BBMerlion

Physics A Level

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QUIZ 1 SOLUTION

Meausurement, Kinematics, Dynamics, Forces, Energy, Motion in Circle, Gravitational Field, Oscillation

Question 1

A. Let h = height of well

t_1 = time for rock to travel to the surface of water

t_2 = time for sound to travel to the mouth of well

$h = \frac{1}{2} g t_1^2$ (1)

$h = v t_2$ (2)

$$t_1 + t_2 = 2.4\ s$$

Substituting eqn. (2) to eqn. (1) and substituting value of t_2, we get

$$\frac{1}{2} g t_1^2 = v(2.4 - t_1)$$

$$4.9 t_1^2 = 806.4 - 336 t_1$$

$$4.9 t_1^2 + 336 t_1 - 806.4 = 0$$

$$t_1 = 2.32\ s$$

$$h = 26.37\ m$$

Question 1

B. i) Let t_1 = time for rocket to travel with engine fires
t_2 = time for rocket to travel without using engine
When the engine fires,

$$h = v_0 t_1 + \frac{1}{2} a t_1^2$$
$$1000 = 80t_1 + 2t_1^2$$
$$t_1^2 + 40t_1 - 500 = 0$$
$$t_1 = 10\ s$$
$$v_1 = v_0 + at$$
$$v_1 = 120 \frac{m}{s}$$

When the engine fails,

$$h = v_1 t_2 - \frac{1}{2} g t_2^2$$
$$-1000 = 120t_2 - 4.9t_2^2$$
$$4.9t_2^2 - 120t_2 - 1000 = 0$$
$$t_2 = 31.06\ s$$

Total time rocket in motion:

$$t_1 + t_2 = 41.06\ s$$

Question 1

(ii) Maximum altitude occurs when v = 0,

$$0 = v_1 - gt$$

$$t = \frac{120}{9.8} = 12.24\ s$$

$$h_{maximum} = v_1 t - \frac{1}{2} g t^2 + 1000$$

$$= 120 \times 12.24 - \frac{1}{2} \times 9.8 \times 12.24^2 + 1000$$

$$= 1734.7\ m$$

(iii) $v_f = \sqrt{2gh}$

$$= \sqrt{2 \times 9.8 \times 1734.7}$$

$$= 184.4\ m/s$$

C. $Thickness = \frac{volume}{surface\ area}$

$$= \frac{3.78 \times 10^{-3}}{25} = 1.512 \times 10^{-4}\ m$$

Question 2

A. $\sum F = ma$

For m_1: $T = m_1 a$

For m_2: $T - m_2 g = 0$

Substituting the above equation, we get

$$a = \frac{m_2 g}{m_1}$$

To make all blocks static,

$$F = (M + m_1 + m_2)a = (M + m_1 + m_2)\left(\frac{m_2 g}{m_1}\right)$$

Question 2

$$\sum F_y = L_y - T_y - mg = L\cos 20 - T\sin 20 - 7.35\ N = ma_y = 0$$

$$\sum F_x = L_x + T_x = L\sin 20 + T\cos 20 = m\frac{v^2}{r}$$

$$m\frac{v^2}{r} = 0.75\frac{35^2}{60\cos 20} = 16.3\ N$$

We have the simultaneous equations

$$L\sin 20 + T\cos 20 = 16.3\ N$$
$$L\cos 20 - T\sin 20 = 7.35\ N$$
$$L + T\frac{\cos 20}{\sin 20} = \frac{16.3}{\sin 20}$$
$$L - T\frac{\sin 20}{\cos 20} = \frac{7.35}{\cos 20}$$
$$T(\cot 20 + \tan 20) = \frac{16.3}{\sin 20} - \frac{7.35}{\cos 20}$$
$$T(3.11) = 39.8\ N$$
$$T = 12.8\ N$$

Question 3

A. Consider the work done on the pile driver from the time it starts from rest until it comes to rest at the end of the fall. Let d = 5.00 m represent the distance over which the driver falls freely, and h = 0.12 m the distance it moves the piling.

$$\sum W = \Delta K: W_{gravity} + W_{beam} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

so,

$$(mg)(h+d)\cos 0 + Fd\cos 180 = 0$$

Thus,

$$F = \frac{mg(h+d)}{d} = \frac{2100(9.8)(5.12)}{0.120} = 8.78 \times 10^5\ N$$

The force on the pile driver is upward

Question 3

B. The energy of the car is $E = \frac{1}{2}mv^2 + mgy$

$E = \frac{1}{2}mv^2 + mgd\sin\theta$ where d is the distance it has moved along the track

$$P = \frac{dE}{dt} = mv\frac{dv}{dt} + mgv\sin\theta$$

When speed is constant,

$$P = mgv\sin\theta = 950(9.8)(2.2)\sin 30 = 1.02 \times 10^4\ W$$

$$\frac{dv}{dt} = a = \frac{2.2 - 0}{12} = 0.183\ m/s^2$$

Maximum power is injected just before maximum speed is attained:

$$P = mva + mgv\sin\theta = 950(2.2)(0.183) + 1.02 \times 10^4\ W = 1.06 \times 10^4\ W$$

At the top end,

$$\frac{1}{2}mv^2 + mgd\sin\theta = 950\left(\frac{1}{2}(2.2) + 9.8 \times 1250\sin 30\right) = 5.82 \times 10^6\ J$$

Question 4

A. (i) $\sum F = -2T \sin\theta\, \hat{\boldsymbol{j}}$ where $\theta = \tan^{-1}\left(\frac{y}{L}\right)$

Therefore, for a small displacement

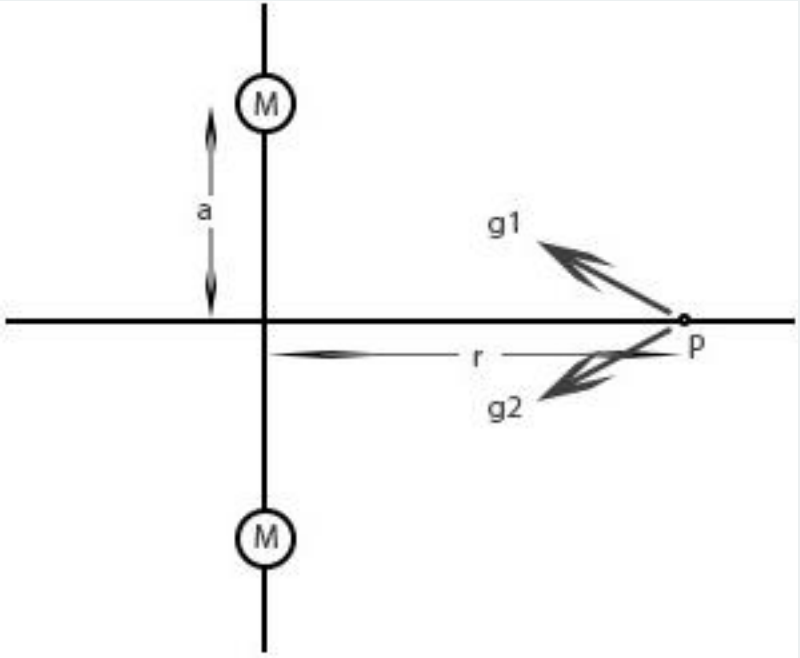
$\sin\theta \approx \tan\theta = \frac{y}{L}$ and $\sum F = -\frac{2Ty}{L}\hat{\boldsymbol{j}}$

(ii) The total force exerted on the ball is opposite in direction and proportional to its displacement from equilibrium, so the ball moves with simple harmonic motion. For a spring system,

$\sum F = -kx$ becomes here $\sum F = -\frac{2T}{L}y$

Therefore, the effective spring constant is $\frac{2T}{L}$ and $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{2T}{mL}}$

Question 4



Question 4

B. (i) $g_1 = g_2 = \frac{MG}{r^2+a^2}$

$$g_{1y} = -g_{2y}$$
$$g_y = g_{1y} + g_{2y} = 0$$
$$g_{1x} = g_{2x} = g_2 \cos\theta$$
$$\cos\theta = \frac{r}{(a^2 + r^2)^{\frac{1}{2}}}$$
$$g = 2g_{2x}(-\hat{\boldsymbol{i}})$$

or

$g = \frac{2MGr}{(r^2+a^2)^{\frac{3}{2}}}$ toward the center of mass

(ii) As r approaches 0, the above equation approaches $\frac{0}{a^3} = 0$

(iii) As r becomes much larger than a, the expression approaches $\frac{2MGr}{r^3} = \frac{2MG}{r^2}$

Reference

- Physics for Scientist and Engineer, 6^{th} ed, Serway Jewett