m}$ and a y-component $A_y = -24.0 \text{ m}$ in the follow problems:

(i) The magnitude of this velocity vector is $A =$ _____
 A = 2.00 m B = 6.78 m C = 6.59 m
D = 32.6 m E = 46.0 m F = 528 m A B C D E F

(j) The Standard Angle for \vec{A} is _____
 A = 42.6° B = 47.4° C = 132.6°
 D = 137.4° E = 312.6° F = 317.4° A B C D E F

M (e=2.71828) r r y X mass < =====
 OR

“Merry Christmas!”



And the Winner of the \$10,000,000 Ansari X-Prize is... (50,000 points)

2.) On 4 October 2004, history was made when the privately funded, non-government Scaled Composites SpaceShipOne successfully flew into space twice in two weeks. Space is defined as an altitude of 100. km (100,000 m) above the surface of the Earth. (a) Calculate the value of g , the acceleration due to gravity, 100. km above the surface of the Earth. $M_{\text{Earth}} = 5.98 \times 10^{24} \text{ kg}$, $R_{\text{Earth}} = 6.37 \times 10^6 \text{ m}$, $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$.



$$\begin{aligned} r &= R_E + 100. \text{ km} = 6,370,000 \text{ m} + 100,000 \text{ m} \\ &= 6,470,000 \text{ m} \\ F_G &= \frac{GmM}{r^2} = mg \\ g &= \frac{GM_E}{r^2} = \frac{(6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})}{(6,470,000 \text{ m})^2} \\ &= 9.528 \text{ m/s}^2 \text{ (still close to } 9.81 \text{ m/s}^2) \end{aligned}$$

(b) SpaceShipOne is carried aloft by another aircraft called the White Knight. It was released at $h_1 = 14,100 \text{ m}$ (46,000 feet) above the Earth and climbed to an altitude of $h_2 = 115,200 \text{ m}$ (377,591 feet or 71½ miles). Let's treat this flight like a tossing a ball. What speed v_1 would this ball need, if it traveled straight up from h_1 to h_2 ?



Going straight up, turning point at top, $v = 0$.

Using Kinematics. . . Using Conservation of Energy. . .

$$\begin{aligned} v_y^2 &= v_{0y}^2 - 2g(y - y_0) \\ 0 &= v_{0y}^2 - 2g(y - y_0) \\ v_{0y}^2 &= 2g(y - y_0) \\ v_{0y} &= \sqrt{2g(y - y_0)} \\ &= \sqrt{2(9.81 \text{ m/s}^2)(115,200 \text{ m} - 14,100 \text{ m})} \\ &= \sqrt{1,983,582 \text{ m}^2/\text{s}^2} = 1408 \text{ m/s} \end{aligned}$$

$$\begin{aligned} mgh_1 + \frac{1}{2}mv_1^2 &= mgh_2 + \frac{1}{2}mv_2^2 \\ gh_1 + \frac{1}{2}v_1^2 &= gh_2 \\ v_1^2 &= 2g(h_2 - h_1) \\ v_1 &= \sqrt{2g(h_2 - h_1)} \\ &= \sqrt{2(9.81 \text{ m/s}^2)(115,200 \text{ m} - 14,100 \text{ m})} \\ &= \sqrt{1,983,582 \text{ m}^2/\text{s}^2} = 1408 \text{ m/s} \end{aligned}$$

(c) The rocket engine burned for 84.0 seconds. If SpaceShipOne started at a speed $v_0 = 200. \text{ m/s}$, find the constant acceleration a needed to reach the speed v_1 . If you didn't get an answer to (b), use $v_1 = 894 \text{ m/s}$ (2000 mph, about Mach 3).

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} = \frac{v_{\text{final}} - v_{\text{initial}}}{t} \\ &= \frac{1408 \text{ m/s} - 200. \text{ m/s}}{84.0 \text{ sec}} \\ &= 14.38 \text{ m/s}^2 \end{aligned}$$

Or about 1½ gee's average acceleration.

(Because mass isn't constant in the real problem, the acceleration is not constant, and peaks at about 3 gee's.)

(d) How far did the rocket travel during these 84.0 seconds? It is possible to solve this without (c).

Using answer to (c):

Using average speed:

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} = \frac{v_{\text{final}} - v_{\text{initial}}}{t} \\ &= \frac{1408 \text{ m/s} - 200. \text{ m/s}}{84.0 \text{ sec}} \\ &= 14.38 \text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} x &= x_0 + v_0 t + \frac{1}{2} a t^2 \\ &= 0 + (200. \text{ m/s})(84.0 \text{ sec}) + \frac{1}{2} (14.38 \text{ m/s}^2)(84.0 \text{ sec})^2 \\ &= 16,800 \text{ m} + 50,730 \text{ m} = 67,530 \text{ m} \end{aligned}$$

$$\begin{aligned} v_{\text{average}} &= \frac{v_{\text{final}} + v_{\text{initial}}}{2} \\ &= \frac{1408 \text{ m/s} + 200. \text{ m/s}}{2} \\ &= 804.0 \text{ m/s} \\ d &= v t = (804.0 \text{ m/s})(84.0 \text{ sec}) \\ &= 67,540 \text{ m} \end{aligned}$$

(e) On the video of the flight, the announcer says that SpaceShipOne reached its maximum height when the rocket engine stopped. Is this TRUE or FALSE? What one short statement can you write to prove your case?

FALSE

Because $v_y \neq 0$ when engine shuts down.



The Real Polar Express (50,000 points)

3.) The Lima Locomotive Works Pere Marquette 2-8-4 Berkshire number 1225 (really, no kidding!), considered one of the most attractive steam locomotives of all time, was the model for the engine in the movie *The Polar Express*. It weighs 443,000 lbs. (mass = 201,000 kg). (a) This engine is capable of delivering 4000. hp. Find the work Number 1225 can do in 10.0 seconds. $1 \text{ h.p.} = 746 \text{ W}$



$$4000. \text{ hp} \times 746 \text{ W} / \text{hp} = 2,984,000 \text{ W}$$

$$P = \frac{W}{t}$$

$$W = Pt = (2,984,000 \text{ W})(10.0 \text{ sec})$$

$$= 29,840,000 \text{ J}$$

(b) The 1225 has a maximum "drawbar tractive effort" or applied force of 69,400 lbs. (309,000 N). If the locomotive only moves itself (no passenger cars in tow), how far can it move from rest in 10.0 seconds? *Start with Newton's Second Law.*

$$F = ma$$

$$a = \frac{F}{m} = \frac{309,000 \text{ N}}{201,000 \text{ kg}} = 1.537 \text{ m/s}^2$$

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$= \frac{1}{2} (1.537 \text{ m/s}^2) (10.0 \text{ sec})^2$$

$$= 76.85 \text{ m}$$

(c) The main driving wheels of the 1225 are 69.0 inches in diameter (1.75 m). At 79.0 mph (35.3 m/s), find the centripetal acceleration a_c at the rim of the wheels.

$$r = \frac{D}{2} = \frac{1.75 \text{ m}}{2} = 0.8750 \text{ m}$$

$$a_c = \frac{v^2}{r} = \frac{(35.3 \text{ m/s})^2}{0.8750 \text{ m}} = 1424 \text{ m/s}^2$$

Wow! That's equivalent to 145 gee's!

(No wonder we don't strap ourselves to the outside of locomotive wheels at 79.0 mph!)

(d) The boiler pressure is 245 psi (1,690,000 Pa) at a temperature of $400.^\circ\text{F} = 204^\circ\text{C}$. A volume of steam, $V_1 = 1.00 \text{ liters}$, inside the boiler at this pressure and temperature is leaked outside at 1.00 atm pressure (101,300 Pa) and $212^\circ\text{F} = 100^\circ\text{C}$. Find the volume of this steam on the outside.



$$T_1 = 400.^\circ\text{F} = 204^\circ\text{C} = (204 + 273)\text{K} = 477 \text{ K}$$

$$T_2 = 212^\circ\text{F} = 100.^\circ\text{C} = (100 + 273)\text{K} = 373 \text{ K}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$$

$$= \frac{(1,690,000 \text{ Pa})(1.00 \text{ L})(373 \text{ K})}{(477 \text{ K})(101,300 \text{ Pa})}$$

$$= 13.05 \text{ L}$$

(e) Tom Hanks waves his arm to let the engineer, 404 feet (123 m) away, know it's time to go. The engineer blows the whistle, also 404 feet away. Find out how long it takes light to go from Tom Hank's arm to the engineer and for sound to get back to Tom Hanks. *In this cold air, the speeds are 323 m/s and 300,000,000 m/s.*



$$d = vt$$

LIGHT:

$$t = \frac{d}{v} = \frac{123 \text{ m}}{300,000,000 \text{ m/s}} = 4.100 \times 10^{-7} \text{ sec}$$

SOUND:

$$t = \frac{d}{v} = \frac{123 \text{ m}}{323 \text{ m/s}} = 0.3808 \text{ sec}$$

"Attention K-Mart Shoppers!" (50,000 points)

4.) (a) Mary's 48.0 kg shopping cart rolls away from her at 2.00 m/s and runs into Bills 66.0 kg shopping cart heading towards her at 2.00 m/s. Find the speed and direction of the two carts after they hit and stick together.

$$\begin{aligned} m_1 v_1 + m_2 v_2 &= (m_1 + m_2) V \\ V &= \frac{m_1 v_1 + m_2 v_2}{(m_1 + m_2)} \\ &= \frac{(48.0 \text{ kg})(+2.00 \text{ m/s}) + (66.0 \text{ kg})(-2.00 \text{ m/s})}{(48.0 \text{ kg} + 66.0 \text{ kg})} \\ &= -0.3158 \text{ m/s} \end{aligned}$$

The two stuck together carts are heading towards Mary.

(b) One of the lights overhead burns out, but all the rest stay lit and at the same brightness. Are all the lights connected together in SERIES or PARALLEL?

PARALLEL - because if they were all in series together, the current would run through each light and then when one burned out, the circuit would be broken and they would all go dark.

(c) A lawn mower engine has an Actual Efficiency of 50.0%, but is advertised as being 95% efficient. Identify and calculate the likely third efficiency in this problem.

$$\begin{aligned} \mathcal{E}_{2nd \text{ Law}} &= \frac{\mathcal{E}_{Actual}}{\mathcal{E}_{Carnot}} \\ \mathcal{E}_{Carnot} &= \frac{\mathcal{E}_{Actual}}{\mathcal{E}_{2nd \text{ Law}}} = \frac{0.500}{0.950} = 0.5263 \text{ or } 52.63\% \end{aligned}$$

The 95.0% efficiency must be the 2nd Law Efficiency.
(We have two equations with \mathcal{E}_{Carnot} in them.)

(d) A 125 kg crate slides along the floor and comes to a stop. If $v_0 = 2.00 \text{ m/s}$, and the coefficients of friction are 0.600 and 0.800, then find the distance d it took for the crate to slide to a stop.

We are sliding, so need kinetic friction, which is always the smaller coefficient of friction.

$$\begin{aligned} \sum F_y &= F_n - mg = 0 \\ F_n &= mg = (125 \text{ kg})(9.81 \text{ m/s}^2) = 1226 \text{ N} \\ F_{f,k} &= \mu_k F_n = (0.600)(1226 \text{ N}) = 735.6 \text{ N} \\ \sum F_x &= -F_{f,k} = ma \\ a &= \frac{-F_{f,k}}{m} = \frac{-735.6 \text{ N}}{125 \text{ kg}} = -5.885 \text{ m/s}^2 \\ v^2 &= v_0^2 + 2a(x - x_0) \\ 0 &= v_0^2 + 2a(x) \\ 2ax &= -v_0^2 \\ x &= \frac{-v_0^2}{2a} = \frac{-(2.00 \text{ m/s})^2}{2(-5.885 \text{ m/s}^2)} = 0.3398 \text{ m} \end{aligned}$$

(e) The famous K-Mart Blue Light Special has a blue light with a wavelength $\lambda = 440. \text{ nm} = 440. \times 10^{-9} \text{ m}$. If the speed of light in air is approximately $3.00 \times 10^8 \text{ m/s}$, find the frequency f of this blue light and the period T for it to make one oscillation.

$$\begin{aligned} c &= f \lambda \\ f &= \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{440. \times 10^{-9} \text{ m}} = 6.818 \times 10^{14} \text{ Hz} \\ T &= \frac{1}{f} = \frac{1}{6.818 \times 10^{14} \text{ Hz}} = 1.467 \times 10^{-15} \text{ sec} \end{aligned}$$