Physics of Astro winter wk 3

ZITA
22 Jan 06

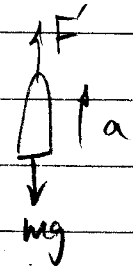
Ch 4 #5, 21, 34, 40, 72, 55

21. (II) A Saturn V rocket has a mass of 2.75 × 10⁶ kg [handwritten: $m =$] and exerts [handwritten: $F =$] a force of 33 × 10⁶ N on the gases it expels. Determine (a) the initial vertical acceleration of the rocket, (b) its velocity after 8.0 s [handwritten: $t =$], and (c) how long it takes to reach an altitude of 9500 m [handwritten: $x =$]. Ignore the mass of gas expelled (not realistic) and assume g remains constant.

$F' = ma'$

(a) $a' = \frac{F'}{m} = \frac{33\times10^6\,N}{2.75\times10^6\,kg}$

$a' = \frac{3\cdot 11}{2\frac{3}{4} = \frac{11}{4}} = 3\cdot4 = 12 \left(\frac{N}{kg} = \frac{m}{s^2}\right)$ = thrust acceleration



Note that the rocket needs an upward acceleration of g just to LEVITATE, so only part of a' contributes to the upward acceleration a:

$$\Sigma F = F' - mg = ma$$

thrust, weight, actual upward accel.

$$a = \frac{F' - mg}{m} = \frac{F'}{m} - g = a' - g = 12\,\frac{m}{s^2} - 9.8\,\frac{m}{s^2} = 2.2\,\frac{m}{s^2}$$

After 8 sec:

(b) $V = V_0 + at = 0 + at = 2.2\,\frac{m}{s^2}(8\,s) = \_\_\_\_\_\_\ \frac{m}{s}$

(c) Time to reach $x = 9500\,m$? $x = \frac{1}{2}at^2 + V_0t + x_0$ ($V_0 = 0$, $x_0 = 0$)

$$t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2\cdot 9500\,m}{2.2\,m/s^2}} = \_\_\_\_\_\_$$

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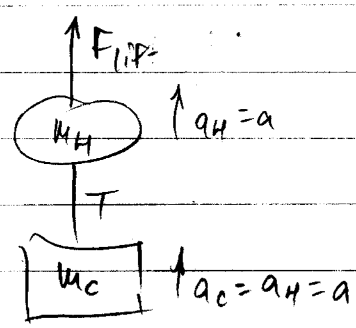
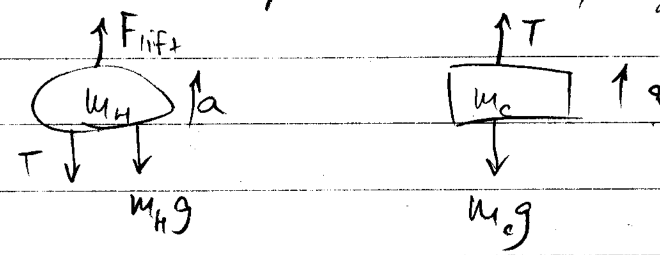
m_H m_C a

34. (II) A 7500-kg helicopter accelerates upward at $0.52\ m/s^2$ while lifting a 1200-kg car. (*a*) What is the lift force exerted by the air on the rotors? (*b*) What is the tension in the cable (ignore its mass) that connects the car to the helicopter?

If the rope isn't stretching, then $a_H = a_c = a$



Draw separate free-body diagrams



$\Sigma F = ma$: $m_H a = F_{lift} - T - m_H g$, $m_C a = T - m_C g$

Two equations in two unknowns. Solve for T and F_{lift}

Eliminate ① $T = F_{lift} - m_H g - m_H a$ ② $T = m_C a + m_C g$

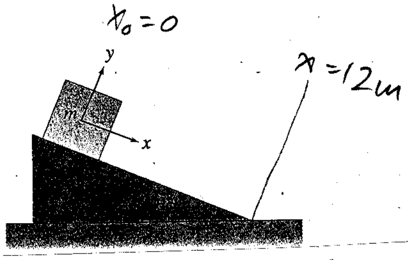
$F_{lift} - m_H(g+a) = m_C(a+g)$

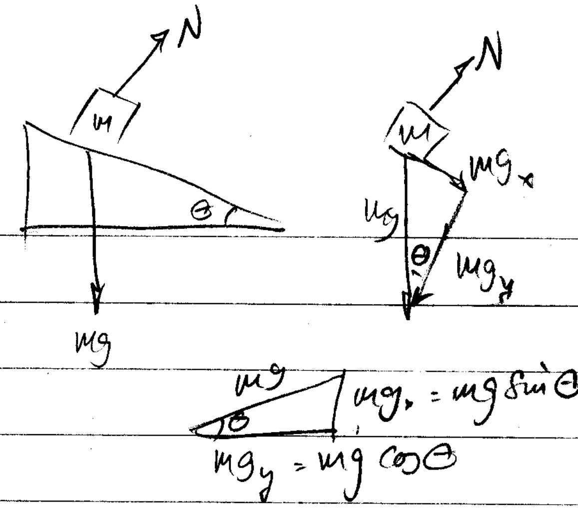
Solve for $F_{lift} = (m_C + m_H)(a+g) =$

We could sub F_{lift} into Eqn ① to find T, but we already have ②: $T = m_C(a+g) =$

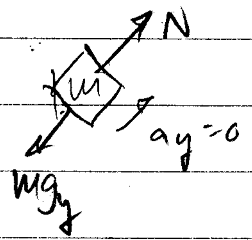
21

40. (II) The block shown in Fig. 4–44 has mass $m = 7.0$ kg and lies on a smooth frictionless plane tilted at an angle $\theta = 22.0°$ to the horizontal. (*a*) Determine the acceleration of the block as it slides down the plane. (*b*) If the block starts from rest 12.0 m up the plane from its base, what will be the block's speed when it reaches the bottom of the incline?





y:

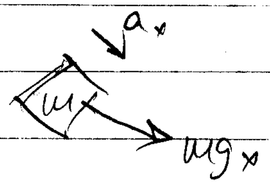


Draw a free body diagram for each direction

$\Sigma F_y = ma_y$ Block is not jumping up off the incline or falling through it,

So $a_y = 0$ $\quad N - mg_y = ma_y = 0$

$N = mg_y = mg\cos\theta$



In the absence of friction,

$\Sigma F_x = ma_x = mg_x$

So $a = a_x = g_x = g\sin\theta$

$a = 9.8\frac{m}{s^2}\sin 22° =$ ______ m/s^2

(b) $x(t) = x_0 + V_0 t + \frac{1}{2}at^2$ → time to reach bottom is $t = \sqrt{\frac{2x}{a}}$

(with $x_0 = 0$, $V_0 = 0$)

Speed at bottom: $V(t) = V_0 + at = at = a\sqrt{\frac{2x}{a}} = \sqrt{2xa}$ (with $V_0 = 0$)

You could get the same answer by solving $V^2 - V_0^2 = 2ax$

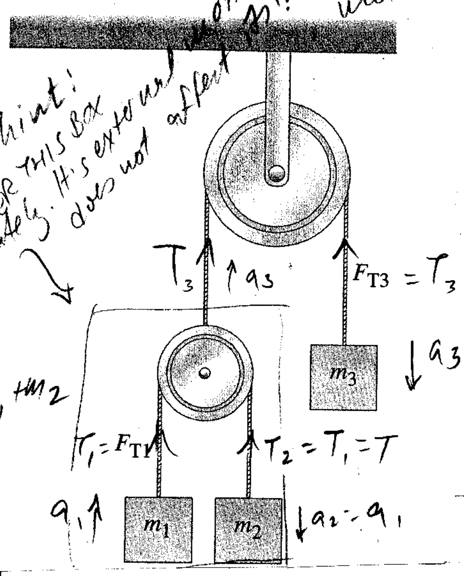
39 m/s $V(t) = \sqrt{2xa} = \sqrt{2(12m)(\quad m/s^2)} =$ ______ $\frac{m}{s}$

22

Let arrows indicate directions. Avoid ⊖ signs.

55. (III) The double Atwood machine shown in Fig. 4–52 has frictionless, massless pulleys and cords. Determine (*a*) the acceleration of masses m_1, m_2, and m_3, and (*b*) the tensions F_{T1} and F_{T3} in the cords.

Paul L's hint: CONSIDER THIS BOX Separately. It's external motion does not affect internal motion



$$\sum F_3 = m_3 a_3$$

$$\downarrow \sum F_3 = m_3 g - T_3$$

$$m_3 a_3 = m_3 g - T_3 \quad (1)$$

T, m_3, a_3, $m_3 g$

T_3, a_3, $(m_1 + m_2) g$

$$\uparrow \sum F = ma$$

$$T_3 - (m_1 + m_2) g = (m_1 + m_2) a_3 \quad (2)$$

$T_1 = T$ (INSIDE THE BOX)

m_1, $\uparrow a_1 = a$, $m_1 g$

$T_2 = T_1 = T$, m_2, $\downarrow a_2 = a_1 = a$, $m_2 g$

$$\sum F_1 = m_1 a_1 \qquad \sum F_2 = m_2 a_2$$

$$T - m_1 g = m_1 a \qquad m_2 g - T = m_2 a$$

Ch 4

The easiest problem:

(5.) (I) What is the weight of a 58-kg astronaut (*a*) on Earth, (*b*) on the Moon ($g = 1.7\ m/s^2$), (*c*) on Mars ($g = 3.7\ m/s^2$), (*d*) in outer space traveling with constant velocity?

Weight = mg depends on local gravity, though the astronaut's MASS DOES NOT CHANGE

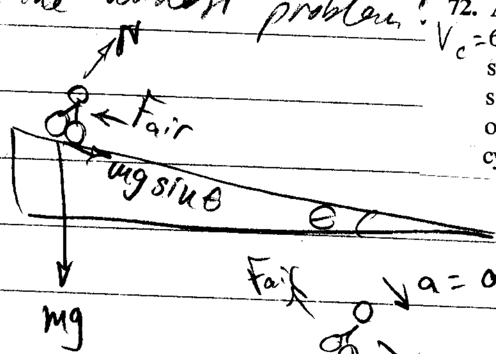
(a) on Earth, $W_{Earth} = 58\,kg \cdot 9.8\,\frac{m}{s^2} =$ ______ N

(b) on Moon, $W_{moon} = 58\,kg \cdot 1.7\,\frac{m}{s^2} = \frac{1}{6} W_E =$ ______ N

(c) on Mars, $W_{mars} = 58\,kg \times 3.7\,\frac{m}{s^2} =$ ______ N

The hardest problem?

72. A bicyclist can coast down a 5.0° hill at a constant speed of $V_c =$ 6.0 km/h. If the force of air resistance is proportional to the speed v so that $F_{air} = cv$, calculate (*a*) the value of the constant c, and (*b*) the average force that must be applied in order to descend the hill at 20.0 km/h. The mass of the cyclist plus bicycle is 80.0 kg. = m



COASTING: SPEED = CONSTANT

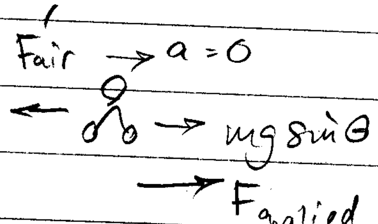
$\frac{dv}{dt} = 0 = a$

$\Sigma F = ma = 0$

$F_{air} - mg\sin\theta = 0$

$cv = mg\sin\theta$

(a) $c = \frac{mg}{v}\sin\theta = \frac{80\,kg \cdot 9.8\,m/s^2}{6 \cdot 10^3\,\frac{m}{hr} \left| \frac{hr}{3.6 \cdot 10^3 s} \right|} \sin 5° =$ ______ kg/s



(b) $\Sigma F = 0 = F_{applied} + mg\sin\theta - F'_{air}$

$F_{applied} = F'_{air} - mg\sin\theta$

$V' = \frac{20\,km}{hr} \left| \frac{10^3 m}{km} \right| \frac{hr}{3.6 \cdot 10^3 s} \Big| =$ ______ m/s

$F_{applied} = cV' - mg\sin\theta =$ ______ N

Physics of Star Trek ROCKET PROBLEM

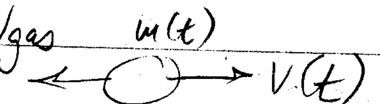
p.25 - "To accelerate to half the speed of light, The Enterprise must burn 81 times its entire mass in Hydrogen fuel" (1% of which streams out as He atoms after fusion)

$V_{final} = \frac{c}{2}$ $\qquad M_0$ - INITIALLY Enterprise Mass + fuel

$V_{exhaust\ gas} = \frac{c}{8}$ (relative to rocket)

Show that $M_0 = 81\, M_{final} = 81\, M_{ship}$

First try it NONRELATIVISTICALLY (too simple) as in Ex 9-18 on Giancoli p. 229



$dm \longrightarrow F_{thrust} = V_{gas} \frac{dm}{dt}$

We'll ignore initial acceleration to overcome gravity - assume we're out in space

($F = ma$ is, more generally, $F = \frac{d}{dt} m v = m \frac{dv}{dt} + v \frac{dm}{dt}$)

Momentum conservation : $-m \frac{dv}{dt} = V_{gas} \frac{dm}{dt}$

$$-m\, dv = V_{gas}\, dm$$

$$-\frac{dv}{V_{gas}} = \frac{dm}{m}$$

$$\frac{1}{V_{gas}} \int_{t=0}^{t} dv = \frac{1}{V_{gas}} (V(t) - V_0) = \frac{V_{final}}{V_{gas}} = -\int \frac{dm}{m} =$$

($V_0 \rightarrow 0$)