This is a Class 1 exam

Lebanon Evangelical School for Boys and Girls

Lebanon Evangelical School

for Boys and Girls — Loueizeh - Baabda

Stage Exam 01

06NOV2023

Do NOT write in this box. Your MARK will be placed here.

Subject :	Physics
Class :	12M and 12E
Teacher :	Mr. Ali Moukalled
Duration :	1 hour

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

Exercise1 (15 points)

Collision

Consider two simple pendulums (S_1) and (S_2):

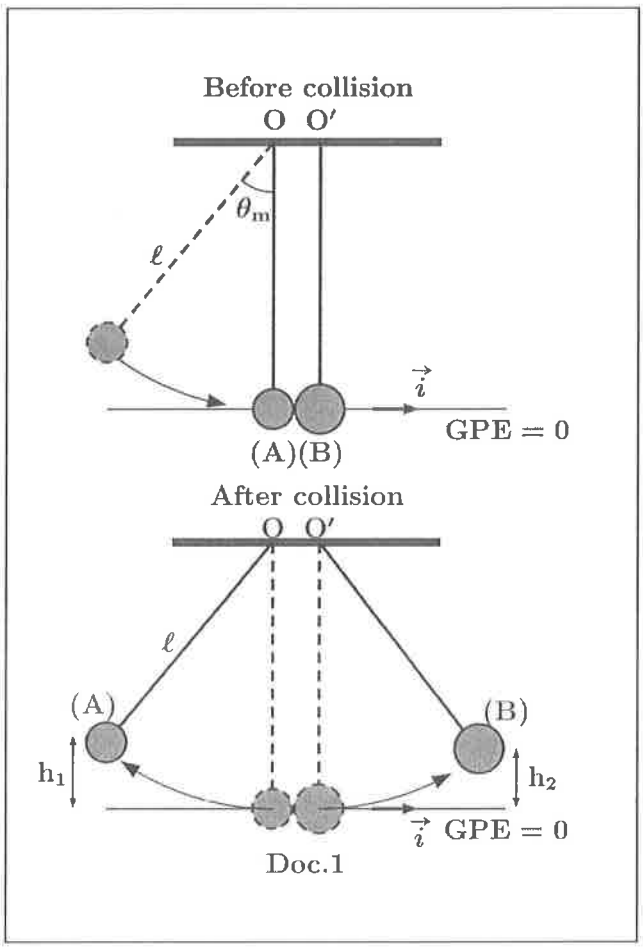
- pendulum (S_1) is formed of a sphere (A), taken as a particle of mass m_1, suspended to the lower extremity of a light inextensible string of length ℓ. The upper extremity of the string is fixed, at O, to a support;
- pendulum (S_2) is formed of a sphere (B), taken as a particle of mass $m_2 > m_1$, suspended to the lower extremity of a light inextensible string of same length ℓ.

The two strings are vertical and the two particles touching each other (Doc.1).

Neglect air resistance and friction around O and O'.

Take:

- the horizontal plane passing through the lowest positions of (A) and (B) as a reference level for gravitational potential energy;
- $g = 10 m'/s^2$.



Doc.1

1. The pendulum (S_1) is shifted in the vertical plane by an angle θ_m from its stable equilibrium position, the string remains taut, and then (A) is released from rest.
   Determine, in terms of g, ℓ and θ_m, the expression of the speed v_1 of (A) when the pendulum (S_1) passes through the equilibrium position.
2. When (S_1) passes through the equilibrium position, (A) makes a head-on elastic collision with (B). Determine in terms of m_1, m_2 and v_1 the expressions v'_1 and v'_2 of the algebraic values of the velocities $\vec{v}'_1$ and $\vec{v}'_2$ of (A) and (B) respectively just after this collision.
3. Specify the signs of v'_1 and v'_2.
4. P'_1 and P'_2 are respectively the algebraic values of the linear momentum of (A) and (B) just after this collision :
   $P'_1 = \frac{-2}{75}$ Kg.m/s and $P'_2 = \frac{1}{15}$ Kg.m/s.
   (a) Determine the algebraic value of the linear momentum P_1 of (A) just before collision.
   (b) Deduce the value of the angle θ_m if $\ell = 40$cm and $m_1 = 20$g.

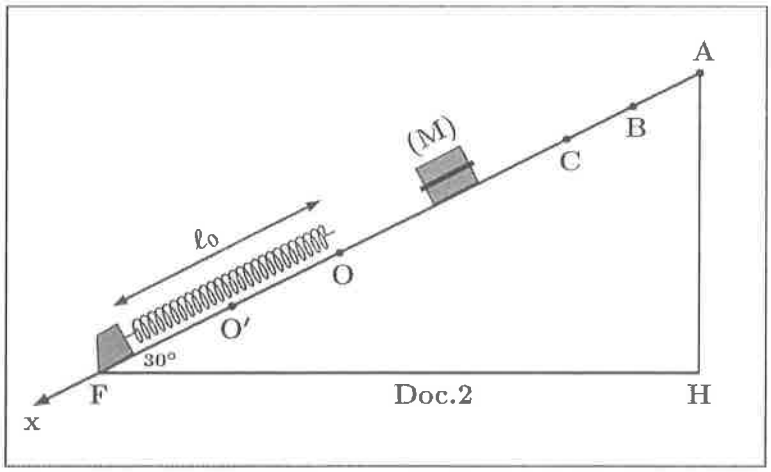
5. The maximum heights attained by (A) and (B) after this collision are $\mathbf{h_1}$ and $\mathbf{h_2}$ respectively (Doc.1).
   (a) Determine the expression of $\mathbf{h_1}$ in terms of $\mathbf{v_1'}$ and g.
   (b) Write the expression of $\mathbf{h_2}$ in terms of $\mathbf{v_2'}$ and g.
   (c) Determine the ratio $\frac{\mathbf{m_1}}{\mathbf{m_2}}$ such that: $\mathbf{h_1 = h_2}$.

Exercise2 **(7 points)**

Motion of a block on an inclined plane

A block (M), considered as a particle of mass $\mathbf{m = 0.5Kg}$, can move on a straight track AF, situated in a vertical plane and inclined by an angle $\boldsymbol{\alpha = 30°}$ with the horizontal. Point A is taken as an origin of the x-axis confounded with (AF). A massless spring of natural length $\boldsymbol{\ell_0 = 50cm}$ and force constant k is placed on the inclined track; one of its ends is fixed at F, and the other end is free at O (Doc.2).
(M) is released without initial velocity from the top A of the track AF, and then it passes through point B with a velocity $\vec{V}_B$ of magnitude $\mathbf{V_B = \sqrt{2}m/s}$ and through point C with a velocity $\vec{V}_C$ of magnitude $\mathbf{V_C = \sqrt{2.4}m/s}$. After point C, (M) continues its motion without friction, hits the spring and compresses it by a distance OO'.
The aim of this exercise is to determine k.
Take:

- the horizontal plane containing (FH) as a reference level for the gravitational potential energy;
- $\mathbf{AB = BC = 20cm, AF = 1.6m}$;
- $\mathbf{g = 10m/s^2}$.



Doc.2

1. Calculate the mechanical energy of the system [(M),Earth] at A, B and C.
2. Deduce that:
   (a) the motion of (M) between A and B takes place without friction;
   (b) (M) is submitted to a force of friction $\vec{f}$ during its motion between B and C.
3. Show that the internal energy of the system [(M), Earth, Track, Atmosphere] increases by 0.4 J during the motion of (M) between B and C.

Turn the page

4. Determine the magnitude **f** of the force of friction $\vec{f}$, supposed constant and parallel to the displacement, exerted on (M) during its motion between B and C.
5. The mechanical energy of the system [(M),Earth] at O is $\mathbf{ME_O = 3.6J}$. Why ?
6. (M) reaches O, and compresses the spring by a maximum distance $\mathbf{OO' = 24cm}$. Determine the value of **k**.

GOOD LUCK

SE01: 20232024 / Physics / 12ME SOLUTION

Exercise 1

1) In the absence of friction, the M.E is conserved (1)

$$M.E_{\theta=\theta_m} = M.E_{\theta=0}$$

$$\cancel{K.E_{\theta_m}} + G.P.E_{\theta_m} = K.E_0 + \cancel{G.P.E_0}$$

$$mg\ell(1-\cos\theta_m) = \frac{1}{2}m_1V_1^2$$

$$g\ell(1-\cos\theta_m) = \frac{1}{2}V_1^2$$

$$V_1^2 = 2g\ell(1-\cos\theta_m)$$

$$\boxed{V_1 = \sqrt{2g\ell(1-\cos\theta_m)}}$$ (1)

2) During collision, the system (m_1, m_2) is isolated
=> the linear momentum is conserved

$$\vec{P}_{\text{just before collision}} = \vec{P}_{\text{just after collision}}$$

$$m_1\vec{V_1} + m_2\vec{V_2} = m_1\vec{V_1}' + m_2\vec{V_2}'$$ (1)

$$\boxed{m_1V_1 = m_1V_1' + m_2V_2'}$$ (1) algebraic expression

$$m_1V_1 - m_1V_1' = m_2V_2'$$

$$\boxed{m_1(V_1 - V_1') = m_2V_2'}$$ (2) (1)

The collision is Elastic

$K.E_{\text{before collision}} = K.E_{\text{after collision}}$

$$\frac{1}{2}m_1v_1^2 = \frac{1}{2}m_1v_1'^2 + \frac{1}{2}m_2v_2'^2$$

$$m_1v_1^2 - m_1v_1'^2 = m_2v_2'^2$$

$$m_1(v_1^2 - v_1'^2) = m_2v_2'^2 \quad (1)$$

$$\boxed{m_1(v_1 - v_1')(v_1 + v_1') = m_2v_2'^2} \quad (3)$$

$$\frac{(3)}{(2)} \quad \frac{m_1(v_1 - v_1')(v_1 + v_1')}{m_1(v_1 - v_1')} = \frac{m_2v_2'^2}{m_2v_2'}$$

$$v_1 + v_1' = v_2'$$

$$\boxed{v_1' - v_2' = -v_1} \quad (4) \quad (1)$$

$$\begin{cases} m_1v_1 = m_1v_1' + m_2v_2' & \text{---- (1)} \\ -v_1 = v_1' - v_2' & \text{---- (4)} \quad \times m_2 \end{cases}$$

$$\begin{cases} m_1v_1 = m_1v_1' + m_2v_2' \\ -m_2v_1 = m_2v_1' - m_2v_2' \end{cases}$$

$$v_1'(m_1 + m_2) = v_1(m_1 - m_2) \quad (1)$$

$$\boxed{v_1' = \frac{v_1(m_1 - m_2)}{m_1 + m_2}}$$

$$\begin{cases} m_1V_1 = m_1V_1' + m_2V_2' \\ -V_1 = V_1' - V_2' \quad \times(-m_1) \end{cases}$$

$$\begin{cases} m_1V_1 = m_1V_1' + m_2V_2' \\ +m_1V_1 = -m_1V_1' + m_1V_2' \end{cases}$$

$$2m_1V_1 = V_2'(m_1+m_2)$$

$$\boxed{V_2' = \frac{2m_1V_1}{m_1+m_2}}$$

3) $V_1' < 0$ since $m_1 - m_2 < 0$ so (m_1) rebounds
$V_2' > 0$ m_1 & V_1 are positive

4) $P_1' = \frac{-2}{75}$ Kg m/s $\qquad P_2' = \frac{1}{15}$ Kg m/s

a) During collision, the Linear momentum is conserved

$$\overrightarrow{P}_{\substack{just\\before\\collision}} = \overrightarrow{P}_{\substack{just\\after\\collision}}$$

$$\overrightarrow{P_1} = \overrightarrow{P_1'} + \overrightarrow{P_2'}$$

$$P_1 = -\frac{2}{75} + \frac{1}{15}$$

$$P_1 = \frac{1}{25} \text{ Kg m/s}$$

b) $P_{\substack{just\\before}} = m_1V_1$

$0.04 = 0.02 \times V_1$

$V_1 = 2$ m/s

Replace in V_1

$2 = \sqrt{2g\ell(1-\cos\theta_m)}$

$2 = \sqrt{2\times10\times0.4(1-\cos\theta_m)}$

$\theta_m = 60°$

5) a) M.E$_{\theta_m}$ = M.E$_0$

G.P.E$_{\theta_m}$ = K.E$_0$ (after) For m_1

$\frac{1}{2}m_1V_1'^2 = m_1gh_1 \Rightarrow \boxed{h_1 = \frac{V_1'^2}{2g}}$

5) b) Similarly to 5 (a)

$$h_2 = \frac{V_2'^2}{2g}$$

(1)

c) $h_1 = h_2$

(1)

$$\frac{V_1'^2}{2g} = \frac{V_2'^2}{2g} \Rightarrow V_1'^2 = V_2'^2, \quad V_1' = V_2'$$

$$\frac{2m_1V_1}{(m_1+m_2)} = -\frac{(m_1-m_2)V_1}{(m_1+m_2)}$$

$$2m_1 = -m_1 + m_2$$

$$3m_1 = m_2$$

(1)

$$\boxed{\frac{m_1}{m_2} = \frac{1}{3}}$$

Exercise 2

$m = 0.5\,kg$, $\alpha = 30°$, $\ell_0 = 50cm = 0.5m$, $V_A = 0\,m/s$, $V_B = \sqrt{2}\,m/s$

$V_C = \sqrt{2.4}\,m/s$

$AB = BC = 0.2m$, $AF = 1.6m$

1) • $M.E_A = K.E_A + G.P.E_A$

$= mgh_A$

$= mg\,AF\sin\alpha$

$= 0.5 \times 10 \times 1.6 \times \sin 30$

$= 4\,J$

$M.E_A = 4\,J$ (0.5)

• $M.E_B = K.E_B + G.P.E_B$

$= \frac{1}{2} m V_B^2 + mgh_B$

$= 0.5\,mV_B^2 + mg\,BF\sin\alpha$

$= 0.5(0.5)(2) + 0.5 \times 10 \times 1.4 \times \sin 30$

$= 4\,J$

$M.E_B = 4\,J$ (0.5)

• $M.E_C = K.E_C + G.P.E_C$

$= \frac{1}{2} m V_C^2 + mg\,FC\sin 30$

$= 0.5(0.5)(2.4) + 0.5 \times 10 \times 1.2 \times 0.5$

$= 3.6\,J$

$M.E_C = 3.6\,J$ (0.5)

2. a) $M.E_A = M.E_B = 4\,J$ (No friction) (0.5)
b) $M.E_B \neq M.E_C$ (Friction exist) (0.5)

3. The system [(M), Earth, Track, Atmosphere] is energy isolated

$$E_T = M.E + U = \text{constant}$$
$$\Delta M.E + \Delta U = 0$$
$$\Delta U = -\Delta M.E$$
$$= -(3.6 - 4)$$
$$= +0.4\,J$$

(1.5)

ΔU (the internal energy) increases by 0.4 J

4. $\Delta M.E = -f \times BC$
$-0.4 = -f \times 0.2$
$f = 2\,N$ (1)

$f = 2\,N$

5. $M.E_C = M.E_O = 3.6\,J$ due to the absence of friction from C to O. (1)

6. $OO' = 0.24\,cm$
$M.E_O = M.E_{O'}$
$K.E_O + G.P.E_O + E.P.E_O = K.E_{O'} + G.P.E_{O'} + E.P.E_{O'}$

$$3.6 = \frac{1}{2} K OO'^2 + mgh_{O'}$$

$\ell - OO'$

$$3.6 = 0.5K(0.24)^2 + 0.5 \times 10 \times (\ell - OO')\sin\alpha$$
$$3.6 = 0.0288K + 0.65$$
$$K = 102.43\,N/m$$

(1)

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