Momentum and impulse

Starter

1. **(Review of last lesson)** A scientist thinks that the speed, v, of a wave travelling on the surface of the water is given by $v = kh^{\alpha}\rho^{\beta}g^{\gamma}$ where k is dimensionless, h is the depth of the water, ρ is the density of the water and g is the acceleration due to gravity.
   (a) Use dimension analysis to find values for α, β and γ.
   (b) Decide whether waves travel faster in:
      (i) deep or shallow water
      (ii) winter (when water density is greater) or summer.

Working: (a) $[v] = \mathrm{LT}^{-1}$

$[kh^{\alpha}\rho^{\beta}g^{\gamma}] = \mathrm{L}^{\alpha} \times \left(\mathrm{MV}^{-3}\right)^{\beta} \times \left(\mathrm{LT}^{-2}\right)^{\gamma}$

Equating powers:

M: $\beta = 0$

T: $-2\gamma = -1 \quad \Rightarrow \quad \gamma = \frac{1}{2}$

L: $\alpha + \gamma = 1 \quad \Rightarrow \quad \alpha = \frac{1}{2}$

(b) (i) Since $h^{\frac{1}{2}}$ i.e. the power of h is positive, the higher the value of h, the higher the value of v. So waves tribal faster in deep water.

(ii) Since the power of density, ρ, is zero, the velocity of the waves are unaffected by the density of the medium.

E.g. 1 Write down the momentum of a child of mass 40 kg running with a speed of 3 m/s.

Working: Momentum $= mv$: Momentum $= 40 \times 3 = 120$ Ns.

E.g. 2 Find the momentum created (impulse) when a golf ball of mass 45 grams is driven from the tee with a velocity of 40 m/s.

Working: 45 grams $\equiv 0.045$ kg

Momentum $= mv$: Momentum $= 0.045 \times 50 = 2.25$ Ns.

E.g. 3 A force, F, acts on a body of mass m kg for a time t seconds such that the body's velocity changes from u to v with constant acceleration. By using $F = ma$ and one of the equations of constant acceleration, find an equation connecting F, t, m, u and v.

Working: $v = u + at \quad \Rightarrow \quad a = \frac{v-u}{t}$

Substitute $a = \frac{v-u}{t}$ into $F = ma$: $F = m \times \frac{v-u}{t}$

$Ft = mv - mu$

i.e force $\times$ time for which the force is applied equals the change in momentum

E.g. 4 A hammer of mass 0.8 kg is moving at 12 m/s when it strikes a nail and is brought to rest. Calculate the change in momentum of the hammer.

Working: Change in momentum $= 0.8 \times 12 = 9.6$ Ns

E.g. 5 In what time will a force of 12 N reduce the speed of a particle of mass 1.5 kg from 36 m/s to 12 m/s?

Working: $Ft = mu - mv$: $12t = 1.5 \times 36 - 1.5 \times 12$

$$t = \frac{1.5(36 - 12)}{12}$$

$$t = 3$$

It will take 3 seconds.

Video: Impulse

Impulse EQ

Solutions to Starter and E.g.s

Exercise
p52 3A Qu 1-14