2024 Ph H2 Q1

Section: Our Dynamic Universe
Topic: Projectiles and Doppler Effect

Question Summary

A Doppler ball is thrown at **11.0 m s⁻¹** at an angle of **36.0°** from a height of **1.60 m**.

- (a)(i) Calculate horizontal and vertical velocity components.
- (a)(ii) Find the horizontal distance to point Q after **1.53 s**.
- (a)(iii) Determine the height **h** above student B (with max reach 2.10 m) at **t = 0.95 s**.
- (b)(i) When the Doppler ball moves at **8.60 m s⁻¹** along ropes, calculate the frequency heard by student B.
- (b)(ii) Explain how the foam protects the circuit board.

(a)(i) Horizontal and vertical velocity components

✅ **Answer:**

- $u_h = 8.9\,\text{ms}^{-1}$
- $u_v = 6.5\,\text{ms}^{-1}$

Working:

$u_h = u\cos\theta = 11.0\cos 36.0^\circ = 8.9\,\text{ms}^{-1}$,

$u_v = u\sin\theta = 11.0\sin 36.0^\circ = 6.5\,\text{ms}^{-1}$.

(a)(ii) Horizontal distance

✅ **Answer:**

$s = 13.6\,\text{m}$

Working:

$s = u_h t = 8.9 \times 1.53 = 13.6\,\text{m}.$

(a)(iii) Height above student B

✅ **Answer:**

$h = 1.2\,\text{m}$

Working:

Vertical displacement at $t = 0.95\,\text{s}$:

$$s = u_v t + \frac{1}{2}at^2 = 6.5(0.95) + 0.5(-9.8)(0.95^2) = 6.18 - 4.98 = 1.20\,\text{m}$$

Since student B's reach is 2.10 m, the ball is **1.2 m above this leve**

(b)(i) Doppler frequency

✅ **Answer:**

$f_o = 638\,\text{Hz}$

Working:

For a source moving towards a stationary observer:

$$f_o = f_s\frac{v}{v - v_s},$$

where $v = 340\,\text{ms}^{-1}$, $v_s = 8.60\,\text{ms}^{-1}$, $f_s = 622\,\text{Hz}$.

$$f_o = 622\frac{340}{340 - 8.6} = 622 \times 1.025 = 638\,\text{Hz}.$$

(b)(ii) Explanation

The foam **increases the time of contact** during the collision, which **reduces the average force** on the circuit board, protecting it from damage (since $F = \frac{\Delta p}{\Delta t}$).

Quick Tips

- Break projectile motion into **horizontal and vertical** components.
- Use Doppler shift: $f_o = f_s\frac{v}{v \pm v_s}$.
- Soft materials reduce force by **increasing collision time**.