Physics 1A Spring 2001 QUIZ 2 . Closed Book. Write in blue or black ballpoint only. 3 questions (2 pages).

> Assume earth's gravity $g = 10\ \text{m/s}^2$.
>
> You may assume the constant-acceleration equations:
>
> $v = v_0 + at \quad x = x_0 + v_0 t + \frac{1}{2}at^2 \quad v^2 = v_0^2 + 2ax$

1. On the moon ($g_M = 1.5\ \text{m/s}^2$) an astronaut launches a small rocket (thrust force 3000N, mass 400kg) at an angle to the horizontal. In the absence of atmospheric friction, the gyro-stablized rocket points upwards at this angle throughout the flight.

a. What is the smallest launch angle for which the rocket will rise up from the surface?

The rocket is launched at an angle of 60 degrees.
b. Show that the (horizontal, vertical) components of the rocket's constant acceleration vector are roughly ($a_x = 3.8\ \text{m/s}^2$, $a_y = 5\ \text{m/s}^2$). (Give 2 decimal places). Hence find the magnitude and angle w.r.t. the horizontal of this acceleration.

After 20s from launch, the motor cuts out and the rocket continues moving under the influence of the moon's gravity alone.
c. What is the rocket's horizontal distance and altitude at this time (20s)?
d. What is the maximum altitude reached by the rocket before it falls back to the moon's surface? **(40 points)**

2. On a windless day, a 15000kg heavy lifting helicpter from NAS Miramar hovers above the ground, with a 5000kg military vehicle suspended below by a steel cable.

Using free-body force diagrams for the helicopter and the vehicle...
a. If the helicopter+vehicle accelerate upwards at 0.6 m/s^2, what is (ii) the required force of the rotor blades on the air, and (i) the tension in the steel cable?

The helicopter now flies straight-and-level with its load still suspended below. Due to air resistance on the vehicle, the steel cable now makes an angle of 15 degrees with respect to the vertical.
b. What is (i) the new tension in the cable, and (ii) the horizontal force exerted by air resistance on the suspended vehicle. **(30 points)**

3. A docker pushes a 100kg container up a 15-degree sloping ramp into a ship.

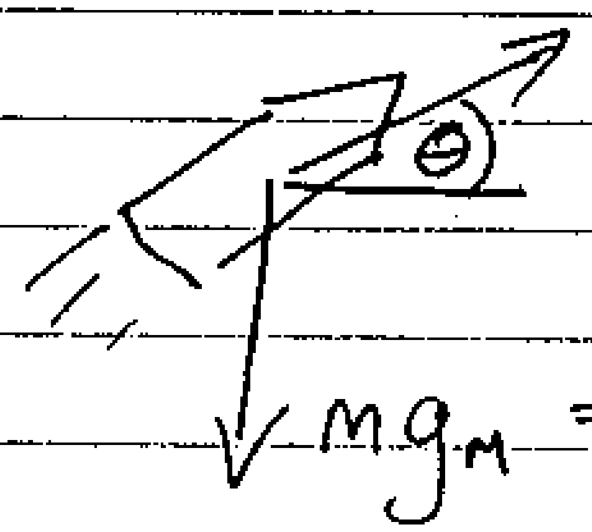
a. What force must the docker apply to keep the container moving at constant speed up the ramp, if there is no friction?

b. At the top of the 8-m long ramp, the lunch bell rings and the docker steps aside - the container slides back down. Show that the container reaches a speed of about 6.4 m/s at the bottom of the ramp. (Give 2 decimal places, and use $g = 10\ \text{m/s}^2$).

c. Fortunately, the container is brought from this speed to rest in 0.25s by colliding with a pile of construction dirt close to the ramp's base. What is the average braking force exerted by the dirt on the container? (Hint: first find the change in momentum). **(30 points)**

Physics 1A Quiz 2 Solutions

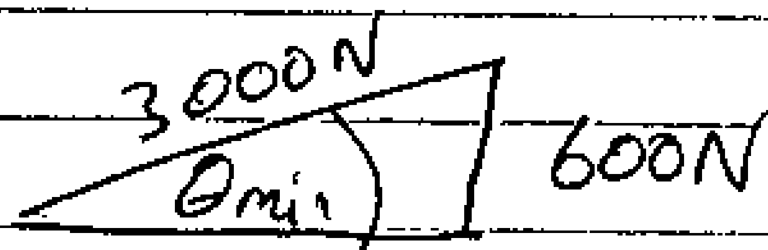
1.



$F_R = 3000\ N$

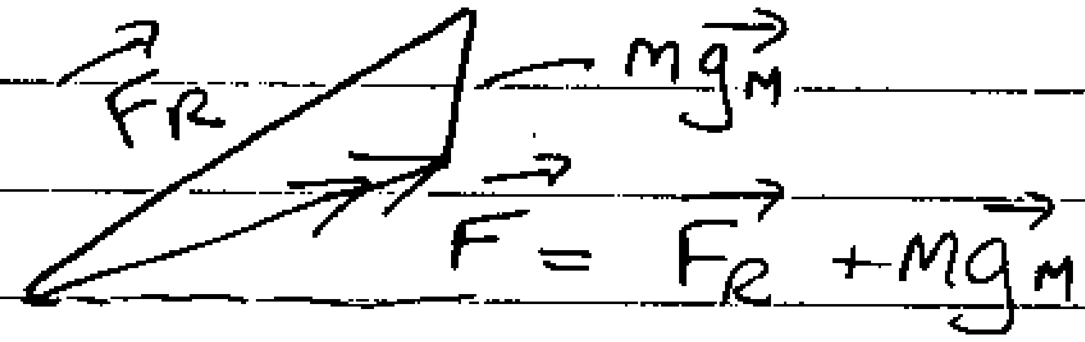
$mg_M = 400kg \times 1.5 m/s^2 = 600 N$

a) At smallest angle θ_{min}, resultant force $\vec{F} = \vec{F_R} + m\vec{g_M}$ is horizontal ($\Rightarrow$ no vertical accel.)



i.e. $\sin\theta_{min} = \frac{mg_M}{F_R} = \frac{600}{3000} \Rightarrow \underline{\theta_{min} = 11.54°}$

b) For $\theta = 60°$



Adding components: x: $F_x = F_R \cos 60° = \underline{1500 N}$

y: $F_y = F_R \sin 60° - mg_M$
$= 3000 \sin 60° - 600 = \underline{1998.1 N}$

$\therefore$ accel. components $a_x = F_x/m = \frac{1500}{400} = \underline{3.75 m/s^2}$

$a_y = F_y/m = \underline{4.995\ m/s^2}$

c) Use $x = \frac{1}{2} a_x t^2$, $y = \frac{1}{2} a_y t^2$ for $t = 20s \Rightarrow \underline{x = 750m}, \underline{y = 999m}$

d) When motor cuts off, $V_y = a_y t = 99.9 m/s$, $\underline{a_y = g_M}$

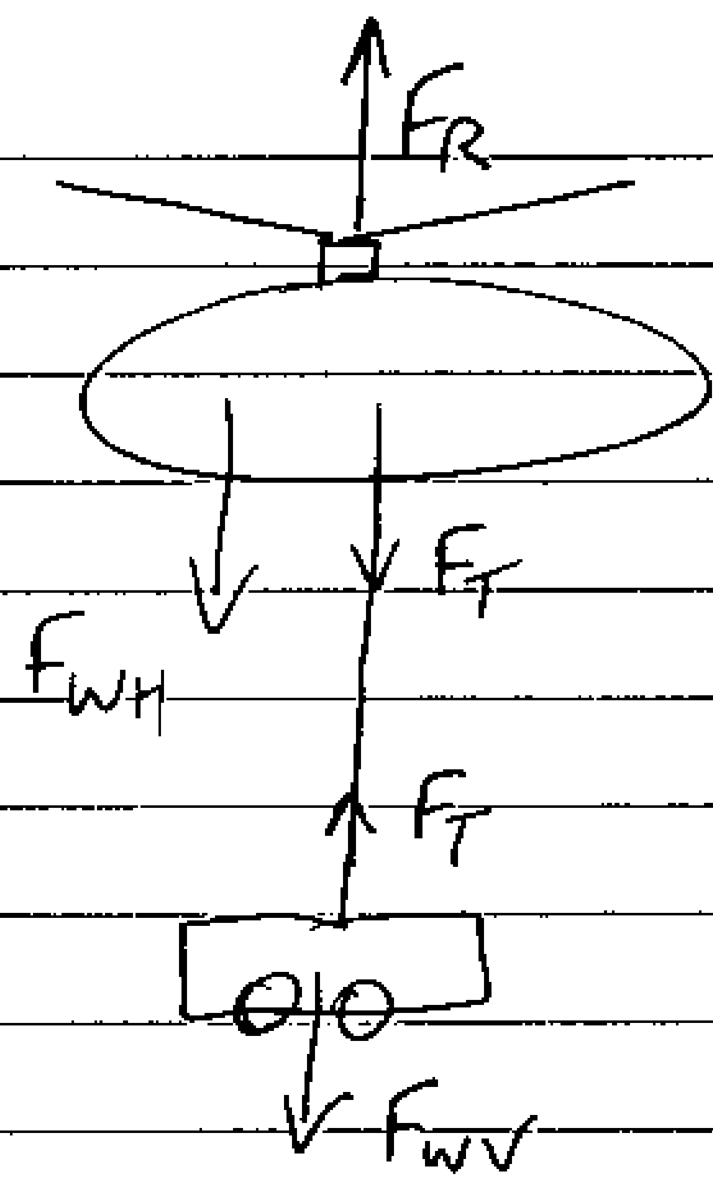
At max. altitude, $V_y = 0$

So use $V_y^2 - 0 = 2g_M h$ where h = height gain

$\Rightarrow h = V_y^2 / 2g_M = \frac{99.9^2}{2 \times 1.5} = \underline{3326.7m}$

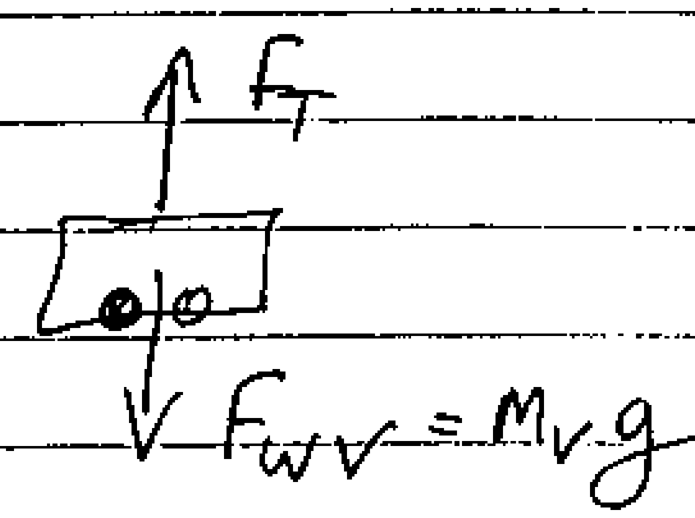
$\therefore$ Max altitude $= 999m$ (for $t = 20s$) $+ h = 4325.7m$

2 a)



System

(i) Vehicle-only



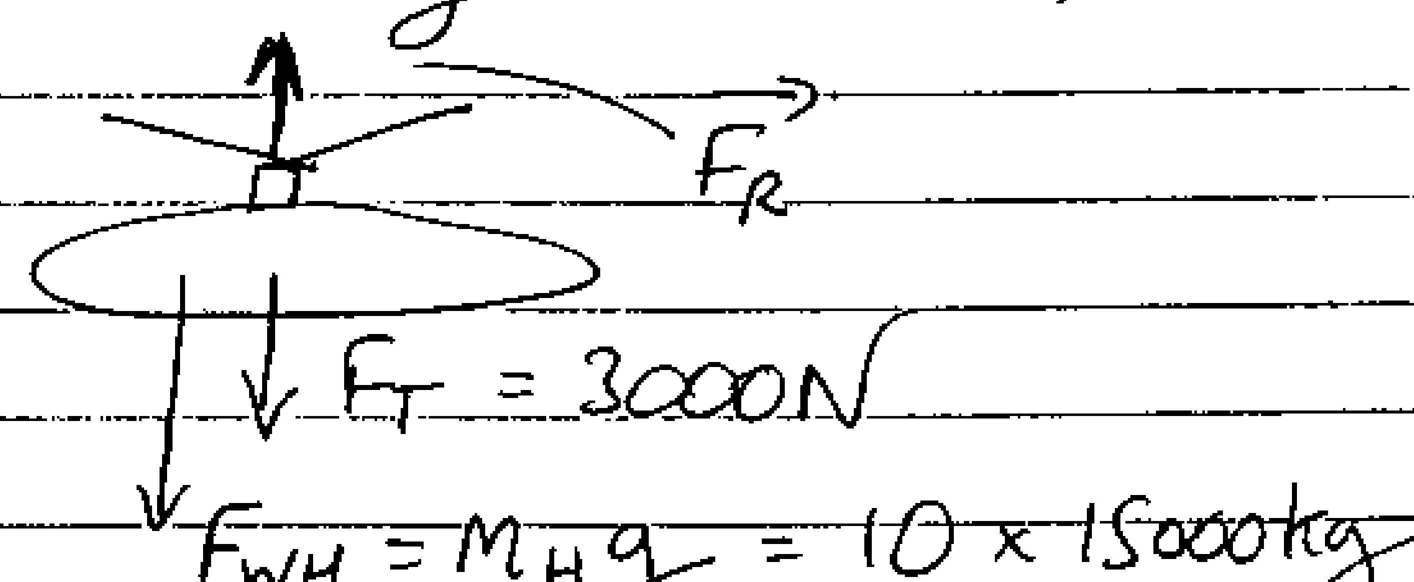
Net. accel of vehicle $= 0{\cdot}6\,m/s^2$ upwards

$\Rightarrow$ net force $F_T - F_{WV} =$ mass x accel $= 5000\,kg \times 0{\cdot}6\,m/s^2$

$\therefore\ F_T = F_{WV} + (5000 \times 0{\cdot}6)$

$= 5000\,kg \times (10 + 0{\cdot}6) = 53000\,N$

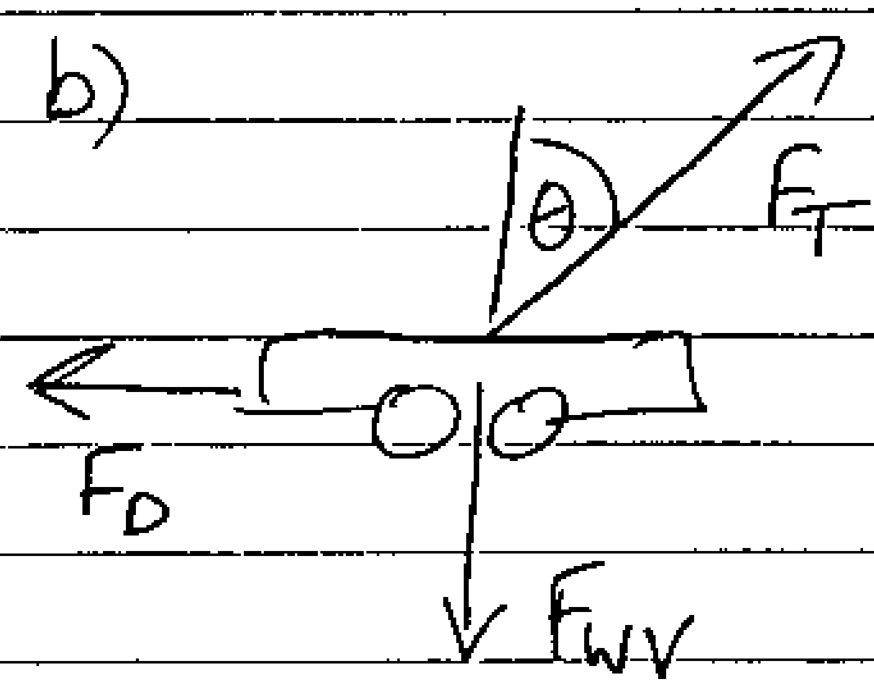
(ii) Helicopeter only.



Net force $= M_H \times 0{\cdot}6\,m/s^2 = F_R - F_T - F_{WH}$

$\Rightarrow$ Rotor force $F_R = M_H(g + 0{\cdot}6\,m/s^2) + F_T = 212\,kN$

b)



Vertical (no accel).

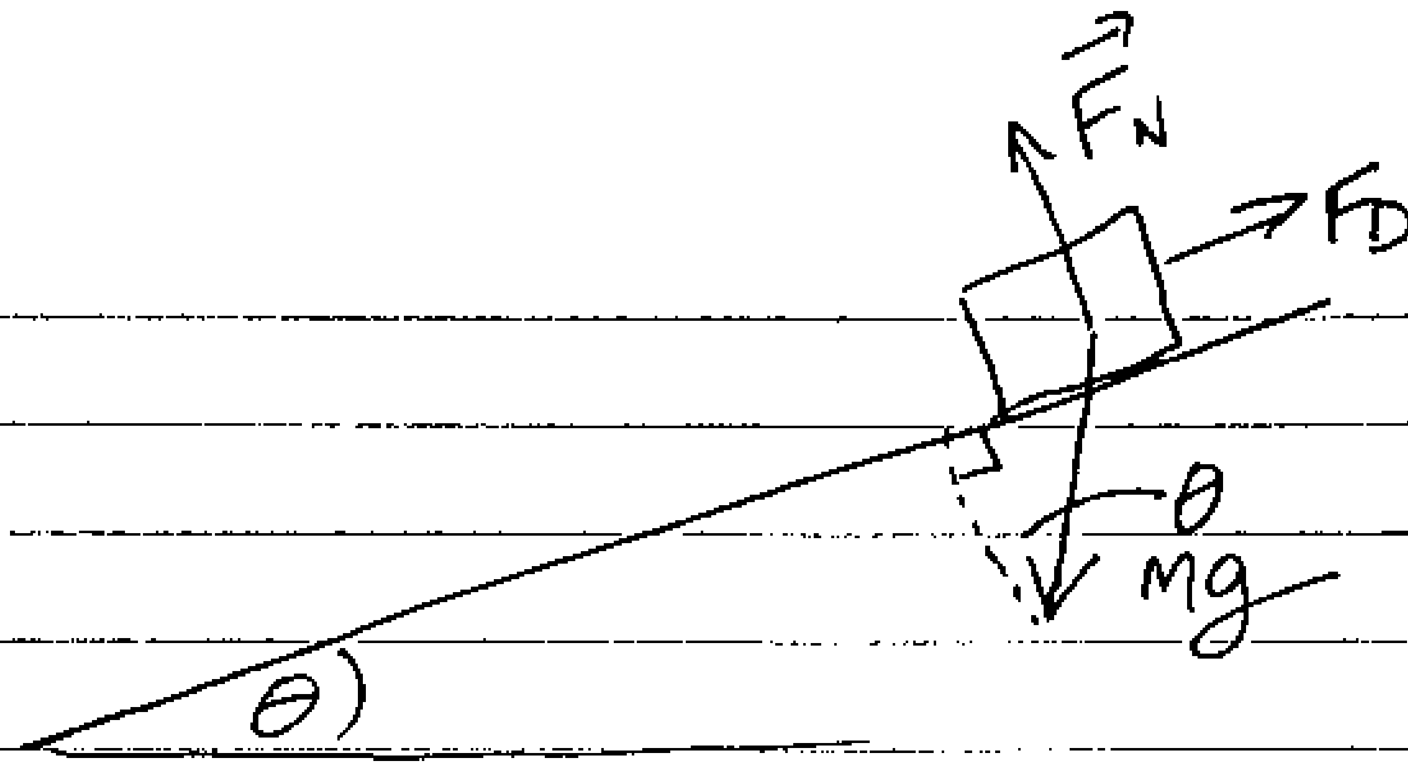
$F_T \cos\theta = F_{WV} = M_V g$

$\Rightarrow$ new $F_T = \dfrac{5000 \times 10}{\cos 15^\circ} = 51763\,N$

Horizontal (no accel.)

Drag force $F_D = F_T \sin 15^\circ = 13{\cdot}4\,kN$

3



a) Along ramp, docker's force $F_D = mg\sin\theta$ (no net accel.)

$= 10 \times 100 \times \sin 15 = 258.8\,N$

b) Removing F_D, net force along ramp $= mg\sin\theta$

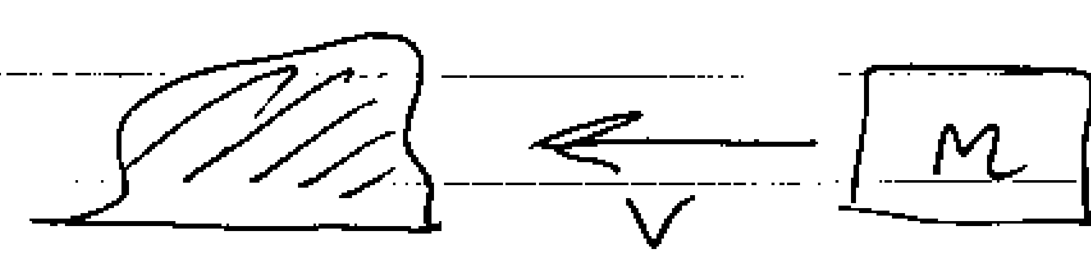
$= \text{mass} \times \text{accel.}$, i.e. $m\frac{dv}{dt} = mg\sin\theta$

$\Rightarrow \frac{dv}{dt} = g\sin\theta = 10 \times \sin 15° = 2.588\ m/s^2$

∴ Over a distance x along ramp $v^2 = v_0^2 + 2(g\sin\theta)x$

$\Rightarrow v^2 = 0 + 2 \times 2.588 \times 8m \Rightarrow v = 6.435\ m/s$ at $x = 8m$.

c) At ramp base



Container's momentum change $\Delta(mv) = m\Delta v$

$= 100 \times (6.435 - 0) = 643.5\ kg\,m/s$

∴ average force $F_{av} = \frac{\Delta mv}{\Delta t} = \frac{643.5}{0.25s} = 2.574\ kN$

(~10 times docker's pushing force)