WEBSITE PROBLEMS: **DYNAMICS**

Level 3

Exercise 1: Two bodies, P and Q, of equal mass are travelling towards one another on a level frictionless track, with speeds u and v respectively. They make an elastic collision. At some instant during the collision, P is brought instantaneously to rest. What is the speed of Q at this instant?

a) zero

b) $(v - u)$

c) $2(v - u)$

d) $\frac{1}{2}(v - u)$

e) $\sqrt{uv}$

Exercise 2: Which of the following is a unit of power?

a) $\mathrm{N\,s^{-1}}$

b) $\mathrm{N\,m\,s}$

c) $\mathrm{N\,m\,s^{-1}}$

d) $\mathrm{N\,m\,s^{-2}}$

e) $\mathrm{kg\,m\,s^{-1}}$

Exercise 3: Two equal sized cubes, X and Y, of masses m and $2m$ respectively, rest on a smooth horizontal plane with a face of one cube in contact with a face of the other. They are accelerated by a force F applied to cube X, on the face opposite to that touching cube Y. What is the magnitude of the force exerted by block Y on block X during this acceleration?

a) 0

b) $\frac{1}{3}F$

c) $\frac{1}{2}F$

d) $\frac{2}{3}F$

e) F

Exercise 4: Two skiers want to reach the top of an incline without pushing. The first skier, of mass m, reaches the start of the incline with a speed v. He just makes it to the top of the incline. The second skier, of mass $\frac{2}{3}m$, has a speed $\frac{2}{3}v$ at the bottom of the incline. Will she make it to the top without pushing? It can be assumed that frictional forces are negligible.

a) No, she makes it to $\frac{8}{27}h$

b) No, she makes it to $\frac{4}{9}h$

c) No, she makes it to $\frac{8}{9}h$

d) Yes, she just makes it to the top

e) Yes, she makes it to the top with a non-zero velocity

Exercise 5: A particle Q of mass 2 kg is resting on a frictionless surface. It is attached to one end of a piece of elastic, with the other end of the elastic being attached to a fixed point. Q is then pulled back and released from rest with the elastic extended 0.5 m beyond its natural length.

After the particle has been accelerated, the string becomes slack. Rather than being let to continue in some kind of oscillatory motion, the string is cut when it first becomes slack. It is travelling at a speed of 4 ms^{-1} when this occurs.

Assuming no losses to friction or other dissipative forces:

a) Calculate the energy stored in the elastic, and the maximum tension in the elastic during the process.

Q then makes an elastic collision with a stationary body P and rebounds back along the same track at 3.0 ms^{-1}.

b) Calculate the mass of P, and its velocity after the collision.

c) If Q had instead been accelerated from rest by a small motor giving a power of 40 W, how long would it have taken to reach a speed of 4.0 ms^{-1}?

Exercise 6: Define impulse and state the law of conservation of linear momentum.

a) A nail of mass 7 g is held horizontally and is hit by a hammer of mass 0.25 kg moving at 10 ms^{-1}. The hammer remains in contact with the nail during and after the blow. Find the velocity of the nail and hammer immediately after the blow.

b) Calculate the impulse between the hammer and nail, clearly stating the units in which it is measured.

c) The nail goes on to penetrate 1 cm into a stationary wooden block. Find the resistive force the block exerts as the nail is pushed into it, assuming the force to be constant.

Exercise 7: A metal block of mass m rests on a rough wooden surface. A thread is attached to the right side of the block and a tension is applied to cause it to move. The motion is opposed by a constant frictional force F_r between the block and the surface.

a) Draw a diagram to show all the forces on the block immediately after motion commences.

b) When the tension in the thread is T, the acceleration of the block is measured to be a. Calculate the new acceleration, a_n, if the tension is increased to $\frac{5}{4}T$.

c) With the tension of $\frac{5}{4}T$ applied, the block accelerates from rest but after a time t the string breaks. Explain the subsequent motion of the block, and also show that it travels a total distance of

$$s = \frac{1}{2}\left(a_n + \frac{a_n^2 m}{F_r}\right) t^2$$

from its initial position.

d) Given that $T = 400$ N, $m = 100$ kg, $t = 2$ s and $a = 0.1$ ms^{-1}, calculate the work done by the block after the string breaks.

Exercise 8: Three particles A, B, and C, each of mass m, lie at rest in that order in a straight line on a smooth horizontal table. The particle A is then projected directly towards B with speed u.

a) Find the velocities of the three particles immediately after the second impact, assuming the collisions are perfectly elastic.

The masses of A, B, and C are now m, $2m$ and $3m$ respectively:

b) Again find the velocities of the three particles immediately after the second impact, assuming the collisions are perfectly elastic.

c) What is the velocity of the composite particle after the second impact, if the balls now collide completely inelastically?

Hint: Draw several diagrams.

a) In a completely elastic collision, no kinetic energy is lost.

c) Completely inelastically means that the particles stick together to form a new particle of mass $m_{\text{new}} = m_1 + m_2$.

Exercise 9:

a) A gun of mass $M = 1000$ kg stands on horizontal ground and can move horizontally against a recoil mechanism. With its barrel raised at an angle of $\theta = 60^\circ$ to the ground, it fires a projectile of mass $m = 20$ kg with a speed $u = 306$ ms^{-1} *relative to the barrel*. Calculate the horizontal impulse on the gun and the total kinetic energy produced by the explosion which fired the projectile. Clearly state the units in which both quantities are measured.

b) If the recoil mechanism brings the gun to rest when it has moved back $r = 25$ cm; find the force exerted by the mechanism, assuming it to be constant.

c) Show that the time taken for the gun to recoil through this distance is $\frac{1}{6}$ s.

Exercise 10:

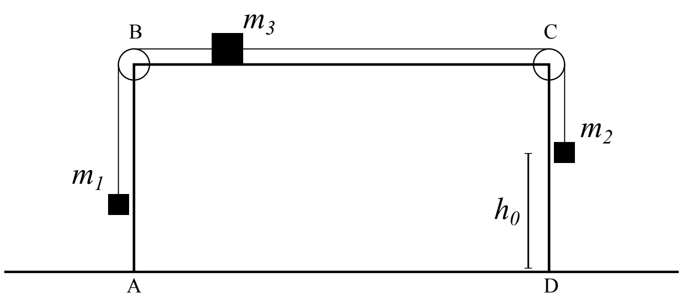

Figure 1

Figure 1 shows the cross section of a smooth table ABCD, standing on the floor AD, with smooth pulleys attached at B and C. Particles of masses $m_1 < m_2 < m_3$ are attached to a light, inelastic, inextensible string which passes over the pulleys as shown. The system is released from rest with the string taut when m_2 is a height h_0 from the floor.

a) Find the initial acceleration of the system.

b) The mass m_2 hits the floor. Describe the subsequent motion of the system until the string again becomes taut. Find the following quantities, given that $m_1 = 1$ kg, $m_2 = 3$ kg, $m_3 = 5$ kg and $h_0 = 0.45$ m:

   i. the velocity with which the system will move just after the string again becomes taut,
   ii. the impulse on m_2 at this instant, and the resulting loss of kinetic energy.

c) Show that, when the system next comes instantaneously to rest, m_2 will be $\frac{4}{9}h_0$ above the floor.

[You may assume that, during the motion, none of the masses come into contact with a pulley.]

Question References

1 - *Used with permission from UCLES, A Level Physics, June 1988, Paper 1, Question 4.*

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