A.

$\vec{v} + \vec{w} = \langle 2, 4, 0 \rangle$.

$-5\vec{v} = \langle -5, -15, 10 \rangle$.

$\vec{v} \cdot \vec{w} = 1 \cdot 1 + 3 \cdot 1 + (-2) \cdot 2 = 0$.

$\text{proj}_{\vec{w}} \vec{v} = \frac{\vec{v} \cdot \vec{w}}{\vec{w} \cdot \vec{w}} \vec{w} = \frac{0}{6} \langle 1, 1, 2 \rangle = \vec{0}$.

$\vec{v} \times \vec{w} = \langle 3 \cdot 2 - (-2) \cdot 1, (-2) \cdot 1 - 1 \cdot 2, 1 \cdot 1 - 3 \cdot 1 \rangle = \langle 8, -4, -2 \rangle$.

B. In Cartesian coordinates, the line is $x + y = 1$. In polar coordinates, the line is therefore $r \cos\theta + r \sin\theta = 1$. Solving for r, we obtain

$$r = \frac{1}{\cos\theta + \sin\theta}.$$

C1. Draw $\text{proj}_{\vec{n}} \vec{\ell}$ in the picture. Also let $\vec{v} = \vec{\ell} - \text{proj}_{\vec{n}} \vec{\ell}$, and draw it in the picture. Also draw $-\vec{v}$. Then

$$\begin{aligned} \vec{r} &= \text{proj}_{\vec{n}} \vec{\ell} + -\vec{v} \\ &= \text{proj}_{\vec{n}} \vec{\ell} + \text{proj}_{\vec{n}} \vec{\ell} - \vec{\ell} \\ &= 2 \frac{\vec{n} \cdot \vec{\ell}}{\vec{n} \cdot \vec{n}} \vec{n} - \vec{\ell} \\ &= 2(\vec{n} \cdot \vec{\ell})\vec{n} - \vec{\ell}. \end{aligned}$$

C2. Well,

$$\begin{aligned} (2(\vec{n} \cdot \vec{\ell})\vec{n} - \vec{\ell}) \cdot (2(\vec{n} \cdot \vec{\ell})\vec{n} - \vec{\ell}) &= 4(\vec{n} \cdot \vec{\ell})^2 \vec{n} \cdot \vec{n} - 4(\vec{n} \cdot \vec{\ell})\vec{n} \cdot \vec{\ell} + \vec{\ell} \cdot \vec{\ell} \\ &= 4(\vec{n} \cdot \vec{\ell})^2 - 4(\vec{n} \cdot \vec{\ell})^2 + \vec{\ell} \cdot \vec{\ell} \\ &= \vec{\ell} \cdot \vec{\ell}. \end{aligned}$$

Therefore the squared length of $2(\vec{n} \cdot \vec{\ell})\vec{n} - \vec{\ell}$ equals the squared length of $\vec{\ell}$, and so their lengths are equal. That fact agrees with C1; reflecting a vector across another vector should produce a vector of the same length.

D. From the equations we can read off normal vectors: $\vec{n} = \langle a, b, c \rangle$ for the first plane and $\vec{m} = \langle e, f, g \rangle$ for the second. Consider the vector $\vec{d} = \vec{n} \times \vec{m}$. This vector is perpendicular to $\vec{n}$ and hence lies in the first plane. Similarly, it is perpendicular to $\vec{m}$ and lies in the second plane. Because it lies in both planes, it must lie in the line of intersection. So

$$\vec{x}(t) = \vec{p} + t\vec{d} = \vec{p} + t\langle a, b, c \rangle \times \langle e, f, g \rangle$$

is a parametrization of that line.

E. Acceleration is the second derivative of position:

$$\begin{aligned} \vec{x}(t) &= \left\langle e^{2t}, \sqrt{t}, t\cos(t+\pi) \right\rangle \\ \Rightarrow \quad \vec{x}\,'(t) &= \left\langle 2e^{2t}, \frac{1}{2}t^{-1/2}, \cos(t+\pi) - t\sin(t+\pi) \right\rangle \\ \Rightarrow \quad \vec{x}\,''(t) &= \left\langle 4e^{2t}, -\frac{1}{4}t^{-3/2}, -2\sin(t+\pi) - t\cos(t+\pi) \right\rangle. \end{aligned}$$

The point in question is where $t = 0$. So the desired acceleration is $\vec{x}\,''(0) = \langle 4, \text{undefined}, 0 \rangle$. [Sorry about the undefined part. It was not my intention to have the acceleration be undefined. I graded generously on that second component.]

F1. Acceleration is the second derivative of position:

$$\vec{x}\,''(0) = \frac{-GM}{|\vec{x}(0)|^3}\vec{x}(0) = \frac{-GM}{|\vec{p}|^3}\vec{p}.$$

F2. If the acceleration $\vec{a}$ is constant, then the velocity $\vec{v}$ is

$$\vec{v} = \int \vec{a}\, dt = t\vec{a} + \vec{c}$$

for some $\vec{c}$. Plugging in $t = 0$, we find that $\vec{c} = \vec{d}$. So $\vec{v} = t\vec{a} + \vec{d}$. Then the position is

$$\vec{x} = \int \vec{v}\, dt = \int t\vec{a} + \vec{d}\, dt = \frac{1}{2}t^2\vec{a} + t\vec{d} + \vec{c},$$

where $\vec{c}$ is now $\vec{p}$. Plugging in our answer for $\vec{a}$ from F1, we obtain

$$\vec{x} = -\frac{GM}{2|\vec{p}|^3}t^2\vec{p} + t\vec{d} + \vec{p}.$$