PROBLEM 12.2

The value of $g$ at any latitude $\phi$ may be obtained from the formula

$$g = 32.09(1 + 0.0053 \sin \phi) \text{ ft/s}^2$$

which takes into account the effect of the rotation of the earth, as well as the fact that the earth is not truly spherical. Knowing that the weight of a silver bar has been officially designated as 5 lb, determine to four significant figures $(a)$ the mass is slugs, $(b)$ the weight in pounds at the latitudes of 0°, 45°, and 60°.

SOLUTION

$$g = 32.09(1 + 0.0053 \sin \phi) \text{ ft/s}^2$$

$\phi = 0^\circ$: $g = 32.09 \text{ ft/s}^2$

$\phi = 45^\circ$: $g = 32.175 \text{ ft/s}^2$

$\phi = 90^\circ$: $g = 32.26 \text{ ft/s}^2$

(a) Mass at all latitudes: $m = \frac{5.00 \text{ lb}}{32.175 \text{ ft/s}^2} = 0.1554 \text{ lb} \cdot \text{s}^2/\text{ft}$

(b) Weight: $W = mg$

$\phi = 0^\circ$: $W = (0.1554 \text{ lb} \cdot \text{s}^2/\text{ft})(32.09 \text{ ft/s}^2) = 4.987 \text{ lb}$

$\phi = 45^\circ$: $W = (0.1554 \text{ lb} \cdot \text{s}^2/\text{ft})(32.175 \text{ ft/s}^2) = 5.000 \text{ lb}$

$\phi = 90^\circ$: $W = (0.1554 \text{ lb} \cdot \text{s}^2/\text{ft})(32.26 \text{ ft/s}^2) = 5.013 \text{ lb}$
PROBLEM 12.4

A spring scale $A$ and a lever scale $B$ having equal lever arms are fastened to the roof of an elevator, and identical packages are attached to the scales as shown. Knowing that when the elevator moves downward with an acceleration of $1 \text{ m/s}^2$ the spring scale indicates a load of 60 N, determine (a) the weight of the packages, (b) the load indicated by the spring scale and the mass needed to balance the lever scale when the elevator moves upward with an acceleration of $1 \text{ m/s}^2$.

SOLUTION

Assume $g = 9.81 \text{ m/s}^2$

$m = \frac{W}{g}$

$\sum F = ma$: $F_s - W = -\frac{W}{g}a$

$W\left(1 - \frac{a}{g}\right) = F_s$

or

$W = \frac{F_s}{1 - \frac{a}{g}} = \frac{60}{1 - \frac{1}{9.81}}$

(b)

$\sum F = ma$: $F_s - W = \frac{W}{g}a$

$F_s = W\left(1 + \frac{a}{g}\right)$

$= 66.81\left(1 + \frac{1}{9.81}\right)$

For the balance system $B$,

$\sum M = 0$: $bF_w - bF_p = 0$

$F_w = F_p$

$W = 66.8 \text{ N}$

$F_s = 73.6 \text{ N}$

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PROBLEM 12.4 (Continued)

But

\[ F_w = W_w \left( 1 + \frac{a}{g} \right) \]

and

\[ F_p = W_p \left( 1 + \frac{a}{g} \right) \]

so that

\[ W_w = W_p \]

and

\[ m_w = \frac{W_p}{g} = \frac{66.81}{9.81} \]

\[ m_w = 6.81 \text{ kg} \]
PROBLEM 12.9

If an automobile’s braking distance from 90 km/h is 45 m on level pavement, determine the automobile’s braking distance from 90 km/h when it is (a) going up a 5° incline, (b) going down a 3-percent incline. Assume the braking force is independent of grade.

SOLUTION

Assume uniformly decelerated motion in all cases.

For braking on the level surface,
\[ v_0 = 90 \text{ km/h} = 25 \text{ m/s}, \quad v_f = 0 \]
\[ x_f - x_0 = 45 \text{ m} \]
\[ v_f^2 = v_0^2 + 2a(x_f - x_0) \]
\[ a = \frac{v_f^2 - v_0^2}{2(x_f - x_0)} \]
\[ = \frac{0 - (25)^2}{2(45)} \]
\[ = -6.9444 \text{ m/s}^2 \]

Braking force.

\[ F_b = ma \]
\[ = \frac{W}{g}a \]
\[ = -\frac{6.944}{9.81} W \]
\[ = -0.70789 W \]

(a) Going up a 5° incline.

\[ \sum F = ma \]
\[ -F_b - W \sin 5° = \frac{W}{g}a \]
\[ a = -\frac{F_b + W \sin 5°}{W} g \]
\[ = -(0.70789 + \sin 5°)(9.81) \]
\[ = -7.79944 \text{ m/s}^2 \]
\[ x_f - x_0 = \frac{v_f^2 - v_0^2}{2a} \]
\[ = \frac{0 - (25)^2}{2(-7.79944)} \]
\[ x_f - x_0 = 40.1 \text{ m} \]
PROBLEM 12.9 (Continued)

(b) Going down a 3 percent incline.

\[ \tan \beta = \frac{3}{100} \quad \beta = 1.71835^\circ \]

\[ -F_b + W \sin \beta = \frac{W}{g}a \]

\[ a = -(0.70789 - \sin \beta)(9.81) \]

\[ = -6.65028 \text{ m/s} \]

\[ x_f = x_0 = \frac{0 - (25)^2}{(2)(-6.65028)} \]

\[ x_f - x_0 = 47.0 \text{ m} \]
PROBLEM 12.11

The coefficients of friction between the load and the flat-bed trailer shown are $\mu_s = 0.40$ and $\mu_k = 0.30$. Knowing that the speed of the rig is 72 km/h, determine the shortest distance in which the rig can be brought to a stop if the load is not to shift.

SOLUTION

Load: We assume that sliding of load relative to trailer is impending:

$$F = F_m = \mu_s N$$

Deceleration of load is same as deceleration of trailer, which is the maximum allowable deceleration $a_{\text{max}}$.

$$\Sigma F_y = 0: \quad N - W = 0 \quad N = W$$

$$F_m = \mu_s N = 0.40 W$$

$$\Sigma F_x = ma: \quad F_m = ma_{\text{max}}$$

$$0.40 \frac{W}{g} a_{\text{max}} \quad a_{\text{max}} = 3.924 \text{ m/s}^2$$

$$a_{\text{max}} = 3.92 \text{ m/s}^2 \rightarrow$$

Uniformly accelerated motion,

$$v^2 = v_0^2 + 2ax \quad \text{with} \quad v = 0 \quad v_0 = 72 \text{ km/h} = 20 \text{ m/s}$$

$$a = -a_{\text{max}} = 3.924 \text{ m/s}^2$$

$$0 = (20)^2 + 2(-3.924)x \quad x = 51.0 \text{ m}$$

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