

Projectile motion worksheet

AQA AS and A level Physics 7407 and 7408

Conveyor transfer and inspection systems

35-40 minutes independent work and 15-20 minutes review 36 marks

Specification points covered

3.4.1.4 Selected projectile motion: independent horizontal and vertical motion, uniform-acceleration calculations and qualitative effects of air resistance.

3.4.1.1 Selected vector skills: resolve velocity into perpendicular components and combine components to find a resultant velocity.

3.4.1.3 Selected motion skills: displacement, mean velocity, constant acceleration and velocity-time graphs.

1 Transferring beads to a lower receiver

An automated inspection line transfers small ceramic calibration beads between conveyors and receivers. In the first arrangement, each bead leaves a horizontal belt at O with speed 2.40 m s^{-1} (Figure 1). The receiver mouth is 0.800 m below O and accepts beads crossing that level at horizontal displacements from 0.900 m to 1.050 m . Treat each bead as a particle. Until Section 3, neglect air resistance and take $g = 9.81 \text{ m s}^{-2}$. Take right and up as positive.

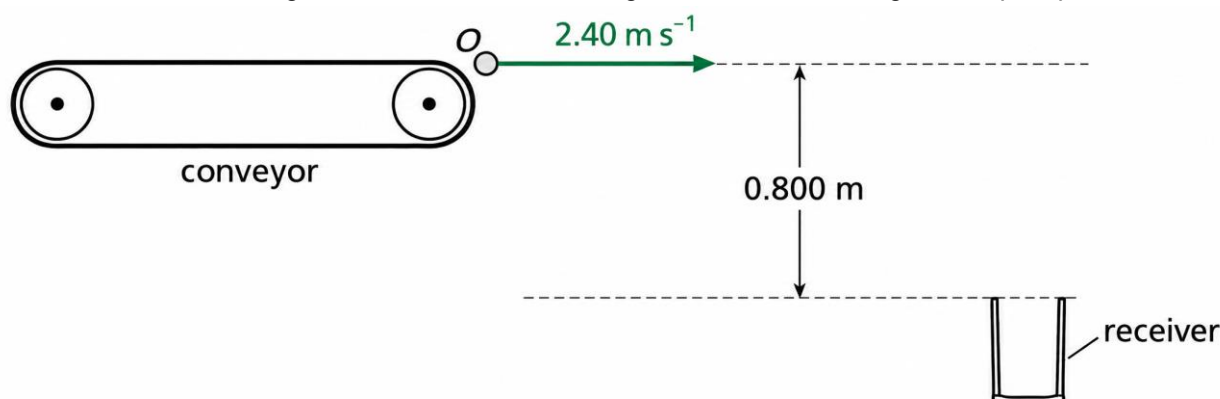


Figure 1 Not to scale

1(a) State the horizontal and vertical components of the acceleration of a bead immediately after it leaves the horizontal belt. **[1 mark]**

1(b) Calculate the time taken for the bead to reach the level of the receiver mouth. **[2 marks]**



1 Checking the lower receiver

1(c) Determine the horizontal displacement when the bead reaches the mouth level. Decide whether the bead enters the opening. **[2 marks]**

1(d) Calculate the vertical component of the velocity just before the bead reaches the mouth level. Include its sign. **[1 mark]**

1(e) Determine the resultant speed and the angle of the velocity below the horizontal at the mouth level. **[2 marks]**

1(f) The horizontal release speed increases by 20%, with all heights unchanged. State whether the flight time changes. Calculate the new horizontal displacement at mouth level and decide whether the bead still enters the opening. **[2 marks]**

1(g) A bead of twice the mass leaves with the same horizontal velocity from the same height. Explain whether its landing position changes in this model. **[2 marks]**

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2 Clearing the inspection baffle

In inspection mode, an inclined belt releases each bead at 4.00 m s^{-1} and 30.0° above the horizontal (Figure 2). Reset $x = 0$ and $y = 0$ at this release point O. A baffle is at $x = 0.600 \text{ m}$ and its top is $y = 0.180 \text{ m}$. The required clearance above its top is at least 10.0 mm . A different receiver has its mouth level with O and accepts horizontal displacements from 1.300 m to 1.500 m .

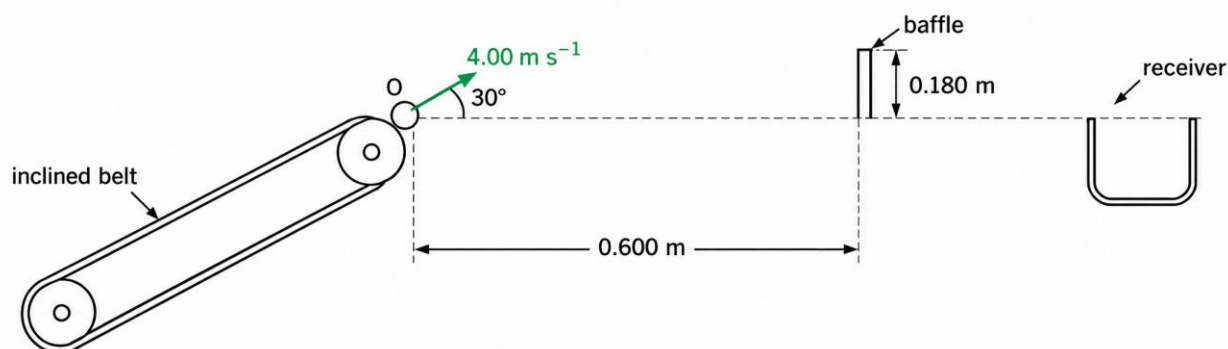


Figure 2 Not to scale

2(a) Calculate the horizontal and vertical components of the initial velocity in inspection mode. **[2 marks]**

2(b) Calculate the maximum rise above O. Explain why the velocity is not zero at the highest point. **[2 marks]**

2(c) Calculate the height of the bead above O when it passes the baffle. Decide whether the bead meets the minimum clearance requirement. **[3 marks]**



2 Positioning the receiver and camera

2(d) Calculate the time at which the bead returns to the level of O and its horizontal displacement then. Decide whether it enters the inspection receiver. **[2 marks]**

2(e) An engineer changes the release angle to 45.0° but keeps the speed at 4.00 m s^{-1} . Calculate the horizontal displacement on returning to the level of O. Decide whether this adjustment is suitable for the unchanged receiver. **[2 marks]**

2(f) Return to the 30.0° setting. An inspection camera triggers when the vertical component of velocity is -1.20 m s^{-1} . Calculate the horizontal displacement and height of the bead relative to O at that instant. **[3 marks]**

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3 Testing the model with a camera

The horizontal arrangement from Section 1 is tested using a side-on camera. Table 1 gives measured bead positions; uncertainties are small compared with the observed changes. The table is experimental evidence, not values calculated from the ideal model.

Table 1

Time t / s	0.000	0.080	0.160	0.240	0.320
Position x / m	0.000	0.187	0.366	0.537	0.700

3(a) Use Table 1 to calculate the mean horizontal velocity during the first time interval and during the last time interval. **[2 marks]**

3(b) Explain what these results show about the model of negligible air resistance. Suggest a physical cause of the observed change in horizontal velocity. **[2 marks]**

3(c) Return to the ideal horizontal-release model in Section 1. On Figure 3, draw the horizontal and vertical velocity graphs from $t = 0$ to $t = 0.40$ s. State what the gradient of the vertical-velocity graph represents. **[3 marks]**

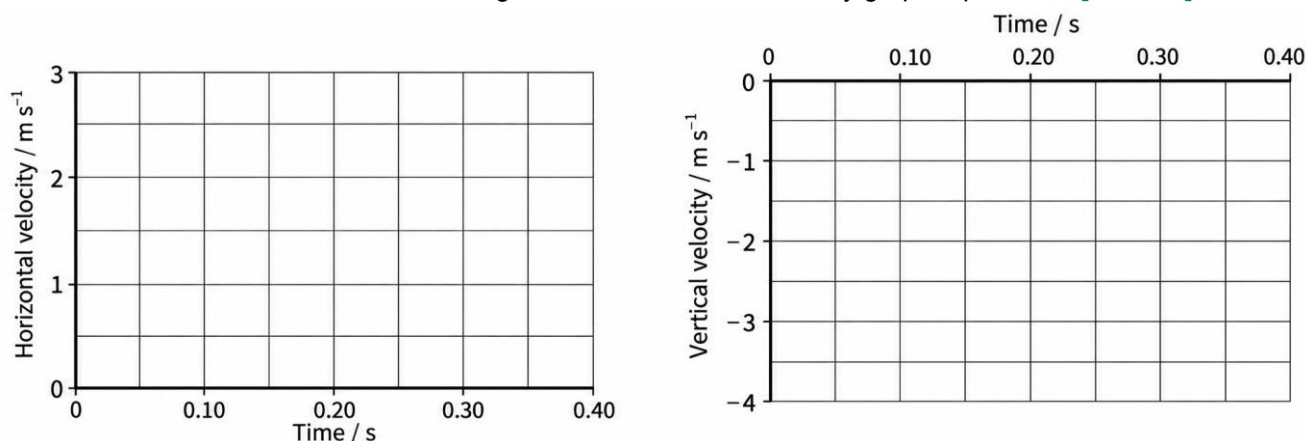


Figure 3 Ideal horizontal release; up is positive

3(d) Describe a video method to test whether the horizontal velocity stays constant during flight. Include how the camera and scale should be positioned, how times are determined, and how the measurements would test the prediction. **[3 marks]**

