Year 3 General Physics — Mechanics problems

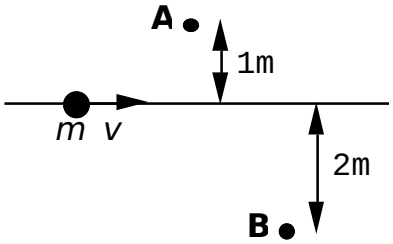
1. A railway engine slowly pushes a carriage along the track at constant speed. Is the horizontal force between the front of the engine and the carriage greater than, less than or equal to the horizontal force between the carriage and the track?

2. A small ball-bearing is placed at the top of a large solid frictionless sphere of radius r and is released, such that it slides down under the force of gravity. At what vertical distance below the top of the large sphere will the ball-bearing leave the surface of the large sphere?

3. A racing car is moving around a horizontal circular track. The coefficient of friction between the car's tyres and the track is μ. The car is travelling at the maximum, constant velocity, v, at which it can maintain the circular motion, radius r, whilst maintaining its grip on the track. Derive an expression for r.

4. A mass m is initially travelling with a velocity v. It is restrained by an elastic band which has a spring constant, k_s. How far does the ball travel past the unstretched length of the band before coming to rest ?

5. A 1 kg mass is moving at velocity v=10 ms^{-1} as shown below. What is the magnitude and direction of the angular momentum about (i) point A (ii) point B.

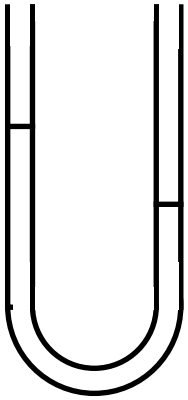


6. A stretched string has a mass per unit length of ρ and tension T. Write down an expression for the velocity of a transverse wave travelling along the string. Two strings of different mass per unit length are joined. One has twice the mass per unit length of the other. What is the ratio of the wavelengths of waves started at one end and transmitted to the other?

7. A neutron has wavelength 10^{-10} m. What is the value of (i) its phase velocity (ii) its group velocity. Which of these velocities is the right one to use in $E = \frac{1}{2}mv^2$?

8. A child weighing 30 kg running at 5 m s^{-1} jumps tangentially onto the outer edge of an initially stationary roundabout of radius 2 m. The roundabout can be considered as having all its mass in the base which is made of 5 cm thick iron of density 7900 kg m^{-3}. What is the resulting angular velocity of the roundabout? Assume no friction in the bearings. What is the centripetal force acting on the child? What constant torque would need to be applied in order to bring the roundabout plus child to a stop in 5 seconds.

9. A U-tube containing water has the level of water displaced as shown and then released. Sketch the height in the left hand tube versus time when
(i) the water is considered as having zero viscosity,
(ii) the water has small viscosity.



Derive an equation for the excess height as a function of time in case (i) in terms of relevant parameters.