**Experiment 2**

**HOW TO MEASURE A MILLISECOND TIME INTERVAL WITHOUT A CLOCK**

**Physical Principles**

1 When a net force acts on an object it produces a change in the momentum of the object. This change in momentum is equal to the impulse exerted on the object by the force.



2 Conservation of Mechanical Energy

*E* = *U* + *K* = constant

kinetic energy *K* = ½*mv*²

gravitational potential energy *U* = *mgh*

total energy *E*

5 3 The **coefficient of restitution** *e* is a measure of the “bounciness” of a ball. It is equal to the ratio of the ball’s speed immediately after *v*2 to the speed immediately before *v*1 bouncing



The value of the coefficient of restitution of balls used in sport is very important. The governing bodies of various sports lay down the permitted *e* values, for example, a tennis ball should have an *e* value in the range 0.73 to 0.76. Values of *e* for different balls used in sport vary widely, for example, for a squash ball *e* is about 0.25 and a golf ball (hit by a wood) is about 0.7

**Problems**

1 If a ball is dropped onto the floor from a height *h*1 it will bounce up to a lesser height *h*2. Use the principle of energy conservation to show that the velocities of the ball just before and just after it strikes the ground are





where vertically up is taken as the positive direction.

Show that for the ball bouncing off the floor, the impact time between ball and floor is



where *F* is the average contact force exerted by the floor on the ball.

**Equipment**

Basket ball, metre rule, carbon paper, paper, bathroom scales

**Procedure**

* Measure the mass of the basket ball.
* Drop the ball from some convenient height *h*1 and measure its rebound height *h*2.
* Determine the velocities of the ball *v*1 and *v*2 immediately before and immediately after impact with the floor respectively.
* To determine the impact time Δ*t*between the ball and floor we have to know the average force exerted by the floor on the ball. We can do this by dropping the ball from the height *h*1 onto a piece of paper covered with carbon paper. The impact will leave a circular mark on the paper. We can estimate the maximum force *F*max experienced by the ball in the impact by placing the paper with the carbon impression of the ball onto the bathroom scales. Then centre the ball and press down on the ball so that it distorts to cover the impression. Convert this to a force reading. To a good approximation, the average force is related to the maximum force by

*F* = ½ *F*max

**Conclusions**

1 Determine the impact time and its uncertainty between the ball and floor.

2 Determine the coefficient of restitution of the ball bouncing on the floor.

3 Comment on the magnitude of your answers for Δ*t* and *e* and relate your answers to ball sports.

4 What is meant by the term “***timing***” in cricket?

**Sample Data**

mass of basket ball (bathroom scales) *m* = (0.58 ± 0.01) kg (± 2%)

initial height (metre rule) *h*1 = (1.50 ± 0.01) m (± 1%)

rebound height (metre rule) *h*2  = (0.74 ± 0.02) m (± 3%)

max force (bathroom scales) *F*max = (65 ± 2 ) kg (± 3%)

*F*max = 640 N (± 3%)

average force *F* = 320 N (± 3 %)

impact velocity *v*1 = - 5.4 m.s-1 (± 0.5%)

rebound velocity *v*2 = + 3.8 m.s-1 (± 1.5 %)

impact time (take largest uncertainty) Δ*t* = 0.01668 s (± 3%)

**Δ*t* = (16.7 ± 0.6) ms (± 3%)**

coefficient of restitution *e* = 3.8 / 5.4 (± 1.5 %)

***e* = (0.070 ± 0.01) (± 1.5 %)**